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***Abstract Book for INQUA 2019***



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## Table of Contents

ORAL PRESENTATIONS.....	3
POSTER PRESENTATIONS.....	1301
AUTHORS INDEX.....	2862

## ORAL PRESENTATIONS

O-0001

### **Sediment budgeting the Last Interglacial, Last Glacial and Holocene for the Lower Rhine valleys, estuaries, deltas and coastal barriers**

Kim M. Cohen<sup>1,2</sup>, Jan Peeters<sup>1</sup>, Gilles Erkens<sup>2,1</sup>, Esther Stouthamer<sup>1</sup>, Hans Middelkoop<sup>1</sup>, Freek S. Busschers<sup>3</sup>, Marc P. Hijma<sup>2</sup>, Wim Z. Hoek<sup>1</sup>

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#### **Abstract**

The Late Quaternary record of the Rhine into the North Sea Basin is voluminous and fairly complete one, albeit that it is found mostly buried below youngest coastal plain deposits (the Netherlands) or shelf-sea drowned (southern North Sea and its back-barrier tidal systems). Mapping and dating of the various units has very much advanced over the last 15 years. Data collection from corings (onshore and offshore), supplemented with CPT and dedicated shallow seismic surveying, has allowed to identify architectural units and lithofacies characteristics, to sample for OSL and 14C dating, and to develop reconstructions of the geological developments. These reconstructions tie in with traditional palynology-based paleoclimatological contexts, with sea-level reconstructions and sequence stratigraphic inferences. More importantly, the mapping has complete coverage of the southern North Sea basin fill, which allows to establish time-sliced sediment budgets allowing to compare the Last Interglacial to the Holocene (natural stages, human overprinted final stages), and the first half of the Last Glacial to the second part (e.g. the Rhine valley across the North Sea floor during the cold and lowstand of 'MIS4' vs. that of 'MIS2'). Our presentation will focus on these two comparisons, based on recent papers. We will highlight what the volumetric analysis concludes, especially in terms of cross-checks of the depositional reconstructions and ideas on timing and length and reworking capacity of successive Late Pleistocene substages.

Selected publications:

Busschers et al. 2007. Late Pleistocene evolution of the Rhine in the southern North-Sea Basin: imprints of climate change, sea-level oscillations and glacio-isostasy. *Quaternary Science Reviews* 26: 3216-3248

Cohen et al. 2017. The North Sea. In Flemming et al. (Eds.), *Submerged Landscapes of the European Continental Shelf - Volume 1 Quaternary Paleoenvironments* (pp. 147-186). New York: John Wiley & Sons Ltd..

Erkens et al. 2006. Holocene sediment budgets of the Rhine Delta (The Netherlands): a record of changing sediment delivery.

Hijma et al. 2012. Pleistocene Rhine-Thames landscapes: geological background for hominin occupation of the southern North Sea region. *Journal of Quaternary Science* 27: 17-32

Peeters et al. 2016. Sedimentary architecture and chronostratigraphy of a late Quaternary incised-valley fill: a case study of the late Middle and Late Pleistocene Rhine system in the Netherlands. *Quaternary Science Reviews* 131: 211-236.



Peeters et al. 2018. Preservation of Last Interglacial and Holocene transgressive systems tracts in the Netherlands and its applicability as a North Sea Basin reservoir analogue. *Earth-Science Reviews (in press/Online Early View)*

O-0002

## Distribution of foraminifers and ostracods in the East Frisian Wadden Sea – establishing a transfer function for relative sea-level change

Juliane Scheder<sup>1,2</sup>, Anna Pint<sup>2</sup>, Peter Frenzel<sup>3</sup>, Friederike Bungenstock<sup>1</sup>, Max Engel<sup>4,2</sup>, Frank Schlütz<sup>1</sup>, Helmut Brückner<sup>2</sup>

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### Abstract

The variability of relative sea-level (RSL) change in the German Bight during the Holocene is still not entirely resolved, as it is highly influenced by different global, regional, and local driving factors. Significant vertical uncertainties are associated with peat layers (indirect relation, post-depositional compaction, lack of data for the last 2000 years etc.), the most commonly used RSL indicator. In light of rising seas and the expected future increase in frequency and magnitude of strongest storm surge events, detailed information on RSL histories and local controlling mechanisms is required to create more realistic future scenarios and to better prepare for future coastal-protection challenges. This study contributes to deciphering Holocene RSL changes at the German North Sea coast in a high vertical resolution using microfaunal and sedimentological data. It is embedded in the interdisciplinary WASA Project (*"The Wadden Sea as an archive of landscape evolution, climate change and settlement history"*, <http://nihk.de/index.php?id=483>).

Recent associations of Foraminifera and Ostracoda from low intertidal to supratidal settings of the barrier island of Spiekeroog in combination with environmental parameters (granulometry, C/N, TOC, salinity) were investigated and quantified in elevation steps of 15 cm in order to generate a transfer function (TF) of RSL change, which can be applied to the stratigraphic record. TFs model the relation between the elevation of sample points relative to mean sea level and relative abundances of foraminiferal species over time; ostracods provide additional habitat and salinity information. The combined use of foraminifers and ostracods for a TF is an entirely new approach. The application of the TF on Holocene sediment cores from nearby Norderney will enable the elaboration of a high-resolution RSL curve for the East Frisian Islands. Radiocarbon age estimates on peat layers provide the chronological framework.

Our first data of foraminifer and ostracod taxa distribution show a clear vertical zonation between the middle salt marsh and the tidal flat with very few individuals in the sand flat area suggesting removal by the tidal current or poor preservation. By means of multivariate statistics the elevation relative to mean sea level was deduced as the main driving factor. The smallest vertical error (49 cm) is associated with our new approach of combining Foraminifera and Ostracoda for a TF, which also outperforms error ranges of classical sea-level indicators, such as basal or intercalated peats. In the future, the number of samples will be increased through a second transect on the mainland side of the backbarrier area of Spiekeroog in order to further enhance the TF performance.

O-0003

## Long-term controls of inherited topography on glacial-postglacial stratigraphy: Late Pleistocene and Holocene landscape evolution at Dogger Bank, North Sea

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### Abstract

Dogger Bank, in the southern North Sea, is a large (~17,500 km<sup>2</sup>), shallow (-15 to -25 m OD) bank surrounded by deeper (-50 m to -80 m OD) water. Site investigation data collected over Dogger Bank as part of the Forewind offshore windfarm project comprises a dense 2D grid of high-resolution, shallow seismic reflection data, boreholes and geotechnical logs, forming a comprehensive, integrated dataset. A transition from glacial to proglacial, terrestrial, coastal and marine sedimentary environments is documented, which makes Dogger Bank an ideal natural laboratory to examine the complex stratigraphic and environmental evolution in response to Quaternary climate change. As such, Dogger Bank provides an important analogue for future process response to projected climate change, allowing for planning and mitigation of effects of ice-sheet retreat, permafrost degradation and sea-level rise.

Mapping of seismic stratigraphy, calibrated to vibrocore and borehole sedimentary facies and combined with Cone Penetration Tests, has revealed the importance of inherited topography on landscape evolution. A large, buried, northeast-southwest trending ridge in the southeast of the study area has chaotic seismic facies, interpreted to represent deformation due to glaciotectonics within a large terminal thrust moraine. Retreat of the ice sheet from this position allowed a moraine-dammed proglacial lake to develop. Two phases of lake fill, an older ice-contact stage and a younger ice-distal stage, reflect a stepped ice-sheet retreat controlled by subglacial topography. Overconsolidated lake sediments imply a period of subaerial exposure leading to desiccation. A series of channels incised into the lake sediments, which are partially infilled by peats and accumulation of organic matter reflecting a warming climate. During the Early Holocene, marine transgression occurred. The rate of rise and mechanism of beach barrier overstepping was controlled by inherited moraine ridge topography, which experienced some reworking through wave ravinement. Finally, a layer of shallow marine sand was deposited, thickening towards the southwest. At the base of this sand, large, erosional forms cut into the overconsolidated proglacial lake fill. Sigmoidal reflectors within the fill of these scours suggest progradation of shallow marine systems to the southeast. The location of these scour-fills is confined to the overconsolidated lake fill.

Inherited topography of glacial origin has controlled subsequent landscape evolution at every stage of at the marine inundation of Dogger Bank. Understanding the controls of such complex stratigraphy is vital for accurate mapping subsurface units. The maps produced highlight the requirement for high-resolution data, both horizontal and vertical, in cost-effective delivery of offshore engineering projects. In the identification of topographic controls on the style and rate of deglaciation and the response of beach barrier systems to rapid sea-level rise provide vital well-preserved analogues to help inform planning and mitigate against the effects of future climate change in low-lying coastal settings.

O-0004

## Quaternary sediment distribution in the central and northern North Sea

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### Abstract

The North Sea area has been subjected to significant changes in the last ~2.7 Myr. A considerable thickness (~1000 m) of Cretaceous-early Pleistocene sediments were eroded during the Quaternary in the basin margin areas of the central and northern North Sea and deposited in deeper parts of the basin. This study focuses on the relationship between erosion and deposition, as revealed by the Quaternary succession in the North Sea Basin, and reconstruction of the latest stage of the basin evolution by the application of seismic stratigraphy. Chronostratigraphic data from a number of exploration boreholes in the Norwegian North Sea sector and shallow boreholes in the UK North Sea sector provided seismic-well ties for selected lines from regional/semi-regional 2D seismic surveys constituting the database. The work has resulted in a detailed interpretation of the Quaternary succession. A total of eight seismic sequences have been identified within the Quaternary succession. A regional downlap surface marks the base of the Quaternary succession in deep parts of the North Sea Basin. The major deposition took place during ~2.7-0.78 Ma when most of the accommodation was filled with sediments derived from the east. Depositional patterns indicate continuous subsidence of basin areas and tilting of the basin margin areas to the west in the central North Sea since Oligocene time, whereas tilting of the basin margin areas to the east started sometimes during the latest Pliocene. Open marine conditions existed in the Central Graben area at the beginning of the Quaternary, whereas coastal and/or deltaic conditions dominated to the east. The shoreline gradually migrated to the west as the accommodation was filled in by sediments. Reduced rate of sedimentation probably developed around ~0.98 Ma in the Central Graben area between 57° and 58°N. This may be linked with the filling of the accommodation and/or inception of the Norwegian Channel around ~1.1 Ma. Most of the sediments eroded in the basin margin and onshore areas since the inception of the Norwegian Channel may be transported by fast-moving ice streams to the North Sea Fan and thus restricted amounts of sediments may have entered the basin beyond the submarine margins of the channel in the central and northern North Sea. This may imply different sedimentary conditions during ~1.1-0.45 Ma within the deep basin and basin margin areas. Glacial environments were probably dominant during the last ~0.45 Ma and repeated glaciation of the central and northern North Sea caused erosion of the basin margin areas. Early Quaternary sediments are nearly completely preserved in the Central Graben area but thicknesses are reduced due to erosion towards the basin margins to the east and west.

O-0005

## Buried Quaternary valleys in the Danish North Sea - Morphologies of an ice margin environment

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### Abstract

The quaternary succession in the Danish Central Graben is dominated by buried erosional channels. We have mapped the extent of these channels using 3D seismic time slices from the Danish Central Graben area. The 3D seismic data is processed for hydrocarbon exploration, and acquisition footprints and low signal to noise ratio thus heavily distort the shallow parts. However, by combining mapping of these channels from 3D seismic time slices with high resolution 2D seismic site survey data we have been able to separate the channel systems into generations, interpret their formation based on infill geometries and plan view morphology, and thereby unravel the geological evolution of the area. We supplement the interpretations with data and age interpretations from geotechnical investigations where possible.

From this integration of different data types, we have found a river valley system that crosses the Southern Danish Central Graben. We interpret the system to have been active in the late Weichselian-Holocene, during and after deglaciation when the area was subaerially exposed. We base our interpretation on a number of observations: The system displays different fluvial styles, from straight channels to meandering, and locally braided systems, revealing large differences in energy over the area. There is a confluence point in the central part of the system, where channels from the north and from mainland Europe converge and change direction towards the east-northeast. It is a tributary system with three hierarchical degrees of tributary channels above seismic resolution. The channel infill is categorized by two seismic facies representing fluvial deposits and transgressive deposits (estuarine or marine). The area shows only little relief, and we have found a mismatch between the apparent flow direction observed from the plan view morphology, and the direction inferred from measured erosional depths of the channels. We attribute this to glacioisostatic compensation of the glacial forebulge, which, due to the low relief in the area, was sufficient to invert the apparent flow direction.

This study emphasizes the importance of differentiating river valleys and tunnel valleys in seismic geomorphology as part of understanding the Late Weichselian to Holocene development of the North Sea and particularly for areas close to the Last Glacial Maximum extent where both morphologies are expected to be present. The study can furthermore be used as input for glacioisostatic models.

O-0006

## Reconstruction of former landscapes and Holocene sea-level rise in the area of the island Norderney, German Wadden Sea

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### Abstract

The interdisciplinary joint project WASA (The Wadden Sea as an Archive of landscape evolution, climate change and settlement history: exploration – analysis – predictive modelling) focuses on the reconstruction of the late Quaternary development in the German Wadden Sea area. The aim is to identify and locate past areas suitable for human occupation before inundation by the rising sea.

More than 120 vibrocores obtained around the East Frisian island of Norderney document a wide range of different local developments explored by stratigraphical, sedimentological and palaeobiological (pollen, non-pollen palynomorphs, foraminifera, diatoms) analyses and interconnected by hydro-acoustic measurements. The AMS <sup>14</sup>C-datings on taxonomically identified macro remains and fine bulk from organic rich layers like peat and lacustrine sediments include double and triple datings to identify outliers, to increase the reliability of age-depth models and to estimate the formation processes of organic fraction. This will provide a robust chronological framework and a detailed timeline of former palaeoecological and sea-level changes.

Close to the recent mainland a complex pattern of bogs and wet heathland characterized by cross-leaved heath (*Erica tetralix*), bog-rosemary (*Andromeda polifolia*) and the peat moss *Sphagnum papillosum* developed during the early and middle Holocene before these environments were covered by marine sediments. Near the barrier island of Norderney and further north Alder carrs existed. While the successive inundation of these landscapes reflect the Holocene eustatic sea level rise, younger peats intercalated in marine sediments clearly prove phases of a decreased (or stagnating) sea level with freshwater conditions at before marine sites. Those phases could have last only a few hundred years with gradual shoreline regression and re-transgression clearly reflected in the changing palynological signals of the marsh and swamp vegetation.

Therefore, our new data underline the existence of natural short termed sea level fluctuations with rates of several millimetres per decade as published by Behre (2007). A comparison with climatic data from the North Atlantic and the Mediterranean point to north hemispheric climate drivers behind this phenomenon, possibly related to variations of the subpolar gyre.

WASA is financed by the „Niedersächsisches Vorab“ of the VolkswagenStiftung within the funding initiative „Küsten und Meeresforschung in Niedersachsen“ of the Ministry for Science and Culture of Lower Saxony, Germany (project VW ZN3197)

Behre K.-E. (2007), A new Holocene sea-level curve for the southern North Sea. *Boreas* 36: 82–102.

O-0007

## The geological evolution of the North Sea Basin during the Quaternary

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### Abstract

Based on an extensive 2D seismic database and data from several hydrocarbon wells, the Base Quaternary surface has been mapped over the entire North Sea Basin. The basin starts on land in the Netherlands (52°N) and ends in the transition zone to the Norwegian Sea offshore of western Norway (62°N). The basin is 1200 km long, 100-200 km wide and 1000 m deep, and is filled with up to 1000 m of sediments (140 000 km<sup>3</sup>). The basin has subsided more or less continuously along the basin axis during the Quaternary, whereas surrounding shelf and land areas have been uplifted.

The infill pattern of the basin is outlined. The southern and central basin was filled in mainly by fluvial sediments from the east and south during the Early and Middle Pleistocene.

The northern North Sea basin was filled in largely by glacial debris-flows deposited in front of an ice sheet covering southern Norway during many glacial periods during the early and middle Pleistocene. The first glaciers appear to have flowed out of the Sognefjorden palaeo-valley at the onset of Quaternary glaciations over Norway some 2.7 million years ago. The depositional regime and changing palaeo-current pattern in the North Sea Basin through the Quaternary are summarized.

O-0008

## Paleodust variability and impacts since the Last Glacial Maximum

Samuel Albani<sup>1</sup>, Natalie Mahowald<sup>2</sup>, Yves Balkanski<sup>3</sup>, Gisela Winckler<sup>4</sup>, Valter Maggi<sup>1</sup>, Barbara Delmonte<sup>1</sup>, Pascale Braconnot<sup>3</sup>, Masa Kageyama<sup>3</sup>

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### Abstract

Mineral dust is both an agent and a tracer of climate change on a range of time scales. Here we briefly review the variability of the global dust cycle since the Last Glacial Maximum as reconstructed from natural archives. We then focus on Earth system model simulations including the dust cycle, and review the proposed strategy for dust experiments in PMIP4. We review the global budgets of dust emissions and atmospheric loads, and we summarize the published estimates in terms of dust feedbacks on different climate states within the last 21,000 years. Specific examples of climate impacts of dust for the mid-Holocene and Last Glacial Maximum will be also discussed.

O-0009

## Atmospheric circulation changes and the simulated dust cycle in Europe during the Last Glacial Maximum

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### Abstract

This study establishes a linkage between the aeolian mineral dust cycle during the Last Glacial Maximum (LGM) and the loess deposits in Europe. The glacial dust cycle in Europe is simulated at high resolution using a regional climate-dust model. The simulated dust deposition rates were compared with fieldwork-based mass accumulation rates determined from more than 70 loess sites in Europe. In contrast to the currently prevailing westerlies, we found that easterly (36%) and cyclonic (22%) weather patterns prevailed over central Europe during the LGM. Together with the cyclones, the recurring dry easterlies associated with a high-pressure system over the Eurasian Ice Sheet (EIS) dominated the dust transport from the EIS margins to eastern and central Europe. Major dust emissions occurred in the zone between the Alps/Black Sea and the southern EIS margin with the strongest emission near the German-Polish border. Based on these emissions, westwards running dust plumes resulted in high deposition rates in western Poland, the German Bight, and on the North German Plain. The agreement between our simulations and the independently reconstructed loess-based accumulation rates corroborates the proposed dust cycle hypothesis for Europe.

O-0010

## Dust responses to orbital and meltwater forcing in the Community Earth System Model (CESM)

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### Abstract

Changing climate conditions over glacial-interglacial cycles affect dust emissions and transport. Predictive dust is now included in the Community Earth System Model (CESM). Atmospheric dust is mobilized from the land by wind in the CESM land model component (CLM). The most important factors determining soil erodibility and dust emission include the wind friction speed, the vegetation cover, and the soil moisture. The dust atmospheric cycle in the CESM (Albani et al., 2014) accounts for these factors and is based on the DEAD (Dust Entrainment and Deposition) model of Zender et al. (2003). Model impacts on climate and biogeochemistry include direct radiative forcing and deposition on snow, ice, and the ocean.

In this talk/poster, we will present CESM results from the iTrace transient simulations from 20ka to 14ka, forced with orbital, greenhouse gas, ice sheet and meltwater variations and from idealized forcing simulations for endmembers of these forcings. We concentrate on changes in the dust emissions, transport and deposition associated with the orbital cycles, the lower glacial greenhouse gas concentrations, and on the Heinrich 1 meltwater event during the last deglaciation.

Albani, S., NM Mahowald, AT Perry, RA Scanza, CS Zender, NG Heavens, V. Maggi, J. Kok, B. Otto-Bliesner [Improved dust representation in the Community Atmosphere Model](#), <http://onlinelibrary.wiley.com/doi/10.1002/2013MS000279/abstract>, Journal of Advances in Modeling Earth Systems, 06, doi:10.1002/2013MS000279

Zender, C.S., Bian, H., and Newman, D. 2003. Mineral dust entrainment and deposition (DEAD) model: Description and 1990s dust climatology. J. Geophys. Res. 108(D14): 4416. DOI:10.1029/2002JD002775.

O-0011

## Minimal impact of modeled drought on natural dust emission and deposition in the Southwest United States

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### Abstract

The assumption that the emission, burden, and deposition of fine dust particles increase during drought in the Southwest United States is common and is the basis of the expectation that future drought will exacerbate regional dustiness with impacts on snowmelt and health. This assumption is supported by observational datasets between drought and the atmospheric burden of fine particles. However, recent long-timescale dust deposition records from the region suggest that sediment availability, rather than drought, is the primary driver of dust deposition in the region, and thus also of other aspects in the dust cycle. Here we concentrate on the Last Millennium Experiment (LME) output from Community Earth System Model (CESM) to investigate further the claim that drought is the major natural driver of the dust cycle in the Southwest.

We regress dust production, atmospheric burden and dust deposition against model drought as identified by Standardized Precipitation Index (SPI) over the years 850-2005 for 10 fully forced ensemble members of the LME. We also investigate the long-term trends in ensemble mean for comparison with paleodust deposition records.

The model shows little relation between dust deposition and regional aridity from 850-2000 CE. Additionally, like the paleodust records, model output suggests relative stability in the dust cycle until the 1900's when all aspects of the dust cycle increase. However, dust deposition in the region increases much more than the increase in regional dust production. This supports the paleo record evidence that drought is not the leading driver of dust in the Southwest US. However, the lack of inclusion of dust grains coarser than 10 microns is likely biasing the model towards long-range transport and precluding any investigation into the regional dust-drought nexus. This likely has implications for other parts of the world as well, as coarse dust particles are prevalent and missing from most models. If regional dust cycles are not modeled adequately, we cannot rely on dust projections that are critical for health and water management.

O-0012

## Regional contributions of ocean iron fertilization to atmospheric CO<sub>2</sub> changes during the last glacial termination.

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### Abstract

The mineral dust aerosol generated from the wind effect on the Earth's surface, acts in the atmosphere altering the radiative balance of the Earth system, interacting with the cloud condensation nuclei and affecting the biogeochemical cycles, because it contains micro nutrients as iron, whose supplies are crucial in marine ecosystems. Effect that is amplified in areas with "High Nutrient Low Chlorophyll" (HNLC) product of its iron limitation. Through data obtained from ice cores, it has been shown that the dust has varied during glacial and interglacial periods, which coincides with the atmospheric CO<sub>2</sub> records, which have varied between 80-100 ppm at the same periods. What has invoked theories such as the one proposed by J. Martin, which relates the effect of iron in the soft tissue pump with the variability of atmospheric CO<sub>2</sub>.

Through a biogeochemical model of intermediate complexity called cGENIE with an emphasis on the carbon cycle, was calculated the reduction of atmospheric CO<sub>2</sub> during the period from the Holocene (10 ka) until the Last Glacial Maximum (21 ka), as result of iron fertilization on the surface ocean. For which were used six dust flux fields, from a reconstruction and five simulations of coupled models. We created eight intermediate artificial levels of dust flux between both periods, and the experiment was carried out with special emphasis on the HNLC zones, in order to estimate the contribution of each of these areas in the global capture of pCO<sub>2</sub>. We found that Southern Ocean contributed over half of the glacial-interglacial total pCO<sub>2</sub> change due to dust-borne iron fertilization, mostly during the older half of the termination. In contrast, the North Pacific contributed about 30% of the dust-induced pCO<sub>2</sub> changes, but only at the end of the termination.

O-0013

## Holocene dust provenance and variability in East Antarctica: new results from the SOLARICE (Dome C) ice core

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<sup>4</sup>University of Pisa, Pisa, Italy. <sup>5</sup>ENEA, C.R. Casaccia, Roma, Italy

### Abstract

We provide a comprehensive overview of eolian dust flux, transport and sources for the central and marginal sectors of the East Antarctic ice sheet during Holocene. Background dust transport variability, investigated by means of dust grain size parameters, is investigated in detail for the Late Holocene through high-resolution data obtained from a new ice core drilled at Dome C in the framework of the Franco-Italian SOLARICE research project. These new results confirm the variable strength and localization of troposphere air subsidence over Antarctica, which is related to local and regional atmospheric dynamics, and highlight the importance of high-resolution ice core analyses for depicting high frequency modes of variability still hidden to discontinuous dust measurements.

We focus also on spatial differences in dust cycle between inner plateau sites and peripheral regions located close to the Transantarctic Mountains, these latter being very sensitive to regional climate changes. The importance of high-altitude rock outcrops in Victoria Land – such as relict flat structural surfaces – and remobilization of volcanic material accumulated from different volcanic sources of Victoria Land are discussed.

O-0015

## Paleoecology and dynamic vegetation modeling reveal past and future forest dynamics in the Olympic Mountains, USA

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<sup>2</sup>Department of Geography, University of Oregon, Eugene, USA

### Abstract

Future climate change is expected to lead to dramatic changes in species abundance and composition, especially in mountain areas with steep ecological gradients. Mountain vegetation will likely shift to higher elevations with warmer temperatures in order to remain in the present-day climatic niche. However, in the mountain ranges of Western North America, climate warming will also lead to an upward shift of the snowline and a decrease in snowpack, which could increase moisture stress during the dry summer months. It is therefore unclear if subalpine mountain forests will be contracting or expanding in the future. Dynamic vegetation models are the method of choice to make detailed projections about the future forest dynamics and associated ecosystem services. However, proper model validation in space and time is crucial for reliable model results.

Here, we use the dynamic vegetation model LandClim to simulate past and future vegetation dynamics at two study sites in the Olympic Mountains (Pacific Northwest). To accurately reflect microclimatic variation in the rugged terrain, we developed a topoclimatic model based on small temperature loggers distributed in the two study areas. We then simulated forest dynamics during the Late Holocene and compared the model output with pollen and macrofossil inferred local and regional vegetation reconstructions from Ptarmigan and Discovery Lake. The model was able to correctly simulate past vegetation composition and abundance at both study sites. We then simulated future vegetation dynamics using downscaled climate projections. Our modelling results indicate that subalpine forests are shifting to higher elevations in the wet, western side of the mountain range, with only little change in regional species composition. However, on the drier, eastern side of the Olympic Mountains, the model projects drastic changes in species composition and even a lowering of the timberline due to insufficient moisture availability.

Our results suggest a non-linear reaction of mountain forests to future climate change depending on local climatic, topographic and edaphic conditions. The projections of future vegetation changes with paleo-validated dynamic vegetation models are an invaluable source of information for ecosystem managers and show policy makers and the general public the urgency of climate change mitigation.

O-0016

## Holocene dynamics of the boreal forest of Eastern Canada: Untangling the drivers of vegetation change using paleoecological data and models

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### Abstract

The boreal forests of Eastern North America developed during the Holocene following the retreat of the Laurentide Ice Sheet. This region now stores a substantial amount of carbon in living biomass, soils, and peat, and has an important biogeophysical feedback to the atmosphere that influences hemispheric climate. While forests developed rapidly on bare ground following ice retreat, the boreal forest was not static over the Holocene. Paleoecological analyses indicate that major changes in species composition, soil properties, and disturbance frequency occurred over the past 6 ka. Understanding the drivers behind these ecosystem dynamics is important for projecting how this globally important forest region may respond to future climate change.

Here we present a study simulating the responses of vegetation and fire to changes in climate during the last 6000 years using a dynamic vegetation model, and evaluating the model output at multi-millennial time-scales using paleoecological archives. We used the LPJ-LMfire model, parametrized for the most abundant tree genera in eastern boreal Canada (*Picea*, *Abies*, *Pinus*, *Populus*) and driven by a Holocene scenario of climate derived from the Earth system model IPSL-CM5A-LR at 10-year resolution. LPJ-LMfire was run with a monthly time-step from 6000 to 0 BP on a 100-km<sup>2</sup> resolution grid covering the boreal forest from Manitoba to Newfoundland. LPJ-LMfire output was analyzed in terms of annual burn rates (ABR), net primary productivity, aboveground biomass and genus-specific cover percentage. We compared ABR and tree biomass simulated by LPJ-LMfire results with paleoecological reconstructions obtained from lacustrine-charcoal and pollen records, respectively.

Our results support the hypothesis that Holocene climate change had an important influence on the dynamics of the boreal forest of northeastern North America. Forest composition acted as an important “bottom-up” control on fire frequency on multi-centennial time-scales. Warm growing seasons at 6000 BP fostered the rapid establishment of vegetation in the east of our study domain, whereas cold spring temperatures limited biomass growth in the west. Low biomass and high *Populus* cover percentage contributed to low simulated ABR. Simulated changes in ABR and biomass over time were not entirely synchronous with reconstructions based on charcoal and pollen. Where LPJ-LMfire shows trends similar to the paleoecological reconstructions, these are often offset in space by several 100s of km. We suggest that the discrepancies between simulated and reconstructed vegetation time series are associated with inaccuracies in the climate model output that was used to drive LPJ-LMfire.

O-0017

## Examples of past and future land biosphere change: results from a dynamic global vegetation model and proxy data

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### Abstract

The combination of models and proxy data permits the extension of short instrumental records to decadal-to-century time scales relevant under global warming. For example, palaeo-ecological data, combined with carbon-vegetation modelling, suggest that silver fir, an important European tree species, may ensure key ecosystem services including stand and slope stability, infrastructure protection, and carbon sequestration under global warming in central Europe (Ruosch et al., 2016). Ruosch et al. present results from simulations with the Land Surface Processes and Exchanges (LPX-Bern) dynamic global vegetation model to assess past and future distributions of silver fir in Europe. LPX-Bern is forced with climate anomalies from a run over the past 21 000 years with the Community Earth System Model, modern climatology, and with 21st-century multi-model ensemble results. Pollen and model results both show range expansion starting during the Bølling–Allerød warm period, interrupted by the Younger Dryas cold, and resuming during the Holocene. The distribution of silver fir expands to the north-east in all future scenarios, whereas the potential (currently unrealized) range would be substantially reduced in southern Europe under high emissions. The results suggest that silver fir could play an important role in adaptation planning in central Europe.

Measurements of the stable carbon isotope ratio on annual tree rings offer new opportunities to evaluate mechanisms of variations in photosynthesis and stomatal conductance under changing CO<sub>2</sub> and climate. The isotopic discrimination is indicative of the ratio between the CO<sub>2</sub> partial pressure in the intercellular cavities and the atmosphere and of the ratio of assimilation to stomatal conductance, termed intrinsic water use efficiency (iWUE). Keller et al. (2017) present isotope-enabled simulations over the industrial period with the land biosphere module (CLM4.5) of the Community Earth System Model and with LPX-Bern. A compilation of tree-ring records suggests on average small 20th century changes in isotopic discrimination. LPX Bern results match these century-scale reconstructions, whereas CLM4.5 simulates an increase in discrimination almost twice as large as revealed by the tree-ring data. The results point to problems associated with the formulation of photosynthesis in CLM4.5, while the proxy data and LPX-Bern results support the idea that the physiology of stomata has evolved to optimize trade-offs between carbon gain by assimilation and water loss by transpiration. In the presentation, examples of LPX-Bern results will be discussed in the context of proxy data.

Keller, K.M. et al.: 20th century changes in carbon isotopes and water-use efficiency: tree-ring-based evaluation of the CLM4.5 and LPX-Bern models, *Biogeosciences*, 14, 2641-2673, 10.5194/bg-14-2641-2017, 2017.

Ruosch, M. et al.: Past and future evolution of *Abies alba* forests in Europe – comparison of a dynamic vegetation model with palaeo data and observations, *Global Change Biology*, 22, 727-740, 10.1111/gcb.13075, 2016.

**O-0018**

## **Climate change and tree growth in Canada: Some forests fare better than others!**

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### **Abstract**

Canada's boreal zone covers 552 million hectares or 28% of the world's boreal zone, of which 223 million hectares are covered by forests. These provide a wide variety of habitats for fauna, flora, and arthropods, and many ecosystem services to humans. In this era of climate change, understanding past and predicting future forest productivity and tree growth are scientific challenges that are central to the development of sustainable forest management practices and policies. However, uncertainties are imposed by the short time period covered by existing forest and remote sensing data. Regional growth and productivity is also tremendously variable over time, such that contemporary data cannot provide information on the full range of variability a given forest experienced and adapted to. Currently available data indicate that the northernmost part of the boreal forest and tundra farther north are exposed to greater climatic warming than other world forests. This should, in theory, increase the level of growth of forest species in these areas. However, tree growth is not only limited by the length of the growing season and the cold, but also by summer drought and excess soil water in the spring and fall. In this presentation, we will synthesize the results of our recent studies on the impacts of climate change on the productivity and tree growth in Canada's boreal forest. Briefly, spatial and temporal changes in past and present forest attributes (productivity, biomass, basal area) have been reconstructed by pollen analysis, forest inventories, satellite data, and dendroecological data. This information from analyses of past amplitudes has been combined with simulations from ecophysiological and global vegetation models to predict future growth under different greenhouse gas emission scenarios. The data synthesis provides compelling evidence that effects of global warming on forest productivity and tree growth are already in progress and there is evidence that local phenotypes are showing signs of maladaptation. Results from projections suggest an increase in the importance of available soil water and heat as constraints on growth over the next century due to warming, but this response may vary to the extent that other factors such as carbon dioxide fertilization, and acclimation to high temperature, contribute to dampening these limitations. We end our presentation by showing that forest-related measures such as human-assisted movement of species' populations could help the migration of pre-adapted populations and could help stabilize the productivity in some areas.

O-0019

## Data-model comparisons reveal long-term vegetation dynamics in two semi-arid mountain regions

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### Abstract

Understanding long-term ecological resilience in the face of climate change requires a network of paleoecological records with sufficient resolution to disclose past ecosystem dynamics, as well as independent information on climate variability through time. These relationships can be particularly challenging to reconstruct in mountainous settings where (1) pollen can be transported long distances; (2) taxonomic assignments of dominant pollen types are often uncertain; (3) environmental gradients are steep and change abruptly; and (4) interactions among climatic and nonclimatic factors are complex. We examine the postglacial vegetation, fire, and climate history of two semi-arid mountain regions: the mixed-conifer forests of the Greater Yellowstone Area (USA) and the forest-steppe border of the eastern Andes (Argentina). In both regions, past ecosystem dynamics are inferred from pollen and charcoal records, which are interpreted in light of modern pollen-vegetation and charcoal-fire relationships. Past variations in temperature and key moisture variables are determined from regional climate modeling (using RegCM4). The data-model comparisons provide examples of ecological stability, transient ecological instability, and abrupt nonlinear dynamics, in which the nature of the response was governed by the intensity of the climate forcing, the intrinsic properties of the ecosystem, and the legacy of past events. In Yellowstone, a striking nonlinear response to gradual warming is evident at the end of the late-glacial period when widespread no-analog assemblages, dominated by shrubs and *Juniperus*, were abruptly replaced by modern mixed-conifer parkland and forest. In contrast, ecological stability is evident in the history of mid-elevation *Pinus contorta* forest, which has exhibited little change since its formation at ca. 9,000 BP. Stability, in this case, is attributed to the ability of *P. contorta*'s to withstand a broad range of climate and fire conditions and outcompete other conifers on infertile substrates. Decreased summer temperature and increased moisture variability in the last 10,000 years is associated with decreasing fire activity and shifting forest composition at low elevations. Along the eastern Andes, late-glacial conditions supported shrubland/steppe with no modern analog. Gradual replacement, first by open *Nothofagus* forest-shrubland at 12,200 BP and then by modern mixed forest at 6,500 BP, suggests a transient unstable equilibrium, forced by changes in temperature, effective moisture, and fire. Submillennial variations between *Nothofagus* and *Austrocedrus* after 6,500 BP indicate development of multiple stable states in response to modest fluctuations in climate and fire. *Nothofagus* established after fires during wet periods, and *Austrocedrus* dominated after fires under dry conditions. Our data-model comparisons thus characterize the late-glacial as a period of unstable ecosystems, in which climate forcing induced abrupt and gradual shifts to new vegetation types and fire regimes, whereas multiple stable states are more evident in the Holocene when vegetation often maintained a dynamic equilibrium within a range of disturbance and climate conditions.

O-0020

## Combining tree-ring records with a dynamic vegetation model to understand climate-driven thresholds for land-cover change in the Southern Rocky Mountains

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### Abstract

Dry coniferous forests in the Rocky Mountains of western North America are sensitive to drought-related disturbance, including wildfire and insect outbreaks. Such disturbances were widespread during recent drought events, prompting concern that increasing drought stress will drive extensive conversion of forests to shrublands and grasslands with corresponding losses of ecosystem carbon, in a warmer and drier future. Dynamic landscape vegetation models can simulate the interactions among climate, disturbance, and vegetation to project long-term land-cover change and therefore inform the development of management strategies that maintain ecosystem services. However, recent observations provide a short window for model evaluation relative to the lifespan of trees, and the periodicity of forest regeneration. We are addressing these challenges by combining simulations with the LandClim dynamic landscape vegetation model with long-term records of drought, fire, and stand dynamics from the Jemez Mountains of New Mexico, USA. Situated at the southern limits of the Rocky Mountains, the Jemez Mountains provide a unique setting to understand long-term climate impacts on forest dynamics. Extensive forests dominated by *Pinus ponderosa* and woodlands of *Pinus edulis* currently exist near their dry limits. Forest regeneration was very limited following recent fires, and drought-related mortality widespread, during recent droughts, which demonstrates the climatic sensitivity of forests in the region. Similar climate-related mortality and disturbance events are documented during the late Holocene by a dense network of tree-ring archives. Tree-ring records provide sub-annual climate and fire records, as well as stand demographic data. We are developing monthly climate scenarios for the period 1600 AD-present by combining tree-ring inferred records of seasonal precipitation with modern weather station data. Climate data include multiyear (i.e., 2-8 years) droughts and wet, cool seasons that affected past fire activity and regeneration. Model initialization relies upon stand demographic data, which also informs evaluation of simulated regeneration, growth, and mortality. Models evaluated with long-term data will ultimately be used to quantify climatic thresholds for mortality and regeneration and be applied to project future land cover change and post-disturbance regeneration.

O-0021

## The Big Burns Project: causes and consequences of fire-regime variability in Rocky Mountain subalpine forests

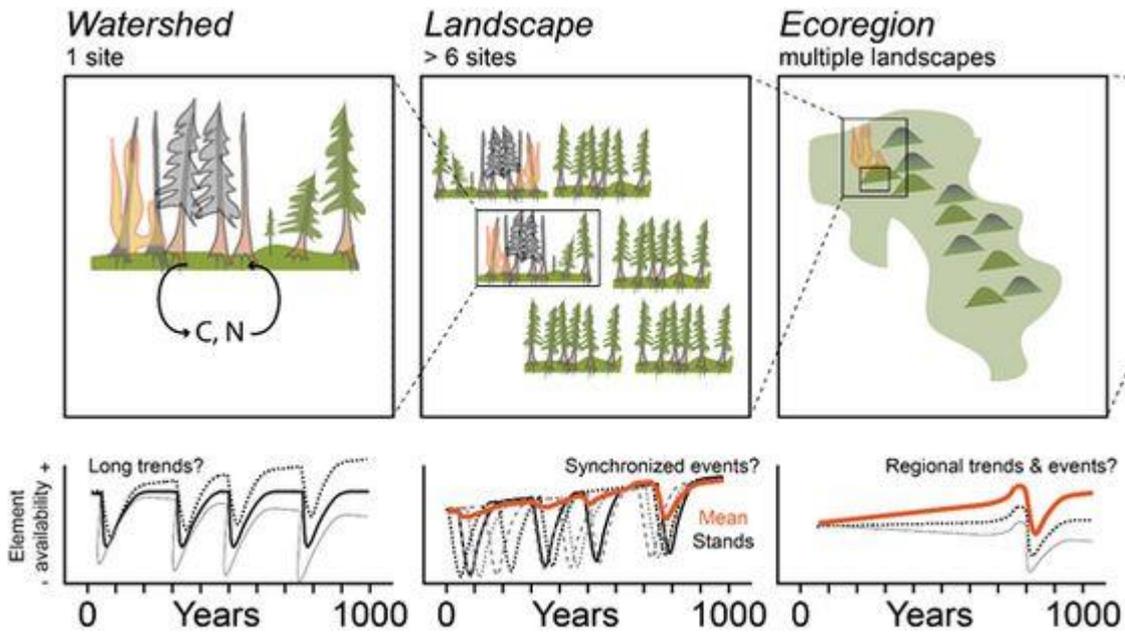
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### Abstract

Shifting disturbance regimes in forest ecosystems are predicted to lead to long-lasting directional changes in ecosystem properties and biogeochemical states, potentially influencing carbon and nitrogen balance over large spatial and temporal scales. While these ideas have a strong conceptual basis and empirical support on decadal timescales, data have been lacking to test them over longer timescales - and to consider their implications for future projections - until only recently. Here we present a framework and a set of testable hypotheses for understanding how coupled climate-fire-ecosystem dynamics scale over space and time to impact carbon and ecosystem properties. We use a combination of ecosystem modeling and palaeoecological reconstructions of fire activity and ecosystem change to test these hypotheses in Rocky Mountain subalpine forests, with a focus on the impacts of fire-regime variability on soil carbon dynamics.

At individual watershed scales, palaeoecological records and ecosystem simulations highlight distinct and significant impacts of wildfires on ecosystem properties, including vegetation, and soil carbon (C) and nitrogen (N) stocks. While ecosystem properties typically return to pre-fire levels over decades, compounding effects from variability in fire severity and the length of fire-free intervals create centennial- to millennial-scale trajectories in some ecosystem properties, including soil C. Our framework predicts that the regional importance of these dynamics depends strongly on the spatial synchrony of fire activity: under scenarios of heterogeneous fire activity across space, regional C stocks will not vary significantly over time; in contrast, during periods of regionally synchronous fire activity, C balance will largely reflect fire-regime variability over centuries or longer. Palaeo records and palaeo-informed modeling spanning millennia provide evidence of both scenarios. Our results imply that fire-regime variability can be a major driver of C trajectories in stand-replacing fire regimes, with compounding effects that may last for centuries. Predicting carbon balance, therefore, depends strongly on the ability of ecosystem models to represent a realistic range of fire-regime variability over the past several centuries to millennia.



O-0022

## Possible link of an exceptionally strong East Asian summer monsoon to a La Niña-like condition during the interglacial MIS-13

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### Abstract

The S5-1 paleosol unit, which corresponds to marine isotope stage (MIS) 13, had undergone the most intense pedogenesis during the Quaternary in the central Chinese Loess Plateau (CLP). It has been suggested to represent the greatest humidity and extremely strong East Asian summer monsoon (EASM). However, the extremely strong EASM occurring in the relatively cool interglacial MIS-13 seems to be a paradox. In the meantime, evidence shows that regional diversity may exist in the relative intensity of the S5-1 soil formation. In order to understand these discrepancies, we first verify systematically the S5-1 soil development across the whole CLP by using numerous available loess records. We then examine the spatial variation of the magnetic susceptibility of different loess-paleosol sections to identify the spatial change of the EASM intensity during MIS-13. We also compare the loess records with other monsoon records in China. Our results show that there is a spatial difference in the intensity of the S5-1 paleosol formation. In the central CLP, S5-1 is indeed the strongest developed. However, in the western CLP, it is weakly developed, whereas the S4 paleosol which corresponds to MIS-11 is the most developed. As compared to MIS-11, the northern front of the EASM during MIS-13 didn't penetrate into or expanded westward, but was located more northerly and eastward. Based on the sea surface temperature records in the tropical Pacific, we suggest that the abnormal variation of the EASM during MIS-13 is related to a strong La Niña or La Niña like climate condition. Under such a condition, the Western Pacific Subtropical High (WPSH) becomes weaker and retreats more northeastward, leading to more precipitation in the mid-east region of northern China (including the east-central CLP), and the summer monsoon rain belt could not penetrate into the western inland.

O-0023

## The climatic fluctuation patterns of the Huaihe semi-humid region in the North and South transition zone of the Eastern China

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### Abstract

The Huaihe watershed located in the North and South transition zone of the Eastern China and is the semi-humid climate region. In the region, northwest wind-transported dusts from the northern arid and semi-arid area deposited and the effect of Jianghuai-specific plum rains is also obvious. However, the climate of the region is different from both the North and the South of China. Therefore, the revealing paleo-climate change of the region is particularly important for understanding of the paleo-climatic pattern of the Eastern Asia. In the study, a Holocene loess-paleosol section in Xiangcheng and a 481m drilling core in Huainan were analyzed. The Holocene climate fluctuations are discussed according to several indices such as proxies of the dust transported distance, wind strength, spring near-surface air-temperature and effective moisture. The 481m long core was compared with paleoclimatic records from other regions by reconstructing its sequences of sedimentary facies. It was found that (1) the whole trend of the climate fluctuation pattern of the Huaihe region was the inverse of the North arid and semi-arid region in different scales since 8Ma. It was wet during cold periods such as glacial periods and dry during warm periods in the region, characterized by the interaction of lacustrine and fluvial facies deposits. During Holocene, the paleosol of the Huaihe region was 1.7-3.8kaBP that was late than 4-7kaBP of the dust source. (2) The characteristics of the climate fluctuation of the Huaihe region may result from that the northward-moving of the plum rains belt was caused by the weakening of winter monsoon and the increased plum rains was due to the westward expansion of the West Pacific subtropical high and the weakening of the India summer monsoon.

O-0024

## Spatial inhomogeneity of orbital-scale monsoon rainfall over Asia

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### Abstract

Chinese speleothems together with loess proxies have provided invaluable information on changes in Asian monsoon variability at the orbital scale. Their close relationship with Northern Hemisphere (NH) summer insolation suggests that solar heating is an important driver of Asian monsoon dynamics. Yet, it still remains unclear how changes in solar radiation affect regional monsoon systems as well as their reflections in paleo-climate records. Furthermore, despite the close proximity of Chinese caves and loess sites, the two archives appear to be sensitive to different types of orbital-scale forcing: oxygen isotope data in speleothems are strongly correlated with NH summer insolation with a much weaker signal in the global ice volume, whereas loess proxies are strongly correlated with the ice volume and sea-level signals. To help understand, why records from nearby locations can have different orbital sensitivities and to better understand the spatial characteristics of East Asian monsoon rainfall, we perform a comprehensive analysis of precipitation and oxygen isotope over Asia using a variety of datasets ranging from interannual to orbital time scales. At the orbital scale, transient climate simulations with LOVECLIM and CESM earth system models reveal that the precipitation amount and its phase relative to the orbital forcing are spatially highly variable over Asia. Our analysis offers new insights into the mechanisms generating regional differences in the orbitally-forced East Asian monsoon system.

O-0025

## Rainfall variations in central Indo-Pacific during historical times

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### Abstract

The characteristics and mechanisms of tropical rainfall variations on centennial- to decadal- scales are still unclear. Here, we reconstruct a replicated stalagmite-based 2700 yr long, continuous record of rainfall for the deeply convective northern central Indo-Pacific (NCIP) region. Our record reveals a decreasing rainfall trend in the NCIP over the past 2700 yr, similar with other records from the northern tropics. On centennial- to decadal-scales, notable dry climate conditions were observed both in the NCIP and southern central Indo-Pacific (SCIP) during the 20th century (Current Warm Period, CWP) and the Medieval Warm Period (MWP), corresponding to enhanced El Niño conditions. Our newly developed 2000-yr ITCZ shift index record supports an overall southward shift of the ITCZ in the central Indo-Pacific and indicates southward mean positions during the early MWP and the CWP. As a result, the drying trend since the 20th-century in the northern tropics is similar to that observed during the past warm period, suggesting that a possible anthropogenic forcing of rainfall remains indistinguishable from natural variability.

O-0026

## **A multi-centennial humid anomaly in the Altiplano: tropical and extra-tropical drivers of the South America Summer Monsoon during recent millennia**

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### **Abstract**

The South American Summer Monsoon (SASM) is the most important atmospheric system in tropical South America, being the major supplier of precipitation north of 20°S. Modern climatological studies indicate that year-to-year changes of the SASM are influenced by large-scale modes of atmospheric circulation sourced in the tropics such as the Intertropical Convergence Zone (ITCZ) and El Niño Southern Oscillation (ENSO). The interplay between these modes results in pronounced precipitation anomalies in the tropical Andes and the Altiplano which impact numerous socioeconomic activities. The drivers behind SASM variations at longer timescales are, however, far less understood due to the shortness of modern instrumental timeseries and the relative low number of paleorecords. This prevents an evaluation of past feedback mechanisms, and whether or not the historical ranges of variation represent the expected boundaries for future conditions.

In this presentation we will show three new pollen-based climate reconstructions expanding the last 4000 years from the Chilean Altiplano (18-21°S), two lake sediment records and one series of 32 fossil rodent middens. The Chilean Altiplano is located at the southern margin of the SASM influence, where up to 90% of annual rainfall derives from the easterly penetration of the SASM during the austral summer. These precipitation patterns exert a tight control on the altitudinal distribution of the main vegetation communities. Hence, our pollen reconstructions allowed a fine characterization of past vegetation changes caused by shifts in the strength of the SASM during recent millennia.

The chronology of the two lake cores is based on multiple AMS <sup>14</sup>C dating, while all rodent deposits were individually dated, providing key complementary short-term information at punctual times. Our pollen records reveal significant changes in vegetation at multi-centennial timescales, most notably a marked expansion of high-Andean vegetation along with significant increases in terrestrial plant productivity and lake levels between ~2200 and ~1400 cal yr BP. We interpret this evidence as a multi-centennial interval of increased precipitation due to a strengthening in the mean state of the SASM. Comparisons with other records from the Altiplano, the Tropical Andes and the Pacific Ocean suggest that this rainfall anomaly was largely decoupled from variations in the ITCZ and ENSO at that time. Additionally, we distinguish a marked latitudinal gradient in proxy responses where sites in the southern Altiplano display this wet anomaly more markedly than sites further north. This evidence is consistent with an extra-tropical source of moisture for the SASM. Our results suggest that the drivers of the SASM variability during recent millennia may have been more complex and variable than previously thought, and therefore caution is required in assuming that the tropical controls of this system observed in the instrumental record are stationary in time.

O-0027

## Stalagmite-inferred hydroclimate dynamics in East Timor over the last deglaciation

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### Abstract

Here we present stalagmite calcite  $\delta^{18}\text{O}$  and inclusion water oxygen and hydrogen isotopic records over past 16.5 thousand years (ka, before 1950 AD) from Lekiraka cave in East Timor ( $8^{\circ}47'10.8''\text{S}$ ,  $126^{\circ}23'31.1''\text{E}$ ; 626 m above sea level), located in the Australian-Indonesian monsoon territory. The paleo-cave temperature record, calculated with coeval carbonate and inclusion water  $d^{18}\text{O}$  data, shows a thermal increasing for 4-6 °C during 16 -12 ka, similar with the trend of past WPWP sea surface temperature change. One of remarkable features of the cave temperature record is 2-kyr thermal valley at 8-6 ka, which does not follow the Holocene-Maximum conditions in the northern hemisphere, instead, is concurrent with the cooling in the Antarctica. Lekiraka stalagmite calcite  $d^{18}\text{O}$  record reveals relatively dry glacial and wet Holocene. Inclusion water oxygen and hydrogen isotopic data suggest that Sunda area was the more important moisture source in the Holocene than during the glacial time. Sunda Shelf landmass, associated with deglacial sea level change and global warming, may lead to the alteration of the regional atmospheric circulation and hydroclimate during deglaciation. However, the air temperature over the entire Holocene could be governed by regional insolation and southern-hemisphere high latitude forcings.

O-0028

## **Abrupt spatio-temporal shifts in Holocene South American rainfall and its relation to low and high-latitude forcing**

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### **Abstract**

Rainfall derived from the South American Summer Monsoon (SASM) is socially, economically, and ecologically crucial for the largest part of South America. Yet the mechanisms driving its spatio-temporal variability are poorly constrained posing a challenge for predicting its evolution under future climate change scenarios. To get insights into SASM-dynamics during the past 5 kyr we investigated a marine sediment core obtained in the vicinity of the Jequitinhonha River delta, Eastern Brazil. As the Jequitinhonha's catchment is under the influence of the SASM and particularly sensitive to changes in moisture availability, it is ideally suited to reconstruct spatio-temporal SASM variability. To assess moisture variability in the river catchment and its potential relation to changes in the marine realm, we utilized a multi-proxy approach comprising X-ray fluorescence core scanning, organic biomarker analyses (i.e., alkenones, compound-specific dD on plant waxes), and X-ray diffractometry. Our data suggests that a decline in the inter-tropical insolation gradient fostered a decrease of SASM intensity over the past ~ 2.7 kyr. This long-term trend is overprinted by centennial to millennial-scale fluctuations, probably driven by climatic forcing of high latitude North Atlantic and equatorial Pacific origin. An abrupt shift in the mean spatial configuration of the SASM occurred at ~2.0 ka, initiating a long-term establishment of drier conditions over eastern Brazil. This shift was paralleled by an abrupt increase in El Niño Southern Oscillation variability as well as by a rapid slow-down of the Atlantic Meridional Overturning Circulation, invoking a complex interplay of low and high-latitude forcing on spatio-temporal SASM dynamics.

O-0029

## Geological evidence for widespread deglaciation of North America during Marine Isotope Stage 3

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### Abstract

The paleorecord offers an important long-term perspective on the interactions between various components of the Earth system. Understanding the climate system during Marine Isotope Stage 3 (MIS 3; 57 to 29 kyr BP) is of particular interest because this interval consisted of a suite of abrupt climate events, notably rapid temperature fluctuations (Dansgaard-Oeschger events) and significant ice sheet instability (Heinrich events). The Laurentide Ice Sheet (LIS) was a dominant ice mass over North America during the Late Pleistocene and played a major role in sea level change, atmospheric circulation and floral/faunal migration. However, little is known with certainty about the dynamics of the LIS during MIS 3, nor the role it played in rapid climate events that characterized this interval. Here, we present evidence suggesting that the LIS was dramatically reduced during MIS 3. We synthesize >700 geochronological data points (radiocarbon determinations, cosmogenic exposure ages, optically stimulated luminescence dates) that constrain a much reduced ice margin and the presence of widespread ice-free landscapes over much of North America at ~42 ka. Key to this hypothesis are sites from the Hudson Bay Lowlands near the center of the glaciated region in east-central Canada. Chronological and paleoecological data from these stratigraphic sections suggest the development of widespread terrestrial landscapes (boreal peatlands) during this period. Interestingly, the hypothesis of a dramatically reduced LIS during MIS 3 was first raised by stratigraphic workers in the early 1980s, however the suggestion was not widely accepted because of the lack of supporting evidence. We provide such evidence using a geophysical model which shows that a reduced ice sheet is consistent with regional and global sea level markers during this interval. If this hypothesis is correct the implications are significant. Notably, dramatically reduced ice over North America during MIS 3 requires a refinement of Late Pleistocene sea level records and possibly a re-evaluation of the processes that drive Dansgaard-Oeschger and Heinrich events, which are often attributed to the dynamics of a much larger ice sheet.

O-0030

## Middle Wisconsinan marine shells near Repulse Bay, Nunavut, Canada: Implications for MIS 3 ice-free conditions in northwest Hudson Bay

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### Abstract

Evidence suggesting reduction of the Laurentide Ice Sheet (LIS) during MIS 3 is widespread but the boundaries of the ice sheet and timing of the minimum ice extent are still poorly constrained. The idea that the Middle Wisconsinan was a period of significant glacial recession in the core area of the LIS has long been debated, and is still disputed today, particularly in the Hudson Bay Lowlands (HBL). Radiocarbon dating of glacially transported marine molluscs in streamlined till south of Repulse Bay, Nunavut, Canada, provides new evidence for MIS 3 deglaciation in the northwest part of Hudson Bay. Middle Wisconsinan finite  $^{14}\text{C}$  ages on 8 mollusc samples varying between 31.7 and 39.2  $^{14}\text{C}$  ka BP (~35.0 and 43.7 cal ka BP) indicate a marine event(s) for a minimum of ~8.7 cal ka. The fossiliferous calcareous till is derived from Paleozoic carbonates in proto-Roes Welcome Sound, and was deposited by a topographically controlled ice stream stemming from the eastern end of the Keewatin Ice Divide. Our findings suggest prior ice-free conditions in the ice stream source area indicating significant glacial recession of the LIS margin during the Middle Wisconsinan, much farther in the interior of the ice sheet than previously known. We propose here various possible configurations of ice limits during MIS 3 for the extended Repulse Bay region. The marine incursion possibly occurred as a result of a calving bay developed from the north in the Gulf of Boothia-Committee Bay area following the recession and collapse of an ice stream which was re-activated after the MIS 3 marine episode(s), and maintained until deglaciation. Alternatively, the development of a calving bay(s) from the east up Hudson Strait may have permitted deglaciation of Roes Welcome Sound and possibly other parts of Hudson Bay. Although these configurations of the LIS may not answer the recurring question whether MIS 3 was a time when the HBL were ice free, they significantly contrast with recent paleo-ice sheet models that suggest full ice conditions in the Repulse Bay region and can therefore contribute to the debate and configuration of the LIS during MIS 3.

O-0031

## The Laurentide Ice Sheet before, during and after MIS3 from a Great Lakes/St. Lawrence River Basin perspective

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### Abstract

The Great Lakes/St. Lawrence River (GL-SLR) drainage network imposes unique paleogeographical constraints for deciphering the periodical waxing and waning phases of the Laurentide Ice Sheet (LIS). In the Quebec City (QC) area, the SLR funnels the waters of the third largest drainage basin in North America. Early workers had already realized the importance of this unique geography in the interpretation of the Quaternary regional stratigraphy and hence glacial history. Indeed, the paleogeography requires that from the moment the LIS crosses the SLR in QC, a significant fraction of the surface drainage in NE North America will be diverted towards the upper reaches of the SLR drainage basin, first through the Hudson River valley and eventually overflowing the major drainage divide between the SLR and the Mississippi River.

Quaternary sediments exposing the last glacial cycle of the LIS are well exposed in the St. Lawrence Lowlands and the Appalachians of Southern Quebec as well as along the shores of Lake Ontario and Lake Erie. Physical stratigraphy is suggesting a complex history of ice margin fluctuation with consequent periodical glacial meltwater damming the upper reaches of the GL-SLR basin tributaries. Fossil organic and carbonate (mostly shells) material is found to be older or at the limit of the radiocarbon method. Fortunately, a large number of state-of-the-art Infrared Stimulated Luminescence (IRSL) dates have yielded depositional ages for waterlaid lithostratigraphic units exposed from Lake Erie to the St. Lawrence Estuary. The luminescence dating methodology has thus contributed to securing the correlation of the lithostratigraphic units across the regional depocenters and to the establishment of a robust chronostratigraphic framework at the scale of the GL-SLR basin.

Thence, an overall clearer image of the events leading from the end of the last interglacial to the Last Glacial Maximum (LGM; MIS2) is now emerging. The MIS5a (?) unglaciated but cool-climate landscape generated stratigraphically significant but thin and discontinuous non-glacial lithostratigraphic units. The transition from the geographically restrained and probably short-lived glacial paleoenvironments of MIS4 to the early MIS3 ice free landscape is poorly exposed and probably obscured by erosion. Several Mid-Wisconsinan sections expose aggrading distal sandy and silty outwash in glacio-isostatically subsiding basinal areas. These ice advance facies should have been time-transgressive over MIS3 time but at this stage of research, similar IRSL ages of ca 35 to 50 ka have been obtained for stratigraphically equivalent sediments collected in different sections of the GL-SLR. This might indicate rapid ice build-up and expansion in the mid part of MIS 3 or a lack of age resolution in the IRSL chronology. Nonetheless, it will be argued herein that the deduced paleogeography enlightens the issue of continental ice volume during MIS3.

O-0032

## A small Laurentide Ice Sheet until mid-MIS 3: Insights from glacial isostatic adjustment modeling, non-glacial deposits, and sea-level histories

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### Abstract

While glacial geologic records track the retreat history of the Laurentide Ice Sheet, constraints on the ice-sheet build-up history are more elusive. As the Laurentide Ice Sheet expanded to its maximum extent at the Last Glacial Maximum (26 ka), it erased most evidence of previous glaciations. However, an increasing number of dated, non-glacial deposits point to a relatively confined Laurentide Ice Sheet during Marine Isotope Stage 3 (MIS 3), suggesting rapid ice growth rates leading to the Last Glacial Maximum. Previous work has demonstrated that sea-level markers along the U.S. mid-Atlantic, which record anomalously high sea-level during mid-MIS 3, are reconciled by a delayed growth of the eastern sector of the Laurentide Ice Sheet. Here we demonstrate that predictions of relative sea-level (RSL) change due to glacial isostatic adjustment involving a late and rapid growth of the Laurentide Ice Sheet are consistent with sea-level bounds associated non-glacial deposits of MIS 3 age in Canada and available RSL histories. In particular, we consider geologic records in the Hudson Bay Lowlands, the St. Lawrence Lowlands, Ontario, and Atlantic Canada. In addition, we run a simple dynamic ice model adopting the paleotopography generated from the glacial isostatic adjustment simulation and predict rapid glaciation rates starting at mid-MIS 3 (44 ka) are feasible when we adopt accumulation rates similar to those observed in the present-day Arctic.

O-0033

## Evidence for multiple advances of the southwestern Laurentide Ice Sheet during MIS 3

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### Abstract

The ice build-up of the Laurentide Ice Sheet (LIS) before the Last Glacial Maximum (LGM) during Marine Isotope Stage 3 (MIS 3; 57-29 kyr bp) is a growing area of interest; however, calibration of pre-MIS 2 (29- 14 kyr bp) LIS models is problematic due to the sparsity of land-based evidence. MIS 3 glacial deposits are rarely found beyond the LGM extent as MIS 2 glaciation eroded or covered most of these older sediments. Iowa, located in the midcontinent of the United States, has glacial tills from both MIS 2 and MIS 3. Extensive fieldwork in the state has collected radiocarbon ages from wood in basal tills and buried soil organics from MIS 3 deposits located below and beyond the MIS 2 boundary. The combined ages place the LIS advances in north central Iowa in two advances, ranging from 46-40 kyr bp and 34-29 kyr bp. Lithostratigraphic relationships also indicate two separate ice advances as multiple outcrops and cores display a weathering zone or weakly developed soil between the tills. The lithology of the glacial diamictons is similar to the sediment deposited by the MIS 2 Des Moines Lobe advance (17-14 kyr bp), suggesting the tills share a common Keewatin source provenance. Thus, these older tills show that Keewatin sourced ice was near or beyond the local LGM extent multiple times during MIS 3. Recent work has proposed a reduction of the LIS during MIS 3, but these radiocarbon ages and ice extents conflict with models that suggest a limited distribution of the southwestern LIS during MIS 3.

O-0034

## The Late Quaternary history of the Fennoscandian Ice Sheet revisited

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### Abstract

Geological data in the form of long sediment records and well-dated sediments and fossil remains are increasingly available from the central areas of Fennoscandian and Laurentide glaciations. This evidence derived from terrestrial archives suggests significantly smaller global ice volumes during the Late Quaternary than classically inferred from marine foraminiferal and coral data. We here give a first compilation of data from an unusually long and fossil-rich sedimentary sequence that is preserved in a depression formed in deeply weathered rocks of a magma intrusion (Sokli Carbonatite Massif) in the Fennoscandian Shield (N Finland). The analysis of multiple proxies (pollen, NPP's, macrofossils, diatoms, chironomids, biogeochemistry), the application of diverse fossil-climate calibration models including classical and machine-learning approaches, and the dating of sediments and fossils by means of OSL and AMS <sup>14</sup>C, have provided detailed environmental and climate reconstructions for the last 130 kyr. The results indicate highly variable environmental and climate conditions in the region. We infer that Fennoscandian glaciation during the Late Quaternary was both considerably smaller in extent as well as shorter in duration than earlier suggestions, which were previously based on the correlation of highly fragmented geological data with the deep-sea oxygen isotope stack. Regarding MIS 3, present-day summer temperatures are reconstructed and were accompanied by large-scale deglaciation. Well-dated evidence from nearby sites indicates that ice build-up to LGM extents may have started only after ca. 35 kyr BP. This newly obtained geological data from the central area of Fennoscandian glaciation calls for renewed calibration of marine data in providing estimates for global ice volumes.

O-0036

## The interplay of adaptation, distribution and extinction among Quaternary large mammals

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### Abstract

Mammal species of northern biomes became adapted to Quaternary conditions but were challenged by its constantly fluctuating nature. Morphometric data on the evolution of the mammoth, for example, demonstrates dental adaptation to more open landscapes and grass/herb dominated food through 2.6 myr of the Quaternary, but up to the middle Pleistocene the complex of populations included variation allowing survival in a range of habitats. Morphometric and ancient DNA studies of the woolly mammoth demonstrate a loss of both morphological and genetic variation through the Late Pleistocene, that likely contributed to the species' ultimate demise. Mapping of radiocarbon-dated mammoth remains illustrates complex range shifts in the interval from 50 kyr onwards, with net reduction of range, and this correlates with loss of DNA clades. Extinction is seen not an instantaneous event but a sequence of regional extirpations, so extinction is visualised, with sufficient data, as 'merely' the zero-point of a process of range reduction. Alternating range expansion and contraction is typical of mammalian species in response to fluctuating Quaternary climate, and extinction is most probable in the contracted refugial phase, which often represents the core area of the species. Comparison of mapped radiocarbon dates in species such as woolly mammoth, woolly rhinoceros and giant deer shows that species act individualistically, according to their individual ecology, in the timing and geographical pattern of their distributional response and ultimate extinction. Survivors may be lucky (surviving a severe bottleneck where analogous species went through the zero point of no return, e.g. musk ox vs. mammoth and woolly rhino), or benefit from adaptive flexibility at the individual and population level (e.g. red deer). Adaptability includes behavioural and ecophenotypic flexibility as well as genetically-programmed variation.

O-0037

## Hungry like a wolf: impacts of carnivore competition on morphology and prey choice

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### Abstract

The wolf, *Canis lupus*, is a survivor of Pleistocene environmental change, making it an ideal candidate for exploring past carnivore community interactions as it persisted through multiple climatic cycles, encountered different competitors and adapted to varying prey resources. Known temporal morphological variation in the cranio-dental complex of British Pleistocene wolves provides a detailed record of relatively fast palaeodietary responses to shifts in competition and environmental change. However, in order to elucidate Pleistocene wolf prey choice and explore more fully the effects of competitive interactions with coeval large carnivores over time, a large-scale direct measurement of wolf palaeodiet through stable isotope analysis was undertaken.

Focussing on Pleistocene cave faunal assemblages from southwest England correlated to MIS 3 (60-25kya: Sandford Hill), MIS 5a (c.80kya: Banwell Bone Cave) and late MIS 7 (c.240-190kya: Hutton Cave, Bleadon Cave), bone collagen from carnivores and a range of prey species present was analysed for carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ). Well-preserved, viable bone collagen was retrieved from each site, confirming the feasibility of stable isotopic studies on material of >50kya in Britain, and notably in sites >190kya, such as Hutton Cave.

Horse *Equus ferus* was an important component of wolf diet in both MIS 7 and 3, whereas when this species was absent from Britain during MIS 5a, reindeer *Rangifer tarandus* became a significant food source. Based on common prey choices, competitive interactions between wolf and spotted hyaena *Crocuta crocuta*, when present, were more important than those with lion *Panthera leo*, whereby separation in prey choice minimised conflict. These interactions are consistent with morphological cranio-dental evidence of wolves becoming more generalist feeders in response to competitive pressure from other large carnivores in MIS 7 and 3. In contrast, elevated  $\delta^{15}\text{N}$  levels in the MIS 5a faunal assemblage are indicative of high levels of meat consumption in all carnivores, combined with a strong environmental stress signal from the herbivores. Again, dietary isotope results are in agreement with the morphological evidence during this time, which suggests that wolves in MIS 5a were hyper-carnivorous in comparison to MIS 7 and MIS 3.

Stable isotope results therefore reveal that wolves shifted prey choices in response to environmental change and large carnivore competition through time, complimenting the dietary specific cranio-dental morphological data. This combined approach highlights the importance of both indirect and direct measurements of palaeodiet, as well as lending further credence to the ecological resilience of the wolf based on their morphological plasticity and behavioural flexibility.

O-0038

## Polar bear's range dynamics in the Late Pleistocene and the Holocene

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### Abstract

Reconstructions of species ranges during the past warming periods are important for understanding the impact of climate change on the distribution of arctic mammals. By analyzing the fossil records of key arctic species together with data on past climates and sea ice conditions, it is possible to investigate the species ranges and, eventually, make inferences about the survival strategy of arctic mammals during climatic conditions warmer than at present. Here, we use the dataset of fossil records to investigate changes in the polar bear's distribution during the Late Pleistocene and the Holocene. Over the decades, hundreds of polar bear bones and teeth have been discovered from the high latitude regions, and these findings represent a minimum number of 229 individuals from 45 sites and date from the Late Pleistocene (15 – 11.7 ka) to the Holocene (last 11.7 ka).

During the last deglaciation, the polar bear was present in the south-western and western margin of the Scandinavian Ice Sheet where it survived until the earliest Holocene about 11 ka. In the Early Holocene, fossils have been discovered from Svalbard and the Zhokhov island in the East Siberian Sea. There are no polar bear findings from 8-6 ka, which is generally the warmest period of the Holocene in the Arctic with summer temperature up to 2.5°C higher than at present, but the findings from 8-9 ka and 5-6 ka suggest that the species was able survive this Holocene thermal maximum in the cold refugias in the high arctic of the East Siberian Sea, the northernmost part of Greenland and the Canadian archipelago. Intriguingly, there are polar bear fossils findings from the Aleutian and Pribilof Islands (Unalaska and St. Paul islands) from 5.4-3.4 ka. Unalaska, the southernmost of these islands, is currently located roughly 400 km south of the modern sea-ice limit and 1000 km south from the nearest polar bear population, and our data suggest that it was outside the area of arctic sea ice in the Mid Holocene. There is firm evidence that the range of polar bear expanded over the late Holocene (last 4000 years) in tandem with the cooling climate and the expanding arctic sea ice. We conclude that an analysis of the Late Pleistocene and Holocene fossil record of the polar bear highlights the major changes in its range in response to climate changes and thus demonstrates the long-term congruence of its range with sea ice and climate.

O-0039

## Arctic-alpine plants survived past forest expansion: a 24,000-year ancient DNA record from the Polar Urals

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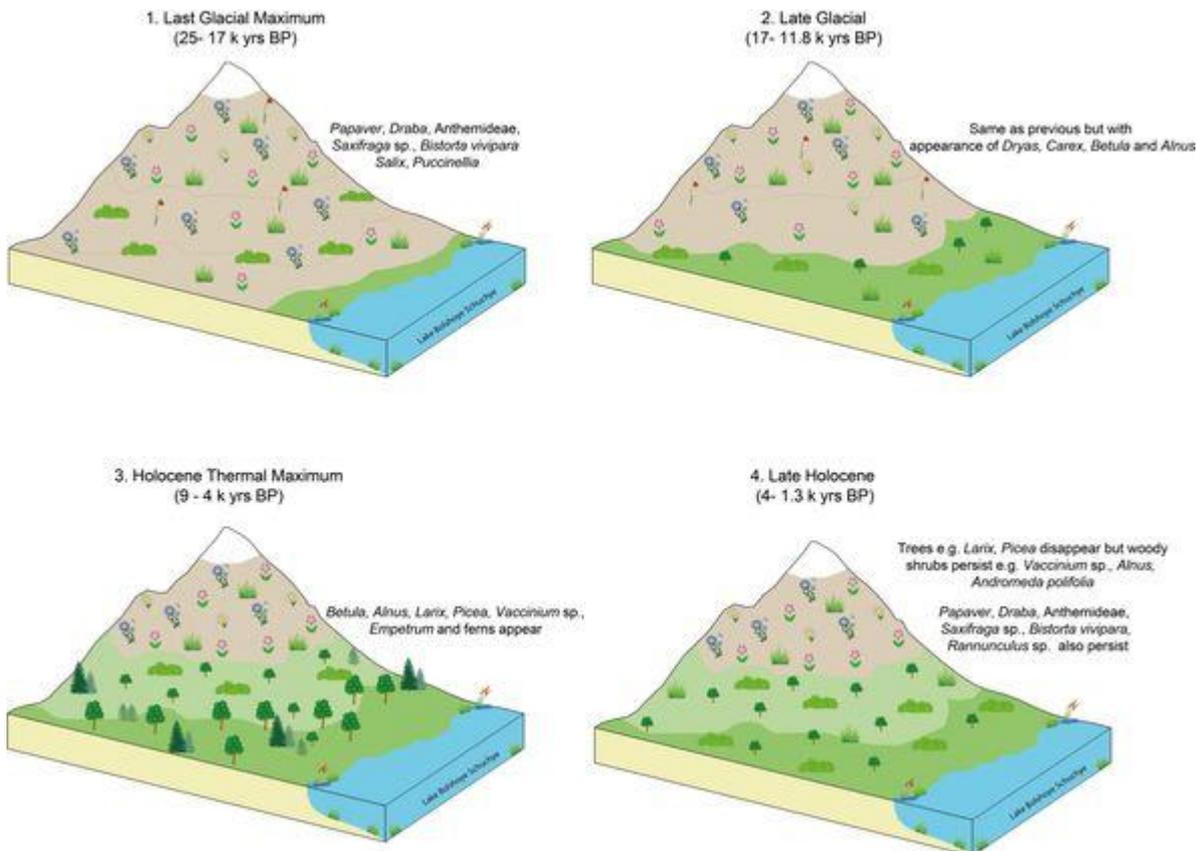
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### Abstract

The ability of arctic and alpine plants to withstand extinction from future climate change will depend, in part, on their ecological resilience and the availability of suitable habitat in a warmer climate. Knowledge of the role of mountain landscapes as safe-havens promoting the persistence of cold-adapted arctic and alpine plants over long timescales is limited. Here, we present a 24,000-year record of plant community dynamics based on ancient DNA extracted from the sediments (*sedaDNA*) of Lake Bolshoye Schuchye, the largest and deepest lake in the Polar Ural Mountains of northern Russia. We identified 167 plant taxa based on *sedaDNA* (45 % identified to genus level, 41 % to species, 14 % to family), which included representatives from all plant functional groups.

We show that cold-adapted plants (e.g. *Arabis alpina*, *Bistorta vivipara*, *Papaver*, *Dryas octopetala*, *Saxifraga oppositifolia*) have survived and persisted in the Polar Urals in the face of changing climate and environmental conditions over the past 24,000 years, despite past northward and upward expansion of forest tree taxa (e.g. *Larix sibirica*, *Picea*, *Betula*) between 9000 - 4000 cal. years ago. The large and topographically complex catchment of Lake Bolshoye Schuchye has retained its diverse species pool over time, with a consistent long-term increase in floristic richness over the past 24,000 years.

Using our *sedaDNA* time-series, we infer that mesoclimatic heterogeneity arising from variable topography in a mountainous landscape facilitates the persistence and co-existence of both cold-adapted and forest plant taxa during warm climate episodes, thereby preserving floristic diversity. Our results highlight the importance and conservation significance of mountainous landscapes as a buffer against the extinction of arctic and alpine plants in a warmer climate.



**Figure 1:** Conceptual model to outline the key changes in plant community composition identified in the *sed*aDNA from Lake Bolshoye Schuchye. Note the continued persistence of arctic and alpine plant taxa through all four time periods of interest.

O-0040

## A study on the ecology and ethology of Pleistocene fauna (cave bear, red deer) by molecular palaeontology techniques

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### Abstract

The palaeobiology of ancient individuals, including already extinct species, can be reconstructed using diverse types of data (i.e. isotope data, DNA, morphology). In this work, we focus on information about the behaviour of individuals and populations obtained from mitochondrial DNA, inherited through motherhood and therefore informing about the family lineage of individuals. We supplemented the study with stable isotope analyses, which are informative about the animals' diet and the environmental conditions, and Strontium isotopes indicating the geological substrate in which they lived.

Examining mitochondrial DNA sequences of Pleistocene red deer (*Cervus elaphus*) from Liñares cave (Lugo, NW of the Iberian Peninsula), we found a high genetic diversity, with individuals belonging to phylogenetically very distant lineages. This corroborates previous studies indicating that this ensemble was formed by stags that failed to form a harem. As in the current red deer, the younger (and in some cases older) male deer formed a separate group that roamed farther away and eventually died in Liñares Cave, whose accumulation in deer remains is interpreted as a catastrophic episode (by sinking or plugging the entrance).

In the case of the cave bear (*Ursus spelaeus*), we studied several caves in the North of the Iberian Peninsula (Eirós, Liñares, A Ceza, all of them in Galicia, and Amutxate, in Navarra) and observed that each site was occupied by bears sharing a single mitochondrial lineage, common to both male and females. These mitochondrial lineages were different between caves, even when we compared animals from the same time period. This is suggesting a homing behaviour (i. e., returning to the place of birth) in cave bears. This behaviour is not observed in its next of kin, the brown bear (*Ursus arctos*), neither fossil nor current, since only occasionally was the occurrence of mother and daughter pairs documented.

On the other hand, the carbon and nitrogen stable isotopes of collagen and the carbon and oxygen stable isotopes of apatite from each species and site, provide clues to the extent of the groups' habitat and how they exploited their ecological niche. We found some climate-related differences between groups of different chronology, but also in the same chronology. This may reflect a difference in the ecological niches of each species, although strontium isotopes indicate that there was no appreciable separation in the territories inhabited by both species.

O-0041

## American mastodon mitochondrial genomes suggest repeated colonization and extirpation in northern latitudes

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### Abstract

Ancient DNA studies have greatly contributed to our understanding of Pleistocene megafaunal ecology, identifying demographic changes not immediately apparent in the palaeontological record. However, phylogeographic studies of North American megafauna have largely focused on grazing species (e.g. mammoths, bison) that primarily inhabited open grassland and steppe-tundra environments. This focus on animals from a single environmental context has resulted in a biased understanding of the roles that climate and human-induced factors had on the population dynamics of American megafauna, omitting key forest and mixed-environment species such as the American mastodon (*Mammuthus americanus*).

Palaeontological work has shown that mastodons and mammoths were differentially affected by climatic shifts, suggesting that forest and grassland species were asymmetrically impacted by Pleistocene glaciations. An examination of the chronology and population dynamics of proboscideans in the North American midcontinent revealed differences in regional habitation patterns of mammoths and mastodons, and extinction dynamics. Similar analyses looking at the radiocarbon record of mastodons in Alaska-Yukon have indicated that all remains are non-finite (>50 kya). Notably this supports previous palaeoecological hypotheses that suggest mastodon presence in the far north was limited to warmer interglacial periods.

To answer questions about the differential evolution and extinction of American mastodons, we extracted ancient DNA from 123 fossil remains spanning their North American range. We generated 33 complete mitochondrial genomes, which we incorporated with the only two previously sequenced mastodon mitogenomes into our phylogeographic analysis. We identified two separate mitochondrial lineages in the Alaska-Yukon region. Molecular clock dating suggests that the mean ages of the two Alaska-Yukon clades fall within at least two separate interglacial periods, with mean ages 92.2-119 kya (MIS 5e interglacial) for one clade, and 238 kya and 270 kya (MIS 7) for the two samples in the other Alaska-Yukon clade. In addition our analysis reveals comparatively low levels of genetic diversity in our largest Alaska-Yukon clade in comparison to samples from south of the ice-sheets.

Our current dataset of 33 new complete mitochondrial genomes represents an approximately 16-fold increase in available data for the American mastodon. Molecular dating analysis supports current palaeoecological theories that propose *M. americanus* occupation of northern latitudes was restricted to warmer interglacials when forests and wetlands would have been abundant. Our data also suggest that mastodon colonization and extirpation in northern latitudes was likely a recurring event that happened at least twice during the Pleistocene. These local extirpations were likely caused when forested habitats were replaced by steppe-tundra vegetation as climates returned to cold, dry conditions associated with glaciations, and will likely hold for most other larger-bodied browsers in Pleistocene



North America. A continued investigation of Pleistocene browsers is necessary to supplement our current understanding of megafauna responses to the unique climatic stressors of the Pleistocene.

O-0042

## The climate of the Olympic Peninsula, northwestern USA, during the LGM based on fossil beetles, pollen and ice margin deposits

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### Abstract

Climate during the LGM (18-25 ka) varied across North America, strongly influencing changes in plant and animal distributions and causing variations in the timing and relative magnitude of ice expansion and recession. The Olympic Peninsula is a high (2700 m) maritime terrain in northwestern Washington at the leading edge of Pacific weather systems. It is ideally situated to assess influences of the Pacific Ocean on the LGM climate when ice sheets covered most of northern North America. Stratigraphy, geomorphology, and geochronology provide evidence that mountain glaciers extended to the lowlands but were substantially less extensive during the LGM than during the mid-Wisconsin and earlier in the Pleistocene. Fossil beetle assemblages from sections at Kalaloch on the coast, and from the South Fork of the Hoh River, contain species that currently inhabit riparian and lacustrine habitats in the boreal zone of Canada and Alaska, and in higher elevations in the Cascades and Rocky Mountains. *Olophrum* species, which today are unknown from the Olympic Peninsula, are represented by fossils of *O. rotundicolle*, *O. boreale* and *O. consimile*. *O. consimile* is especially well-represented and its occurrence today at an elevation above 1000m in the Cascades of northern Washington State indicates summers during the LGM would have been about 4°C cooler. The absence of any wood-boring beetles, in contrast to assemblages from the mid-Wisconsin, indicates an open landscape. The interpretation from fossil beetles supports pollen and macrofossil evidence for an open vegetation of a Sitka spruce and mountain hemlock parkland. The closest analog at sea level for this vegetation is southwestern Alaska where temperatures are about 4°C cooler than the Olympic Peninsula today. Both the vegetation and the insects provide evidence that the climate was at least as wet as that of today and not as dry as the Puget Lowland to the east. A cool wet summer climate is consistent with glaciers advancing to the lowlands. The amount of climatic cooling on the Olympic Peninsula during the LGM is considerably less than at similar latitudes in mid-continental or eastern North America indicating a strong modulation of climate by the Pacific Ocean. *Postscript.* There are several endemic taxa in the living fauna and flora of the Olympic Peninsula which suggests that many taxa survived through multiple glaciations. Whether or not they are true endemics and evolved on the peninsula or accumulated there as a result of dispersion is debated. Among the mid-Wisconsin and LGM fossils of the Kalaloch section is a blind, flightless trechine beetle which today is unknown from North America. The closest living relatives are in the *Trechiana* lineage, known from Asia. The differences in morphology from any living species, however, indicate that isolation on the Olympic Peninsula is ancient and probably pre-Quaternary.

O-0043

## Mapping of mixed landform signatures of palaeo-subglacial drainage over northern Canada

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### Abstract

Subglacial hydrology is a key control on ice sheet flow. To better understand the structure and evolution of the subglacial drainage network, we can use the imprint of meltwater drainage recorded on the beds of former ice sheets. This method has an advantage over contemporary observations as it facilitates the reconstruction of drainage networks over larger spatial (metres to 10's kilometres) and temporal (centennial to millennial) scales; key requirements for understanding the system and informing numerical models. Recent advances in constructing high resolution digital elevation models (DEMs e.g. ArcticDEM) have greatly improved our ability to map the geomorphology of palaeo-ice sheet beds. Nonetheless, despite a long observational history, meltwater landforms such as eskers, tunnel valleys and meltwater corridors, have typically been considered in isolation rather than as an integrated drainage system.

Here, we present the first large-scale integrated map of palaeo-subglacial meltwater pathways over northern Canada. Key to the development of this map was the inclusion of hummock corridors – elongated tracts of hummocks that often exhibit negative relief and undulating long-profiles and frequently contain eskers. These features were efficiently identified and mapped using a new automated method (Lewington *et al.*, in review) based on filtering the raw ArcticDEM data to isolate hummock corridors by wavelength and orientation (two of their defining characteristics). The automatic output was used alongside the published esker pattern to guide centreline mapping of 'complete' meltwater pathways (i.e. eskers, tunnel valleys and hummock corridors).

The output provides data on the distribution, pattern and morphometry of >2,000 meltwater pathways across northern Canada. Notably, the map reveals the commonality of hummock corridors over the area, which often 'bridge the gap' between sections of eskers and/ or tunnel valleys. In comparison to eskers alone, our integrated map reveals less fragmented subglacial drainage pathways with a greater number of tributaries and denser spacing. Along-flow transitions to/ from different meltwater landforms may suggest a meltwater landform continuum whose expression depends on the balance of controls at a particular time and place. Associations between down-flow transitions and flat spots are interpreted as the signature of subglacial lake drainage events. Overall, the consideration of large-scale integrated drainage systems is likely to reveal new associations and insights into meltwater landform formation and network organisation at an ice-sheet scale.

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Lewington, E.L.M. Livingstone, S.J. Sole, A.J. Clark, C.D. Ng, F.S.L. (In Review). An automated method for mapping geomorphological expressions of former subglacial meltwater pathways (hummock corridors) from high resolution digital elevation data.

O-0044

## Glaciofluvial Corridors and Tunnel Valleys Below the South-Central Fennoscandia Ice Sheet

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### Abstract

Knowledge about processes active beneath ice-sheets, and in particular the process connected to glacial melt-water drainage, is crucial for a fundamental understanding of ice sheets and how they react in a warming climate. Investigating sediments and geomorphology of drainage systems below ice sheets is complicated; however, formerly glaciated regions are easily accessible. New datasets, in the form of LiDAR-derived digital elevation models (DEM), have made it possible to map formerly glaciated regions in an unprecedented detail. We have mapped an area in southern Sweden, the south Swedish uplands (SSU), that make up a fair bit of the formerly south-central part of the Fennoscandian Ice Sheet (FIS). This region was deglaciated during the Bølling-Allerød warm period, just prior to the Younger Dryas cold event. During the Bølling-Allerød, large amounts of meltwater were derived from ice-sheets.

At the SSU we have mapped elongate zones of hummocks, which we refer to as corridors. These elongate zones have distinct borders with the surrounding lineated till plain; in some places they show an anastomosing pattern. The corridors have an overall radial pattern that is sub-parallel to overall ice-flow and in places the corridors cut through glacial lineations. We analyzed the morphometry of these corridors. Many show adverse, up-to-the-margin slopes. Corridor width varies 0.2 and 4.9 km, their length are up to 11.8 km and the spacing between corridors is around 10 km, values comparable to data on tunnel valleys (TV) and glaciofluvial corridors (GFC) reported elsewhere. About 2/3 of the corridors display negative cross-profiles (they are incised in the regional till plain), others are positive forms. In the floors of some negative corridors eskers occur that are superposed on hummocks. With machine dug sections of hummocks within one of these corridors we show that at least two of these hummocks consist of subglacial traction till with deformed interbedded sorted sediments. Moreover, we show that the material in these hummocks belong to MIS 4 or 3, using OSL. Based on the morphometrics and our excavations, we interpret the negative corridors to be tunnel valleys.

The radial pattern and regular spacing of the corridors implies the positive forms also have a subglacial meltwater genesis. Using a recent reconstruction of the deglaciation of the FIS we attribute an age to the mapped corridors. Comparing the frequency of corridors per time interval with climate variations from Greenland ice-cores we suggest that the formation of corridors on SSU can be connected to delivery of abundant supraglacial meltwater to the bed during the Bølling-Allerød warm period.

O-0045

## Morphometries of eskers on Mars: comparisons to eskers on Earth and implications for sediment-discharge dynamics of subglacial drainage.

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### Abstract

Mars is a glaciated planet with an extremely cold and hyper-arid climate. It hosts water ice within polar ice caps, ground ice, and thousands of mid-latitude debris-covered glaciers. Until recently, it was widely thought that mid-latitude glaciers on Mars' had been pervasively cold-based since their formation 10s–100s Myr ago.

However, our recent discoveries of eskers associated with ~110–150 Myr old glaciers in the Phlegra Montes [1] and Tempe Terra [2] regions of Mars' northern mid-latitudes indicate that localised wet-based glaciation has occurred during Mars' most recent geological period, possibly driven by locally-elevated geothermal heat flux and strain heating within the glacial ice [1–3]. Eskers are sinuous ridges comprising sediments deposited in glacial meltwater conduits. They are important tools for reconstructing the extent and dynamics of wet-based glaciation on Earth, and have similar potential for Mars.

We used 1–2 m/pixel digital elevation models derived from 25–50 cm/pixel High Resolution Imaging Science Experiment stereo-pair images to measure the planform and 3D morphometries of the mid-latitude Martian eskers, and compare them with the morphometries of Quaternary-aged eskers in Canada [4] and SW Finland [5]. We found that the Martian eskers have remarkably similar lengths, sinuosities and heights to terrestrial eskers, but that the Martian eskers are typically wider and have lower side slopes. Large width-height ratios of the Martian eskers are consistent with our previous measurements of ancient (~3.5 Ga) eskers close to Mars' south pole [6]. These large ratios may arise from differences in either esker degradation state or fundamental glacio-hydrological controls on esker formation between Mars and Earth.

We also used a novel morphometric approach to test evidence for spatio-temporal variations in sediment-discharge dynamics during formation of the Martian esker in Tempe Terra. Our analyses reveal that this esker has a 'stacked' morphology: the crest of a wide, round-crested underlying ridge is superposed by a narrow, sharp-crested to multi-crested ridge. The superposed ridge is aligned with a channel-like depression that incises the underlying ridge. Based on morpho-sedimentary relationships observed along terrestrial eskers [7], we interpret this stacked morphology to represent conduit adjustment as a result of waning meltwater discharge and sediment supply towards the end of the esker-forming drainage episode(s).

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O-0046

## Modern analogues of esker formation: complexity, polygenesis and preservation potential

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### Abstract

Eskers are abundant on the beds of the former Eurasian and North American Ice Sheets, and form a useful record of channelised meltwater activity during deglaciation. As such, eskers have the potential to provide detailed insights into the hydrology of glaciers and ice sheets. However, our process understanding of eskers suffers from a disconnect between detailed morpho-sedimentary investigations of abundant large-scale ancient esker systems, and a relative paucity of modern analogues where esker formation has been observed and documented. Given the widespread retreat of glaciers around the world due to warming over the last ~100 years, it is perhaps surprising that few eskers have been observed forming as modern glaciers retreat. To explore why this might be, and to further our understanding of esker process-form relationships, we present the results of detailed studies into esker systems that have recently emerged from retreating glaciers in Iceland and Svalbard. We use 70 years of aerial photographs and a 2017 Unmanned Aerial Vehicle (UAV) Structure from Motion (SfM) photogrammetric survey to chart the gradual emergence of a complex esker system at Breiðamerkurjökull, Iceland, and recent high-resolution satellite imagery, a 2017 UAV-SfM survey and field observations of an esker system exhibiting similar morphological characteristics that has emerged under markedly different conditions at Hørbyebreen, Svalbard. In both of these systems, a distinctive planform morphology has developed where eskers are orientated in two dominant directions, corresponding to the direction of ice flow (which is commonly seen in ancient esker systems), and also the shape of the ice margin (which is not commonly observed in ancient eskers). These two orientations overlap to form a rectilinear pattern. The similarity in form but stark difference in context (broad, active temperate *versus* confined polythermal) suggests that complex esker morphology might be polygenetic. The eskers at Hørbyebreen contain substantial ice cores and have a high ice:sediment ratio, suggesting that they would be unlikely to survive if temperatures increase enough to melt the ice cores. The Breiðamerkurjökull eskers emerged from terrain characterised by buried ice which then melted out. Our observations lead us to conclude that eskers may reflect a wide range of processes at dynamic ice margins. Constraints on esker morphology include: topographic setting (e.g. confined valley or broad plain); sediment availability; meltwater availability; position of formation (supraglacial, englacial or subglacial); and ice-marginal dynamics such as avulsion, the formation of outwash heads or the burial and/or exhumation of dead ice.

O-0047

## The sedimentary architecture and morphology of the Brampton Kame Belt

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### Abstract

Kames constitute a diverse range of glaciofluvial and glaciolacustrine landform-sediment assemblages that provide information on the style and pattern of deglaciation. The Brampton Kame Belt is one of the largest (>40 km<sup>2</sup>) glaciodepositional complexes in the UK and is located at the centre of the former British-Irish Ice Sheet. A large-scale survey of the kame belt subsurface sedimentary architecture was conducted using ground-penetrating radar (GPR). A 100 MHz Mala Geosciences 'Rough Terrain Antenna' system allowed us to test the application of GPR in investigating complex glaciofluvial landform-sediment assemblages and to provide insight into the formation of the kame belt. The full range of geomorphic features were targeted, including ridges, flat-topped hills, channels and depressions. Where possible, GPR profiles were collected both along and across features in order to provide an insight into their 3D architecture. At two locations, profiles were collected above sediment exposures, which were logged in order to tie the radar data to the sedimentary facies.

The results enable a detailed understanding of individual landform evolution within the kame belt, and provide further insight into subglacial and ice-marginal meltwater drainage pathways during recession of the former British-Irish Ice Sheet. In particular, we identify two main styles of drainage: (1) major drainage axes parallel to ice flow that collapsed to form a series of aligned ice-walled lakes as glacier karst developed during deglaciation; and (2) ice-marginal drainage systems formed parallel to the ice margin as it downwasted. Variations in esker ridge internal structure indicate differences in flow conditions, styles of accretion, and degree of deformation that can be linked to observed differences in ridge morphologies.

O-0048

## Evidence for subglacial hydrofracturing, western Skeiðarársandur, Iceland.

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### Abstract

The western edge of Skeiðarársandur outwash plain has undergone a complex history of ice surging, jökulhlaups and glacial melt resulting in a landscape dominated by moraines, hummocks, glacial outwash, and a curious suite of semi-straight ridges, here referred to as the Súla Ridges. These formed between the turn of the 20th century when Skeiðarárjökull Glacier was near its maximum extent, and 1945 when expressions of the most prominent ridges can be seen on the surface of the glacier in aerial photos. This paper presents an overview of the geomorphology and the sedimentology of the Súla ridges through terrain analysis, ground penetrating radar analysis, and sedimentary analysis.

The ridges are arranged in a somewhat rectilinear pattern which would have been both parallel and at right angles to the former ice margin. They are typically 20-200 m long, 2-10 m wide and 0.5-5 m high with a handful up to 3 km long, and they are covered in pebbles, cobbles and boulders.

100 MHz ground penetrating radar (GPR) lines and grids were collected over several adjacent ridges. The GPR stratigraphy shows an average thickness of 4-8m of layered sediments. Till underlies the surface at depth preventing further significant penetration of the GPR signal. However, a well-defined network of dykes immediately below each ridge is clear in the GPR visualizations. Sedimentary analyses of sediments near the surface of the ridges in hand-dug trenches, and an analysis of the extensive Blautavísl section at the edge of the Súla River channel shows near vertical sheets of open-worked sub-rounded pebbles and cobbles, and thus the ridges are clearly the surface expression of a network of clastic dykes.

It is hypothesized that the ridges are relics of hydrofracture fills that formed during jökulhlaups. The hydrofractures formed near the ice front when rapidly increasing water-pressure during the rising stage of jökulhlaups drove water from overpressured subglacial channels and/or aquifers up through the overlying sediments and ice. These ridges represent the surface expression of where water escaped at the ice surface. As flow waned, sediment was deposited in the cracks. In-situ melting of the ice allowed gradual lowering of these sediments and preservation of the dykes. The study area is known to have been affected by several major jökulhlaups during the timeframe of probable formation, both due to the draining of ice-marginal Lake Graenalón (1935 and 1939), and ice melting during the eruption of the subglacial volcano Grimsvötn (1903, 1922, and 1938).

O-0049

## Late Weichselian glacial megafloods at the southern sector of the Scandinavian Ice Sheet: geomorphological record and palaeogeographical implications

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### Abstract

Geomorphological evidence of catastrophic glacial floods occurs in many formerly glaciated areas of North America, in the mountains of Siberia and Central Asia, and in northern Europe, but similar data have not been documented in the European Lowland thus far. Successful search for such palaeo-megafloods may help to better constrain the dynamics of glacial processes and ice/climate feedbacks during the Late Weichselian, and to inform about the impact of these events on the development of the now oversized valley systems in the European Lowland.

The main goals of our study were to (1) identify the geomorphological evidence of glacial megafloods in northern Poland, (2) determine the morphometric characteristics of landforms generated by these megafloods, and (3) constrain quantitatively the magnitude of these extreme events along the southern margin of the Scandinavian Ice Sheet (SIS).

In northern Poland, we document a Catafluvial Landform System (CLS) that consists of first-order catafluvial landforms including spillways and outwash plains, and second-order features represented by scabland-like landforms, expansion flood bars, megaripples, scour marks and clusters of kettle holes. These landforms derive from two megaflood events different in age (Frankfurt and Pomeranian phases) and in floodwater sources.

The better constrained glacial flood we identify in the eastern part of the ice-marginal spillway system had a peak discharge of about  $2 \cdot 10^6 \text{ m}^3 \text{ s}^{-1}$  (flow velocities up to  $17.1 \text{ ms}^{-1}$  and mean flow depth 19 m), which is comparable with the largest glacial megafloods reconstructed elsewhere in the world. Such rapid release of large volumes of freshwater into the oceans following a transfer across the European Lowland through the meltwater spillways, may have impacted global climate by disrupting the thermohaline circulation.

O-0050

## Late MP site of Farah II: environmental and cultural contexts at the transition to the UP in the southern Levant.

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### Abstract

Two alternative perspectives have been proposed to account for the Levantine Middle to Upper Paleolithic (MP-UP) transition: The first relates the transition to a global evolutionary process closely tied to the appearance of anatomically modern humans, in which periodic climatic “windows” allowed the dispersal of hunter-gatherer groups across the Saharan-Arabian desert belt. The second approach sees the transition as a local, gradual shift in demography and culture. Within this context, it has been suggested that several environmental and/or social processes acted as driving forces for the transition.

Here we present data from new excavations held at Farah II, an open-air site situated near the Nahal (wadi) Besor at the Negev desert margins, Israel. Previous excavations at the site revealed two *in-situ* surfaces, in fluvial loess sediments, dated to 50-60 ka. The lithic assemblages were defined as non-Levallois late MP and the fauna has North African affinities. Notably, Farah II is the only late MP site in the southern region of Israel that has yielded large samples of both faunal and lithic remains, making it an ideal case study to further explore the MP-UP transition.

Initial reconstruction of the sites’ environmental setting, which has implications for understanding the context of the end of the MP was undertaken using; 1) soil and sediment analyses (grain size, carbon and oxygen stable isotopes); 2) archaeobotanical remains (identification of charcoal, pollen, phytoliths); 3) faunal taxonomy and taphonomy. In addition, we have refined the age estimation of the occupation using both Optically Stimulated Luminescence (OSL) and <sup>14</sup>C dating.

OSL results of multi- and single-grain ages concentrate around 44-50 ka, suggesting that the site is 5-15 ka younger than previously thought. Initial results from lithic comparative studies with the MP site of Rosh Ein Mor (D15), located ~ 70 km to the south, illustrates that blade production from single platform cores were already in use within the late MP. This variability encompasses a large local pool of technological practices from which Initial Upper Paleolithic technologies could have drawn from, as demonstrated by the published assemblages from Boker Tachtit, central Negev. This observation supports a local gradual demographic shift rather than population replacement as a plausible explanation for the shift from MP-UP technological traditions.

O-0051

## Re-investigation of two Initial Upper Paleolithic sites in the Jebel Qalkha, southern Levant: Lithic technology, chronology, marine shells, and paleoenvironment

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### Abstract

Chronological and geographical diversity of the IUP records in the Levant has been increasingly recognized, but our understanding of such diversity is still limited due to difficulties in identifying and dating variable IUP assemblages as well as scarce records other than lithics. This problem is more serious in inland than coastal areas because most sites in the former zone consist of shallow deposits with limited stratigraphic evidence and poor organic preservation.

To increase the IUP records of the inland Levant, this paper reports recent re-investigation at two sites (Wadi Aghar and Tor Fawaz) in the Jebel Qalkha area, southern Jordan (Kadowaki and Henry 2019), originally studied by Henry (1995), and presents analyses of lithic technology, chronology, paleoenvironment, and resource procurement behavior. The lithic assemblages from the two sites are characterized by the production of robust blades with large platforms through unidirectional flaking of cores that includes both flat-faced and prismatic forms. Retouched tools are characterized by end scrapers and burins, but they also include a few Levallois-like points. The two lithic assemblages can be grouped in the IUP through quantitative comparisons of techno-typological attributes among the Middle Paleolithic, IUP, and the Early Ahmarian in the Levant.

This observation is consistent with OSL dates (45–40 ka). This time range corresponds to a phase of increasing humidity indicated by sediment-core and shore-level records of Lake Lisan, but a question is how this correspondence was manifested near the sites. To discuss this issue, we present geochemical and sedimentological analyses of sequential sediment samples from the site sections.

The renewed excavations recovered a few marine shells, including *Strombus (Canarium) fusiformis*, *Conus* sp. or *Strombus (Conomurex)* sp., *Cypraea (Erosaria)* sp., and *Pecten* sp. cf. *jacobaeus*. Most of them are likely from the Red Sea, 55 km away, while *Pecten* sp. cf. *jacobaeus* may have been transported from the Mediterranean Sea, 185 km away. Although none of the shells show traces of modification or ochre, they are not likely food residues given their scarcity at the site and the time/distance involved for their transport. Considering the absence of shell transport in the late MP in the Levant, the transport of marine shells to Wadi Aghar and Tor Fawaz may represent one of behavioral changes from the late MP to the IUP in the Levant.

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O-0052

## At the onset of the Initial Upper Paleolithic in Europe: reviewing the Bachokirian from the Balkan Peninsula

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### Abstract

Bacho Kiro Cave is being reinvestigated since 2015 by Bulgarian-German project. The cave is located in the middle part of the Balkan Mountain range in central-north Bulgaria, near the town of Dryanovo. This work follows on the 1970s work of a Bulgarian-Polish team who conducted systematic excavations of the cave's archaeological deposits (Kozłowski 1982).

Here we present on the lithic assemblage from Layer I of the new excavation, known previously as Layer 11, which comes from the base of the Upper Palaeolithic sequence. This assemblage is difficult to place in the existing Middle-Upper Paleolithic framework. Kozłowski (1982) cautiously described it as Pre-Aurignacian, gave it the name Bachokirian, and attributed to the earliest *Homo sapiens* in the Balkans. It is generally agreed that it is not Aurignacian (Rigaud and Lucas 2006; Zilhão and d'Errico 2000; Teyssandier 2003). From a typo-technological perspective, the presence of Levallois combined with Upper Paleolithic tool types (Tsanova and Bordes 2003, Tsanova 2008, Sirakov et al. 2016), has led some to attribute the Bachokirian to the so-called Initial Upper Palaeolithic (IUP) of Eurasia (Kuhn and Zwyns 2014).

Our preliminary observations confirm and add additional details to what has been said of this assemblage. We note that we have found no evidence that its particular character comes from the mixing of separate entities and to the contrary have evidence that the layer is in a good state of preservation. The assemblage itself is characterized by 1) selection of fine-grained aptian flints which come from sources in Ludogorie region between 90 and 180 km northeast of the cave; 2) pointed blades (some of them potentially functioning as tips on projectiles based on diagnostic macro-fractures); 3) variability in the size of blades with small blades produced in continuity; 4) bladelets obtained also by reflaking tools and blanks; 5) reduction method and technique close to Levallois; 6) a high degree of retouched tools and shaping flakes, reduction by reflaking (*rédebitage*), fragmentation and retouch, according to different modalities: on anvil percussion (splintered pieces), on the ventral face of a flake (Kombewa), on the edge of a tool (burin blows); 7) micro wear traces on pointed blades and retouched blades associated with wood cutting, splintered pieces with bone and antler working, and on endscrapers associated with skin scraping; 8) absence of Aurignacian technology (lithic, osseous). Layer I also contains a large faunal assemblage accumulated anthropogenically and personal ornaments made of animal bone and teeth. The combination of these traits plus the new radiocarbon ages of ~45 ka BP (Fewlass et al., in preparation) support the interpretation that the Bachokirian is part of the spread of the IUP at this time and, therefore, very likely represents an early dispersal of *Homo sapiens* into Europe.

**O-0053**

**The most ancient UP of the Eastern Europe: IUP stratum versus Protoaurignacian.**

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**Abstract**

New archaeological materials obtained from the excavation at Kostenki during two last decades led to significant changes in the traditional interpretation of the structure, cultural affiliation, and chronology of the most ancient Upper Paleolithic of the Eastern Europe. The ancient chronological group has been subdivided into two groups: (1) Early Upper Paleolithic (EUP) in the temporal range of 32-36 ka (cal.~36-40 ka) with a typical European bi-modal structure comprising an Aurignacian of pan-European distribution and a local 'transitional' cultural unity – the Streletskian; and (2) a more ancient 'Initial Upper Paleolithic stratum' (IUP stratum) dating to 36-42 ka (cal.~ 41-45 ka) represented by layers both at and below the level of the Laschamp magnetic excursion (cal.~ 41 ka).

Reasons for distinguish IUP-stratum appeared to be followings:

- more ancient stratigraphic /= chronological/ position than EUP in local sequences;
- non-Aurignacian and non-"transitional" affiliation;
- lack of diagnostic mousterian features in the lithic assemblages;
- relatively short period of existence
- lack of visible predecessors and evolution
- high degree of the variability of archaeological materials included lithics, bone and artistic /decorative/ assemblages.

Two cultural unities were included in the IUP-stratum according to these criteria: Spitsyanean (cultural layer II of Kostenki 17 or Spitsyn' site) and new early unknown cultural tradition (cultural layers IVb and IVw of Kostenki 14). The most probable appears to be inclusion in IUP entity of Zaozerie site at the Middle Urals.

Three aspects of the problem are the matter of discussion

(1) Critics of using the notion of IUP for Eastern European materials (Kuhn, Zwyns, Hublin). According to technological features the most close to Middle-East IUP (where this notion come from) are Levallois-derived "transitional" industries of the Central Europe (Kozłowski

(2) Possibility for both Spitsyanean and assemblages of IVb-IVw cultural layers at Kostenki 14 to be identified as Protoaurignacian (Hoffecker, Zwyns, Demidenko, Bataille, Dinnis, Bessudnov);



(3) Increased number of the IUP assemblages in northern Asia owing to which it become to be a global phenomenon, in some measure comparable with East European materials.

The concept of UIP-stratum seems to be useful for the most ancient East European Upper Palaeolithic as a chronological context for the very variable assemblages represented for the moment by single sites.

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O-0054

## Convergence or circulation: cross-comparison between the Initial Upper Paleolithic of the Altai, the Transbaikal and the Selenga drainage system

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### Abstract

With Neanderthals and Modern Humans moving into Central Asia and Siberia, at least two major human dispersals occurred across the Eurasian steppe during the Late Pleistocene. The Denisovans and visited the Siberian Altai more than once, and even met and interbred with Neanderthals, but for the most part their whereabouts remain unknown. Such evidence calls for further archaeological support to document the timing and environmental context of ancient human occupation of Central Asia with the hopes to better understand the drivers of such long-distance population movements. In this context, I present the result of a comparative analysis between three assemblages from regions with different environmental settings: Kara-Bom (Siberian Altai), Kamenka (Transbaikal) and Tolbor-16 (North Mongolia). The three assemblages are considered representative of the Initial Upper Paleolithic in the region because they share clear similarities in terms of typology, blade technology and chronology. Here I focus on the details of the reduction patterns and compare them between the regions. The main questions I would like to address in this presentation are: how similar are these reduction systems? What are the environmental and economic pressure driving the technological choices? Are differences and similarities better explained in terms of adaptation or population history? For analytical purposes, I hypothesize that the stronger the adaptation is, the more support there would be for a scenario of convergent evolution. The lack of apparent change in different environmental settings, however, would suggest that the pattern observed is better explained by alternative hypotheses (e.g. considering degrees of social intimacy, or populations phylogeny links between the contiguous regions). Features potentially sensitive to the local environment such as raw material management, intensity of core reduction, or the alternate use of unidirectional vs. bidirectional flaking, are used as proxy to evaluate the adaptive pressure relevant to the composition of the assemblage. Ultimately, the goal is to discuss the technological consistency of the regional Initial Upper Paleolithic whose sudden appearance coincides with the first occurrence of Modern Humans in Central and Northeast Asia.

O-0055

## Initial Upper Paleolithic/Early Upper Paleolithic interactions in the mountain belt of southern Siberia and eastern Central Asia

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### Abstract

The habitat of hominins, the bearers of Middle Paleolithic (MP) and Upper Paleolithic (UP) traditions in southern Siberia and Mongolia, is associated with the Altai and Sayan ranges of Transbaikalia and Mongolia. The first UP complexes appearing there constitute a distinctive Initial Upper Paleolithic (IUP). Setting aside possible variations related to settlement systems and the specifics of raw material exploitation, this cultural expression was characterized by bidirectional reduction technology targeting the production of large pointed blades, as well as burin-core technology and small subprismatic core reduction for the manufacture of bladelets, as well as an artifact assemblage that included specific tool types and personal ornaments. Paleoanthropological assessment what which hominin species created this technocomplex is speculative and open to discussion. It has been assumed that the IUP was replaced by the Early UP in most areas around 40,000-35,000 kya. New data challenge this simple scenario. The EUP co-existed with the IUP in the Altai region, where they are very similar excluding one unique technology. The presumed EUP in northern Mongolia stands out from the IUP in quantitative, though not qualitative ways. The IUP in southern Mongolia probably persisted until the end of MIS3. There are IUP complexes in Transbaikalia, chronologically younger than fully flake-based EUP industries, which appeared there no later than 40,000 kya. Seen in this way, interactions between the IUP and EUP were far more complex than a simple progression of sequential changes in different cultural traditions. Here, we focus on questions of chronostratigraphy and interaction among presumably different technocomplexes, and possible implications for the peopling of the southern Siberian and Central Asian mountain belt during the second half of MIS3.

O-0056

## The impact of raw material sources on the distribution of initial upper Paleolithic humans in Central Asia

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### Abstract

About 45,000 kya, large-blade based Initial Upper Paleolithic industries appeared almost synchronically in the Altai Mountains, eastern Kazakhstan, Xinjiang, Mongolia, and Transbaikalia. These Karabomian-type industries, originated in the Altai Mountains and spread to the east and south, eventually encompassing all of eastern Central Asia. The Altai Mountain system in Russia and eastern Kazakhstan, along with ranges in Xinjiang and, partially, the Mongolian Altai collectively comprise the so-called Inner Asian Mountain Corridor, primarily associated with the development and dispersal of agriculture (Spengler et al., 2014) and, later, with the Silk Road, going back as far as the hypothetical dispersal of Middle Paleolithic human populations (Glantz et al., 2017). Well-known recently discovered large-blade Initial Upper Paleolithic sites also occur in and near the Inner Asian Mountain Corridor and delineate its new branches, penetrating both mountain ranges and highlands. The main research question driving our work is why did these IUP populations settle in those areas? Our primary project has been focused on the IUP of northern Mongolia. All of the stratified sites in the Orkhon-Selenga belt share a common feature: sources of lithic raw material suitable for manufacturing artifacts, including both primary outcrops and alluvial pebbles, occur at distances of no more than several hundred meters from the archaeological sites in which they are found. Ancient humans preferentially exploited chert clasts; other stone varieties are rare in these archaeological assemblages. The study of human migration routes is associated with the occurrence of sedimentary rocks, widespread throughout the Orkhon-Selenga belt and occurring throughout Central Asia, including Uzbekistan, eastern Kazakhstan, northwest China (Xinjiang), Mongolia and, probably, the Tibetan Plateau. Human migrations through the Selenga Corridor have been the subject of recent study. Preliminary analyses of lithic raw materials indicate that IUP industries here were based on the same sedimentary rocks present in the middle Selenga River region. More than 150 samples from various parts of the IUP zone of dispersal (including the Russian Altai, eastern Kazakhstan, Mongolia and China) were analyzed, providing the opportunity to model the relationship between this technocomplex and primary raw material outcrops on a large geographical scale, including possible migration corridors.

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O-0057

## The history and future of strontium isotopes in ecological and paleoecological applications

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### Abstract

The ability for strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) to answer questions about the mobility of both living and extinct organisms has been recognized for almost 30 years. Yet only a handful of researchers have utilized this geochemical tool to date. This likely reflects prohibitively expensive analytical costs combined with the need for researchers to build empirical reference datasets. However, in recent years, analytical advances have lowered costs. Additionally, spatially-explicit predictive models (called isoscapes), which can provide reference data without the need to conduct laborious field and laboratory studies, are now available for a number of regions on the planet. Accordingly, we may be entering a golden age for strontium isotope research. Nevertheless, there are still a number of gaps in our fundamental understanding of how strontium works. In this talk, I will review our current understanding of the factors that drive spatial variability in strontium isotopes, provide several examples of innovative ways that this geochemical tool has been used to infer the mobility of animals in the past, present additional promising applications of  $^{87}\text{Sr}/^{86}\text{Sr}$  in both modern and paleo-contexts, and discuss important “next steps” for moving the field forward.

O-0058

## Advances in Terrestrial Bioavailable Strontium Isoscaping

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### Abstract

Applying strontium isotope in provenance studies requires a baseline (or isoscape) of how strontium isotope ratios vary spatially in the main sources of food and water consumed by an organism of interest. This “bioavailable” strontium isotopic pool is difficult to predict because it is primarily shaped by the underlying geology but also vary with other geoenvironmental variables including soil properties, aerosol deposition or climate. We first review the advantages and limitations of existing methods to map the bioavailable strontium isotope variations on the landscape. We then propose a globally applicable, scalable, and editable framework for creating bioavailable terrestrial strontium isoscapes for provenance studies. This framework relies on: 1) a global georeferenced compilation of terrestrial bioavailable strontium isotope data, 2) global maps of strontium isotope variations in rocks derived from a process-based model, 3) global climate, soils, aerosols, and geoenvironmental map products, and 4) a random forest regression method (R script). The random forest regression integrates the bioavailable data with selected auxiliary variables (e.g., bedrock model products, and geoenvironmental data) to predict bioavailable strontium isotope variations and a conservative estimate of spatial uncertainty. Here, we test the benefits of using this framework to predict strontium isotope variations in Madagascar, Alaska, and Argentina using new bioavailable strontium isotope datasets generated for these areas. We show that, for each dataset, the calibrated strontium isoscapes explain more than 60% of the variance after independent cross-validation. More importantly, the model efficiently predicts the multi-scale patterning of strontium isotope variations on the landscape by accounting for geological, geomorphological and atmospheric controls. This novel mapping framework will be entirely accessible online and will help scientists interested in using strontium isotopes for provenance applications to generate more systematic and accurate bioavailable strontium isoscapes. This framework can also be integrated with other isotopic systems (e.g., oxygen and hydrogen) to provide more precise geolocation assessment in Quaternary and modern ecosystem studies. We demonstrate the increased precision allowed by dual isotope geolocation through a case study in Alaska. We measure oxygen and strontium isotopes in a 9,000-year-old child’s tooth from the Ancient Beringians Trail Creek site. The combined oxygen and strontium isotopic signature of this infant strongly indicates an origin in the interior upland areas of the Seward Peninsula close to the location where the tooth was recovered. This precise isotope geolocation coupled with analysis of archeological artifacts recovered at the site provided a strong basis to interpret genetic analyses performed on the tooth.

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O-0059

## Strontium isotopes confirm giant extinct lemurs had small home ranges

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### Abstract

The island of Madagascar is currently home to over 100 species of lemurs, and at least 17 additional species were present until the late Holocene. The living taxa are relatively small-bodied and weigh <10 kg. Conversely, all of the now-extinct species were relatively large, ranging in body mass from ca. 12 kg to >100 kg. Among mammals, smaller-bodied species tend to have smaller home ranges than larger-bodied species. This is true for ungulates, carnivores, and anthropoid primates. We might therefore expect that now-extinct large-bodied lemurs had larger home ranges than still extant smaller-bodied taxa. Yet multiple lines of evidence suggest that the extinct lemurs were relatively inactive. These include postcranial (vertebral, sacral, pelvic, limb, hand and foot) anatomy, small semicircular canals (which are balance organs within the inner ear), low periodicity of incremental growth bands in their tooth enamel, and dental morphology (which is related to diet, and in turn activity level in living primates). Thus, on the basis of this evidence, we might expect that now-extinct lemurs had relatively small home-ranges, perhaps as small as those of much smaller-bodied extant lemurs. We use strontium isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) to compare mobility of co-occurring extinct and extant lemurs at three subfossil localities with relatively robust sample sizes and varying bedrock geology: (1) Ankilitelo/Mikoboka, a series of sinkholes in a limestone plateau in southwestern Madagascar; (2) Taolambiby, a seepage deposit underlain by Quaternary alluvium and upper Paleozoic through Triassic sediments in southwestern Madagascar; and (3) Ampasambazimba, a wetland underlain by a variety of Neoproterozoic through Tertiary igneous and metamorphic rocks in central Madagascar. We include eight genera in our analysis: *Eulemur*, *Lemur*, *Lepilemur*, and *Propithecus* (extant), and *Archaeolemur*, *Megaladapis*, *Pachylemur*, and *Palaeopropithecus* (extinct). There are no differences in variance or median  $^{87}\text{Sr}/^{86}\text{Sr}$  between extinct and extant taxa at any of the sites. A single *Palaeopropithecus* at Ankilitelo and a single *Eulemur* at Ampasambazimba have unusually elevated ratios compared to other individuals at the same sites. Extant lemurs have apparently more variable  $^{87}\text{Sr}/^{86}\text{Sr}$  at Taolambiby. This is driven by *Propithecus*, which has significantly more variable  $^{87}\text{Sr}/^{86}\text{Sr}$  than *Pachylemur* (Bartlett  $p=0.0224$ ). These results demonstrate the value of strontium isotopes for testing hypotheses related to the behavior of now-extinct species. Overall, the data support small home ranges for extinct lemurs and instead suggest that, if anything, extinct taxa may have been less active than extant species. This is true for all four extinct genera, including *Palaeopropithecus*, which is thought to have been a suspensory folivore, and *Archaeolemur*, which was likely more terrestrial and more of a generalist. Small apparent isotopic differences among co-occurring taxa may reflect consumption of different foods or spatial partitioning.

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O-0060

## Trail of the mastodon: Reconstructing landscape use with stable oxygen and strontium isotope ratios from a serially sampled tusk

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### Abstract

The mobility of a species affects home range size, landscape use, dispersal patterns, and ability to migrate, making it a fundamental driver of species interactions and community ecology. Improved understanding of the mobility of extinct taxa would fill fundamental voids in our knowledge of past faunas and the evolution of many ecological traits. Strontium isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) show promise for evaluating paleo-mobility because they vary across landscapes largely as a function of bedrock composition and age. Further, organismal tissues incorporate biologically available  $^{87}\text{Sr}/^{86}\text{Sr}$  with minimal fractionation, thereby recording this geographical fingerprint. A limitation of the  $^{87}\text{Sr}/^{86}\text{Sr}$  system is that it requires a reference map of bioavailable  $^{87}\text{Sr}/^{86}\text{Sr}$  to which biological specimens can be compared. These maps are typically developed by sampling  $^{87}\text{Sr}/^{86}\text{Sr}$  in the field, which is time-intensive, costly, and limits the spatial resolution and extent of subsequent analyses. Regional-scale models of  $^{87}\text{Sr}/^{86}\text{Sr}$  have relieved some of these limitations and offer opportunities to reconstruct paleo-mobility and movement patterns at previously impractical scales. Here, we use a published isoscape for North America and a serially sampled male mastodon tusk (*Mammuth americanum*, terminal Pleistocene, Indiana, USA; ISM 71.3.261) to reconstruct intra-annual changes in landscape use for this individual. Using modern elephant ecology as a reference, we also test for changes in landscape use and geographic range between when the male was young (part of a matriarchal herd) and mature (when he likely lived in greater isolation). Further, this individual has perimortem cranial damage evidently induced by another proboscidean's tusk. In modern elephants, such damage is generally inflicted when males battle for access to receptive females. By evaluating paleo-landscape use, we test whether this damage was inflicted in a region used throughout the year, or one with seasonal use. We sampled five years from the mastodon's early life and the three years before death. Powders were milled in ~0.5-mm increments (averaging eight samples per year, with each year visible as a structural unit in tusk dentin) and analyzed for  $\delta^{18}\text{O}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$ . Resulting  $\delta^{18}\text{O}$  data are strongly cyclic, reflecting seasonal variability. Strontium isotope ratios differ significantly between earlier- and later-formed samples, indicating shifts in geography. Early in life,  $^{87}\text{Sr}/^{86}\text{Sr}$  displays less annual cyclicity compared to  $\delta^{18}\text{O}$  values. With maturity,  $^{87}\text{Sr}/^{86}\text{Sr}$  becomes more cyclic. Spatial modeling indicates the mastodon traveled less during earlier years, changing to larger-scale movements as an adult. The mastodon spent substantial time in Indiana and the Minnesota/Iowa/Illinois area early in life. As an adult, he repeatedly visited the Indiana/Ohio/Kentucky area during late-spring and summer; the inferred mastodon mating season. Seasonal timing of these visits paired with inferred cause of death suggests that parts of Indiana/Ohio/Kentucky were this individual's preferred mating area, to which he made extensive ( $10^3$ -km round-trip) annual journeys.

O-0061

## Quaternary Sr isotopic record for the Black Sea and Caspian Sea: Implications for palaeoenvironmental change and endemic fauna

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### Abstract

Constraining the timing and nature of the connections between hydrographic systems is critical to understanding the rates of biological adaptation and faunal migration. Quaternary sediments of both the Caspian Sea and Black Sea contain endemic faunas and their temporal and spatial occurrence has been the principle means of reconstructing the connectivity history of the two basins. However, faunal-turnover is a response to changing environmental conditions (e.g. nutrient and oxygen content, salinity), which can result from aspects of a basin's hydrography (e.g. precipitation – evaporation balance, fluvial discharge, circulation) that are not exclusively controlled by water exchange between the two basins. Consequently, fossil-based reconstructions of the Quaternary connectivity history between Caspian and Black seas are contradictory.

Strontium isotopic ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) in well-preserved fossil carbonates provide an excellent alternative approach because the  $^{87}\text{Sr}/^{86}\text{Sr}$  value of non-marine systems is sensitive to the relative flux of different water sources. We have combined the  $^{87}\text{Sr}/^{86}\text{Sr}$  of fossil ostracods from the Black and Caspian seas with salinity estimates provided by ostracod and dinoflagellate cyst assemblages in a numerical box model to constrain the input sources, and consequently the timing and nature of the connection between the two.

The early-mid Quaternary  $^{87}\text{Sr}/^{86}\text{Sr}$  records from both the Black and Caspian seas overlap and are lower than today's Black Sea ratio suggesting an enduring connection between the two basins either via one-way flow or two-way exchange and isolation of the Black Sea from the Mediterranean up until ~1 Ma. Subsequent rise in the  $^{87}\text{Sr}/^{86}\text{Sr}$  of the Black Sea and divergence from the persistently low Caspian Sea ratios indicate episodic Mediterranean input however, with influxes consistently lower than the present day levels until the Holocene. Quantitative analysis of the Caspian Sr isotope data suggests two water sources that do not contribute to Caspian today: the Amu Darya and, prior to ~2 Ma, a minor component of ocean water from the Arctic.

The geochemical records are broadly consistent with coeval evidence of faunal exchange. However, the paired Sr-salinity data provide a more detailed and robust connectivity history with respect to both the timing and nature of past connections. As such we now have a connectivity framework against which complex faunal patterns of expansion and extinction can be interpreted.

O-0062

## The energetic cost of travel: Linking strontium and nitrogen isotope analyses from bison as indices of mobility and nutritional stress

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### Abstract

Bison were a dominant feature on northern landscapes during the Late Quaternary. We employ a novel approach coupling and comparing strontium and nitrogen isotopes present in ancient and modern bison to provide proxies of bison mobility and nutritional status. As a modern analogue, we conducted stable nitrogen isotope analyses of sequentially sampled tail hairs (keratin) from modern bison from Alaska. These modern bison composed a recently established (Spring 2015) herd of wood bison (*Bison bison athabascaae*) released into the wilds of Alaska. In addition to analyses of many typical members of the main herd, we also analyzed tail hairs from a suite of individuals that had either undergone starvation and subsequent death, or had traveled large distances, corroborated by satellite tracking. Nutritional stresses caused by starvation and the caloric tolls of long distance travel both produced a notable increase in the stable nitrogen isotope values. This pattern resulted from these individuals essentially consuming their own proteins, which imparts a sequential isotopic record in nitrogen rich tissues that grow incrementally, such as tail hairs or horn sheaths. Although tail hairs from bison are not typically found in the fossil record, similar nitrogen isotope analyses aimed at examining the physiological status of ancient bison can be conducted on cores taken from the keratin composing bison horn sheaths. These horn sheaths are abundant in the Beringian fossil record and maintain a continuous record of physiological changes and stresses throughout a bison's lifetime. Stable nitrogen isotope analyses of horn sheaths can then be coupled with analyses of strontium isotope ratios (Sr87/86 values) of tooth enamel serial sampled from bison molars (molars 1,2 and 3) used as proxies for paleo-mobility. Strontium isotope ratios have previously been used as a geological tracker of (paleo) mobility, as Sr87/86 ratios vary according to a landscape's underlying geology and location. By coupling these two isotopic paleoecological proxies it is possible to examine whether bison travelled large distances and whether they experienced physiological costs associated with travel. To enhance our use of strontium isotopes to geolocate bison, we conducted and present results from strontium isotope analyses of modern, georeferenced rodents, used to create a spatial model of bioavailable strontium isotope signatures across Beringia ('RodeMap'). We also present a case study coupling nitrogen and strontium isotope analyses of a single well-preserved, articulated steppe bison specimen (>50,000 years old), demonstrating the advantages of a multi-isotope approach to examine this particular bison's life history. The early life of this individual showed evidence of both significant markers of paleo-mobility and physiological stress. Our multi-isotope method allows us to examine possible causes of death (i.e. starvation) periods of resource-limitation through life, migrations, and illustrates the potential costs of paleo-mobility in ancient bison.

O-0063

## Tracking ~30 years of movement and feeding ecology of a 17,000-year-old woolly mammoth (*Mammuthus primigenius*) from Arctic Alaska

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### Abstract

Arctic Alaska is experiencing rapid environmental changes in response to recent warming. Radical environmental changes also occurred during and after the last glacial maximum (LGM, ~21,000 years ago). During the LGM, this region was inhabited by a variety of now extinct megafauna, including the iconic woolly mammoth (*Mammuthus primigenius*). What caused the extinctions of these ice-age megafauna is still hotly debated. Although the life of mammoths has sometimes been portrayed as including large seasonal migrations, this inference remains untested and is based on the behavior of extant proboscideans rather than on paleo-data. To gain insight into the life history of a mammoth from the Arctic, we longitudinally split the curved, 1.5-meter-long tusk of a bull mammoth using a band saw. The specimen is one of two tusks associated with a skull from a single individual found north of the Brooks Range above the Arctic Circle. Calibrated radiocarbon dates from both the skull and one of the tusks indicate this bull mammoth died 17,000 calendar years ago during the closing millennium of the LGM in this part of the Arctic. After sectioning the tusk to reveal annual growth bands, we used sequential samples taken from along the entire length of the exposed inner surface of the tusk for stable isotope analyses (N and C on the organic fraction and C and O on the inorganic fraction) as well as strontium isotope ratio ( $\text{Sr}^{87}/\text{Sr}^{86}$ ) analysis in order to reconstruct the animal's feeding ecology, environment, as well as its movements through the course of its life. This temporally precise, multi-isotope reconstruction allows insight into the life history of a woolly mammoth between birth and death, including its diet, changing nutritional state, and geographic movement. Based on histological and seasonal isotopic oscillations, we estimate this mammoth was ca. 30 years old when it died and that he wandered extensively during several, multi-year periods of his life. Death seems to have followed an extended period of starvation.

O-0064

## **Cultural heritage sites in coastal areas. Use, monitor, manage and preserve sites & landscapes under climate change and development pressure (CULTCOAST)**

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### **Abstract**

Cultural heritage (CH) and cultural environments are highly valued environmental goods, but these values are under serious threat from multiple sources. Climate is changing now at an even higher rate than expected in some of the worst-case climate scenarios, with increasing temperatures, changes in precipitation, decreasing permafrost, more frequent and severe storms, sea level rise, reduction of sea ice, floods, avalanches and changing vegetation (Climate Research Unit, 2018). These changes increase the risks of geo-hazards, e.g. erosion caused by wind, waves and rivers that threaten particularly coastal CH sites, environments and landscapes. The northern areas are particularly sensitive because they suffer more from combined threats and have previously been well protected by the aid of permafrost and sea ice. The Arctic areas act as a sensor and an early warning-system for the rest of the world. Impacts there are likely to be felt further south in the future. This emphasizes the need for further research on climate change impacts in the northern areas. As impacts and effects of climate change are global and the bequest value of heritage, preserving it for future generations, is of relevance everywhere, our studies will be transferable to CH management plans and mitigation actions at national and global scales, to meet the UN Sustainable Development Goals on resilient and sustainable settlements and taking urgent action to combat climate change and its impacts.

Our project focuses on the individual and combined impacts of climate change induced geo-hazards and pressure from tourism and development in northern Norway, using the Arctic and sub-Arctic sites as basis for future modelling that will have global use. Based on existing methodologies for mapping and documentation, strategies for mitigation and conservation will be developed to protect these sites in the decades towards the year 2100. We intend to map, monitor and gather input from selected case sites below and above ground on Svalbard and Andøya to develop improved knowledge-based methods for evaluating and prioritizing sites. We'll further develop mitigation measures and management strategies related particularly to coastal CH sites, environments and landscapes threatened by geo-hazards, in close cooperation with national and international expertise. Our interdisciplinary approach of combining archaeology, architecture, geography, quaternary geology and climate science has not previously been considered or implemented.

This research will produce impacts in the form of compilations and analyses of existing data, definitions of change indicators, standardised methods for defining baseline conditions and methods for deciding on monitoring programmes. We also aim to provide a positive environmental impact by producing management and mitigation strategies for individual sites as well as for national and international strategies on CH preservation and adaptation. We also aim to raise awareness about CH and Climate Change among the general public.

O-0065

## Fragile heritage from high-elevation ice: understanding and protecting the archaeo-ecology of ice patches in the Greater Yellowstone Area, USA

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### Abstract

Changing climate is causing perennial ice patches at high latitudes and high elevations to melt, resulting in the release of ancient paleobiological and archaeological materials that, until recently, were in cryogenic-like stasis. Ancient organic artifacts emerging from the ice include baskets, leather and hair cordage, and millennia-old wooden shafts once used for hunting. Ice patches are also releasing stone tools, plants, and the remains of animals. In North America, the field of “ice patch archaeology” refers to the study of anthropogenic materials recovered in association with these retreating features. Researchers in Europe frequently refer to this field as “glacial archaeology,” in part because of archaeological finds in glaciated passes. The stable ice in these ice patch features exhibits little internal deformation or movement and can preserve otherwise perishable materials for millennia.

The exposure of ancient archaeological and paleobiological materials in the Greater Yellowstone Area (GYA) of Wyoming, Montana and Idaho, USA, is a tangible indication of climate change in the Rocky Mountain West (Lee and Puseman 2017). The well-preserved materials that are emerging—and the historical and environmental contexts we find them in—hold clues about past and present climate change, and in the U.S. and Canada they also speak to how indigenous populations interacted with high-elevation landscapes. Areas that today are often characterized as “empty” wilderness were home to groups of Native Americans for millennia. The mountains remain sacred to many peoples, and the heritage of many Native American tribes is inexorably tied to the Rocky Mountains through story, song, traditional ecological knowledge, and ceremony (Lee et al. 2004).

Ice patch materials are charismatic and useful for engaging and educating the public about the long tenure of Native American people in the alpine and about the Earth’s changing climate (Lee et al. 2018). While enormous loss has likely occurred, increased snow loads at some ice patches suggest there is still time to engage with these features in a thoughtful manner (Reckin 2017). Yellowstone National Park has been a strong supporter of this research, and the talk will highlight ongoing efforts there.

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Representative Greater Yellowstone Area ice patch (photo: INSTAAR/Boyer [www.kestrelaerial.com](http://www.kestrelaerial.com)).

O-0066

## **Severe Weather and the Reliability of Desk-Based Vulnerability Assessments. The impact of Hurricane Maria to Puerto Rico's Coastal Archaeology**

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### **Abstract**

Within the context of climate change, sea level rise is threatening not only coastal communities globally, but also the archaeological record of their history, knowledge and culture. As a response, inter-institutional databases of heritage are increasingly being coupled with other widely-available cyberinfrastructure to assess the magnitude of the threat and the vulnerability of cultural heritage, in order to begin the design of actionable steps or mitigation of impact. This presentation focuses on the coastal archaeology of Puerto Rico to assess the reliability of desk-based vulnerability assessments in the context of disasters against the backdrop of the damage caused by Hurricane Maria. The study conducted a walkover survey of 11 km of coast on the north-central portion of Puerto Rico and documented context, visible impact, and level of threat from coastal erosion, among other factors. The analysis demonstrated that a desk-based assessment conducted in 2017 severely underestimated the vulnerability of coastal resources. While two sites were predicted to be vulnerable, the survey identified eight damaged sites. In addition to damaged sites, which in our study location was 400% above expected, the process of climate change is occurring as traumatic catastrophic events, after which hundreds of volunteers pour in to provide support. Notwithstanding their often well-intentioned response, the sense of urgency of relief efforts ends up ignoring local processes, knowledge, traditions and social dynamics. The period of recovery after a catastrophe is a highly sensitive time for affected communities, and the process of recovery jeopardizes the preservation of intangible cultural heritage. These results call for heightened attention to the actual process of climate change and post-catastrophe recovery, not just for cultural heritage, but also for coastal and marine ecosystem management and for the resilience of human communities.

O-0067

## Impact of Sea level Rise on Heritage Resources of the Delaware Estuary

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### Abstract

The Delaware Bay is the second largest estuary along the U.S. Atlantic coast that has been occupied by humans throughout Holocene. Using geoarchaeological approach we conducted paleo-landscape reconstructions at selected sites with documented coastal archeological resources in order to reveal connections between human settlement and coastal environments. We documented more than 10,000 archeological sites within the Delaware Bay coastal zone. Sea level rise (SLR) poses a major threat to natural and historical resources present in the low-lying coastal areas. Most of the estuarine shoreline is fringed by salt marshes that have been developing for the past 2,000 years but are now being lost at various rates. We applied the knowledge of wetland evolution driven by RSL from site specific to estuarine scale in order to assess the vulnerability of existing cultural resources along the coast of the Delaware Bay. Predictive models of future SLR suggest that 10% of the archeological and historical resources will be inundated or surrounded by salt marsh by 2050.

Our multi-disciplinary approach contributes to the development of a multi-scalar “Landscape Archaeology of Wetlands” methodology for contextualizing the archaeological record of wetland landscapes and the results will help to prioritize protection of Delaware Bay heritage resources and promote the development of stakeholder partnerships for future resources conservation and/or management.

O-0068

## Using Ground-penetrating Radar and Citizen Science to Document and Monitor Erosion of Coast Shell Middens, Maine, USA

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### Abstract

Archaeological sites are threatened by climate change as increasing rates of sea level rise intensifies damage from storm-driven waves. In Maine, USA, over 2,000 indigenous shell middens containing mollusk shells, artifacts, and faunal remains are disappearing as a result of sea-level rise, storm intensification, and increased freeze-thaw action. Composed primarily of shells, these middens also contain artifacts and faunal remains that document up to 4,000 years of indigenous coastal occupation. These sites range in size from the impressive, 5-6 meter thick oyster shell middens of the midcoast region to the many smaller clam shell middens dotting mainland and island coasts. Most of the known sites are documented on the basis of the presence of eroding material or cursory testing, with few being revisited within decades of original description. Only one to two middens per year can be professionally excavated due to funding constraints. As a result, the current condition of most of these sites is unknown and knowledge of erosion is anecdotal.

This presentation details a two-pronged approach to developing a database of shell midden information for use by culture heritage managers to understand patterns of loss and prioritize scarce resources. 1) Typically, shell midden areal extent and thickness is determined using widely spaced test units. This approach provides limited and discontinuous information. However, a ground-penetrating radar (GPR) survey, in combination with stratigraphic information from previous documentation or limited excavation, provides a continuous record of profiles across the site. Additionally the technique is nondestructive, requires minimal staff, and allows for efficient data collection. While individual artifacts cannot be resolved in GPR records, accumulations of rocks, soil layers, and potential occupation horizons may be identified. Although GPR cannot entirely replace a detailed excavation, an initial GPR survey of a shell midden site can provide information regarding site extent and vertical shell distribution. 2) Site characterization is important, but without ongoing monitoring provides no information on site condition or erosion rates. To address this challenge, a citizen science group, the Maine Midden Minders, is being developed to train interested volunteers from conservation organizations, tribal communities, and individual citizens to document seasonal to annual changes at middens. Measurements are made using simple tools, and site conditions documented using digital photography. This information is collected into database that will archive site location, size, condition, and photographs. This data will be available only to state cultural heritage agencies and researchers as a way of protecting site integrity and landowner privacy. The resulting database can then be used to identify vulnerable sites and allocate resources. The result of these two approaches in to combine proven archaeological and geoarchaeological techniques with citizen science observations to develop an integrated approach to management and rescue of important coastal heritage.

O-0071

## Weekly oxygen isotope measurements in teeth reveal environmental variation

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### Abstract

Oxygen isotopes in tooth enamel vary with temperature, precipitation and evaporation cycles during an organism's development, aiding reconstructions of past environments. Enamel is typically sampled by drilling to recover oxygen inputs from food and water consumed during tooth formation. This method has limited spatial resolution, yielding samples that integrate long formation times of unknown chronological age and therefore limit the recovery of seasonal environmental patterns from teeth.

To address this dilemma we employ a Sensitive High Resolution Ion Microprobe (SHRIMP SI) to measure oxygen isotope compositions ( $\delta^{18}\text{O}$ ) from tooth enamel on a spatial scale of 15-30  $\mu\text{m}$ , which can be related to daily increments and birth lines to determine formation times and calendar ages.  $\delta^{18}\text{O}$  values of sheep enamel measured by SHRIMP SI are nearly identical to those from silver phosphate microprecipitation, confirming the fidelity of this approach for enamel bioapatite oxygen recovery (Smith et al. 2018). Here we analyze teeth from wild orangutans collected more than a century ago, along with two fossil orangutan teeth from Lida Ajer, Sumatra –the site that yielded the oldest insular Southeast Asian human remains 63-73,000 years ago (Westaway et al. 2017). Molars were sectioned following standard procedures, and sequentially sampled on a spatial scale corresponding to a near-weekly timeframe along the enamel-dentine junction using secondary-ion mass spectrometry. Standardized  $\delta^{18}\text{O}$  values were related to temporal records of formation over 3-4 years per tooth (Smith 2016).

Oxygen isotope values in wild-shot Bornean and Sumatran orangutan first molars ranged from 11.3-19.9 ‰ and 13.4-20.4 ‰, respectively. Concurrently forming left and right molars from the same fossil orangutan ranged from 15.4-20.1 ‰ and 15.1-19.9 ‰, supporting the biogenic fidelity of this palaeoclimate record. All teeth showed isotopic variation on a circannual basis, particularly after the initial period of exclusive mother's milk intake.

Enamel is the most impermeable tissue in the human body, and the recovery of similar  $\delta^{18}\text{O}$  values from these unburied and fossilized orangutan molars strengthens the usefulness of teeth for probing ancient climates. We have demonstrated here and in other studies that isotope variation in mammalian tooth enamel formed over multiple years is substantial, even in equatorial regions. Future research on slow-growing primate teeth may help to conclusively establish whether environmental variation was a significant force in the evolution and dispersal of the human genus (*Homo*) and our own species 300,000 years ago.

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O-0072

## High resolution paleoenvironmental records from East African fossil apes

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### Abstract

Environmental seasonality is often invoked as a driver of the evolution of novel hominin and nonhuman primate adaptations, but it is difficult to reconstruct, particularly in association with relevant fossil remains. Here we employ a Sensitive High Resolution Ion Microprobe (SHRIMP SI) to measure enamel oxygen isotope compositions ( $\delta^{18}\text{O}$ ) on a spatial scale of 15  $\mu\text{m}$  in two *Afropithecus turkanensis* specimens from the early Miocene site of Kalodirr (Western Lake Turkana, Kenya) (Leakey and Leakey, 1986). Thin sections of the teeth were sampled sequentially along the enamel-dentine junction using secondary-ion mass spectrometry, and standardized  $\delta^{18}\text{O}$  values were related to daily and near-weekly temporal records of enamel formation (Smith *et al.*, 2003).

Sequential near-weekly measurements reveal several years of seasonal fluctuations in  $\delta^{18}\text{O}$  values associated with temporal variation in regional hydrology, animal physiology, and behavior. Measurements from both molars reveal mean  $\delta^{18}\text{O}$  values (24.1 and 20.5 ‰, VSMOW) that are distinct, with greater seasonal variation in the molar with higher  $\delta^{18}\text{O}$  values (ranges 5.5 and 3.3 ‰). Evaluation of molar formation times suggests that the temporal oscillations that account for most variation in  $\delta^{18}\text{O}$  values are yearly, with shorter cycles accounting for approximately one third of the observed  $\delta^{18}\text{O}$  variation.

$\delta^{18}\text{O}$  values in these apes are similar to bulk enamel measures from nearby Plio-Pleistocene fossil monkey (*Theropithecus*) specimens (average 21.2 ‰: Cerling *et al.*, 2013), despite the fact that Miocene sites are generally thought to have wetter, more forested environments. Our data demonstrate substantial seasonal variability at a single locality. Intra-tooth  $\delta^{18}\text{O}$  variation in both *A. turkanensis* molars is comparable to inter-tooth variation in *Theropithecus* specimens at individual sites in eastern and western Turkana that span millions of years. Furthermore, seasonal patterns measured here in both molars barely overlap, altogether showing variation of ~8 ‰ across both specimens, suggesting that the species inhabited hydrologically diverse landscapes over a relatively narrow temporal and geographic window. In particular the larger range of values seen in one individual may suggest a strongly seasonal environment, supporting anatomically-based reconstructions of *A. turkanensis* as a hard-object (sclerocarp) feeder (Rossie and MacLatchy, 2013). Spatially precise and developmentally informed microsampling strategies have the potential to recover seasonal climatic and behavior patterns as long ago as the early Miocene, and will contribute to elucidating the complex relationship between seasonality, primate behavior, and evolution.

O-0073

## Reconstructing patterns of palaeoseasonality during the Weichselian: Sub-annual palaeotemperatures from the La Ferrassie rockshelter

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### Abstract

Exploration of the relationship between paleoclimate and hominin behaviour is central to Palaeolithic Archaeology and the study of past human lifeways. At middle and high latitudes the consideration of seasonal climatic conditions and temperatures is particularly important as a means of better understanding human-environment interactions and hominin adaptations. However, much of the existing palaeoclimate record is derived from broad regional or global scale proxies, and it remains a challenge to explore the implications of such climate reconstructions on temporal and spatial scales that are relevant to hominin activity at individual sites. Palaeotemperature information gleaned from oxygen isotopic analyses of faunal remains provides an opportunity to gain insights into sub-annual resolution seasonal temperature cycles on a smaller, more local level that, significantly, can be linked directly to archaeological contexts.

Here we present high resolution seasonal temperature data to contextualize Neanderthal activity during the early and middle Weichselian glaciation (MIS 4 and 3) at the site of La Ferrassie, southwest France. Palaeotemperatures are obtained from oxygen isotope analyses of sequential enamel samples from herbivore teeth from Layers 2, 5A and 5B. Carbon and nitrogen isotope ratios of bone collagen from Levels 2 through 5 are used to corroborate diachronic trends seen in the  $\delta^{18}\text{O}$  data. Exploiting the direct relationship between faunal remains and hominin activity at the site, we explore changes in palaeotemperature and palaeoseasonality during MIS3 and MIS4 across multiple levels of occupation. The isotope data document change in environmental conditions from MIS 4 to MIS 3, not only in more well known average conditions but also showing substantial differences in summer and winter temperature extremes. Using the high resolution isotope data, we reconstruct a more rounded picture of climatic conditions faced by Neanderthals during warm and cold phases of the Weichselian glaciation. Combining new isotopic results with existing studies of the site, we investigate the relationship between environmental change, site use, and faunal resource exploitation at La Ferrassie. In this framework, we also explore the challenges and opportunities of integrating high-resolution isotope data with lower resolution isotope data as well as additional environmental indicators, such as faunal spectrum and micromorphological data, along with broader climatic models.

O-0074

## Sub-seasonal palaeoenvironmental records from mollusc shells and implications for Upper Palaeolithic modern human occupation in the Levant

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### Abstract

Humans respond to changes in their local environment on daily to seasonal timescales. Therefore, a robust assessment of the impact of environmental change on human behaviour requires an understanding of local environmental change at seasonal to sub-seasonal resolution. Stable isotope records from mollusc shells provide one of the few sub-seasonal resolution palaeoenvironmental proxies in the mid to high latitudes. Obtaining these records from food-refuse archaeological specimens enables the reconstruction of a more detailed picture of how humans responded to environmental changes in the past.

Here we present sub-seasonally resolved environmental reconstructions from stable isotope analyses of marine and terrestrial mollusc shells from the Upper Palaeolithic archaeological assemblage of Ksar Akil in Lebanon. Oxygen isotope analyses of marine mollusc shells provide sub-monthly resolved snapshots of sea surface temperature, whilst oxygen and carbon isotope analyses of terrestrial gastropod shells provide sub-seasonally-resolved records of rainfall variability and vegetation change. These highly resolved environmental records, coupled with well-dated archaeological sequences provide a framework for assessing the complex interplay between early modern humans and their local environments. We found evidence for fluctuating temperature, rainfall and seasonality regimes throughout marine isotope stage (MIS) 3, some of which appear to be linked to northern hemisphere millennial-scale climate oscillations. The archaeological records show human occupation occurred during both warmer and cooler phases and during both high and low seasonality regimes, indicating that modern human populations were somewhat resilient to the resource uncertainty that would have accompanied these changing temperature and seasonality regimes. These paired cultural-environmental records have enabled an examination of human-environment interactions during critical periods of the late Pleistocene in a region with comparatively few high-resolution climate records.

O-0075

## Carbonates in human water systems as a high-resolution rainfall proxy

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### Abstract

Ancient Rome represents a rare opportunity to compare a longitudinal study of rainfall records with an unusually extensive historical record covering more than a millennium. The few existing climate records covering this period and region suffer from dating uncertainty, discontinuity and human impact, however. This paper investigates the potential of dark layering in calcium carbonate deposits formed in past water systems as a well-dated and high-resolution proxy for rainfall distributions, through a case study in ancient Rome's Anio Novus aqueduct. Such a proxy would have broad applicability, since carbonate deposits are found in water systems from Australia's Great Artesian Basin to pre-Columbian North America.

The historical and archaeological evidence relating to the water system provides precise chronological boundaries for the formation of these deposits. Dark, mm-scale aqueduct travertine layers have often been thought to represent annual growth bands, which would improve dating of the deposits within the historical boundaries. In each case, however, the layering needs to be tested for annual cycles of oxygen isotopes (Passchier et al., 2016).

Dark-coloured layers within deposits from ancient Rome's Anio Novus aqueduct are present on multiple scales down to the micron-scale (Keenan-Jones et al., 2014). The dark layers' multi-scalar distribution and elevated organic concentrations are consistent with formation during the organic-rich flows of the Anio Novus' source water (the Aniene River) during storm events, well-characterized by ancient and modern sources. Growth rate estimation suggests that the mm-scale dark-layer clusters represent extended rainy periods, of which there are now 1 or 2 each year. The practically instantaneous response of the upper Aniene River to rainfall events makes it possible that micron-scale dark layers in the Anio Novus travertine represent a period of hours, and thus likely record individual storm cells.

This paper will present stable isotope ratio measurements from the Anio Novus deposits to investigate the time period over which these mm-scale dark layers formed. The oxygen isotope ratio of the Aniene River is now largely constant throughout the year due to the dampening effect of the limestone aquifers, which are currently the subject of a monitoring program. Hence, seasonal temperature changes should lead to seasonal cycles in the oxygen isotope ratio of the Anio Novus' carbonates. These measurements will also be a record of temperature variation.

Apart from its palaeoclimatic value, this rainfall record will illuminate the influence of climate on flooding, disease and fire, all concerns in densely-populated ancient Rome.

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O-0076

## The WAIS Divide ice core water-isotope record: new constraints for multi-year Pacific Basin climate variability over the last 31,000 years

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### Abstract

Ultra-high resolution water isotope measurements ( $\delta D$  and  $\delta^{18}O$ ) from the WAIS Divide Ice Core (WDC) have been analyzed using a continuous flow analysis system. The water isotopes are a proxy for local and regional temperature, as dictated by the hydrologic cycle and broad-scale atmospheric circulation patterns. An annual signal is preserved across the entire Holocene. Multi-annual signals persist for at least the last 31,000 years, which is the extent of the annually-resolved depth-age scale. When a diffusion correction is applied to the data, we observe a decline in the multi-year signal strength at  $\sim 16$  ka bp. General Circulation Modeling using HadCM3 shows this change point arises from an inter-hemispheric cascade of events: the decay of the Laurentide/Cordilleran ice sheets altered the tropical Pacific mean state and affected the strength of interactions between the tropical Pacific and high southern latitudes. Ultimately, this change was responsible for a shift in Indonesian ecosystems from grassland to rainforest, and reduced inter-annual and decadal variability in West Antarctica by nearly half. During the Holocene, the multi-annual signal strength is rather constant, but additional variability is revealed in the annual signal amplitude, maximum summer, and minimum winter values. The warmest winters occur at  $\sim 9.3$  ka bp, concurrent with the largest collapse of the east Asian monsoon and possibly linked-reductions in the extent of West Antarctic sea ice. The summer signal dominates the amplitude of the summer-winter signal, and appears to trace with max solar insolation curves centered on the Southern Ocean. There is also millennial-scale variability apparent in the annual amplitude that bears similarity to other millennial oscillations in the North Atlantic, tropical Pacific, the Asian-Australian monsoon system, and possibly elsewhere. Overall, the high-resolution nature of the WDC water isotope record has transformed our understanding of sub-decadal climate signals within the most recent glacial-interglacial cycle, and provides an unprecedented opportunity to improve model skill for paleoclimate environments linked to the Pacific Basin.

O-0077

## Hydroecologic response of a northern Alberta boreal lake to ocean-atmosphere influenced cycles during recovery from the Little Ice Age

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### Abstract

A high-resolution (near annual) paleoecological record from “Alberta Lake East”, a boreal upland lake in Northeastern Alberta, Canada archives the ecological history of the lake ca. AD 1875-2010. We use this record to quantify the response of the lake to regional warming during recovery from the colder climate conditions that prevailed there during the Little Ice Age (LIA). Arcellinida (testate lobose amoebae), which are an important intermediary food web component in lakes and preserve well in the sedimentary record, were utilized as a proxy of temporal ecological change in the lake. In the late 19<sup>th</sup> century the arcellinidan fauna was dominated by opportunistic centropxyxids, which were well suited to the lower productivity LIA conditions. By the early 20<sup>th</sup> century, as the polar front had retreated northward at the close of the LIA, the arcellinidan populations became initially dominated by difflugiids and subsequently by *Centropxyxis tricuspis*, indicative of progressively higher productivity conditions associated with longer ice free seasons and warmer summer water temperatures. Time series analysis of temporal changes in the abundance of individual arcellinidan taxa and functional groups obtained from a chronologically well constrained freeze core were used to identify overprinting cyclic climatic influences on lake hydroecology, particularly that of El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). The ENSO phenomenon is known to have a significant influence on interannual climate variability in western Canada, and has been associated with fluctuations in winter precipitation and temperature in the study region. Positive PDO conditions are associated principally with variation in winter temperatures across the region. Wavelet analysis identified a strong ca. 2-9 year cyclicity that correlates well with ENSO frequency in all arcellinidan proxies, and a weaker ca. 60 year cyclicity that correlates well with PDO frequency within the difflugiid and *C. tricuspis* populations. Correlation analysis between arcellinidan populations and the Nino 3.4 and PDO instrumental data revealed that taxa associated with higher productivity (e.g. difflugiids) were negatively correlated with +ENSO and +PDO conditions, which are associated with decreased precipitation and reduced nutrient runoff from lake catchments. The close relationship between arcellinidan ecology and subdecadal changes in climate at Alberta Lake East demonstrates the high sensitivity of northern lake ecosystems to climate variability.

O-0078

## Organic geochemical markers of sea-level changes

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### Abstract

Targeted analysis of organic materials in soils is useful for evaluating past environmental conditions, as specific fauna / flora are related to sea-level changes. However, this depends on the preservation of macro and microfossils in the sediment. Specific molecular fossil compounds (termed biological markers or biomarkers), preserved in the soil matrix, may also be directly linked to organisms and hence to the conditions in which they thrived. Variations in biomarker distributions have therefore become a powerful tool for understanding changes in palaeoclimate conditions. Understanding the main drivers for local past climate changes can inform predictions of future sea-level rise.

This work determines the utility of molecular fossil marker evidence for Quaternary sea-level changes in sediment deposits from the UK, alongside establishing detailed chronologies for the sediments by amino acid racemisation (AAR) dating of carbonate shells and foraminifera. The cores consisted of unconsolidated immature sediments from the mid-late Pleistocene (< 500,000 years) that represented sea-level transgressions. The production of organic geochemistry biomarkers (such as chlorophyll pigments and lipids) change as a response to palaeoenvironmental conditions, providing a useful marker for sea-level changes. Fluctuations in the pigment and *n*-alkane distribution reflect changes in primary producer activity, while the GDGT-based index of branched and isoprenoid tetraether lipids (BIT) differentiates between terrigenous and marine organic matter inputs. Lipids were analysed by GC-FID and HPLC-MS while analysis of chlorophyll pigments was carried out using a new UHPLC-DAD method. The AAR chronology provides temporal constraints to the transgressions, enabling the reconstruction of Pleistocene sea-level changes beyond the capabilities of <sup>14</sup>C dating.

The results from biomarker analyses show excellent time-resolved agreement with the lithological and ecological interpretation, but enabled a more sensitive response of different primary producers to changing conditions to be observed. Linking the pigment, lipid and chronological records, the impact of climate change on the primary producer communities and preservation of molecular signatures can therefore be assessed over transgressive phases of sea-level change. This coupled approach - using biogeochemical markers within temporally constrained deposits - enables exploration of a far wider set of sediments for understanding the past.

O-0079

## Are relative sea-level databases always reproducible?

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### Abstract

Collating and presenting relative sea-level (RSL) data from around the world in a well-defined sea-level protocol, considering all the possible errors involved, has become an essential part of sea-level studies. Interpretation and analysis of various sea-level indicators form the most important part of such an exercise, and different approaches during this endeavor can cause major differences between databases which are essentially sourced from the same data. Here we present an RSL database from southern Africa, a tectonically stable far-field region, prepared using data from the published literature to encompass the post-Last Glacial Maximum (LGM) sea-level history spanning 21 to 5 ka. This database currently contains 39 sea-level indicators, including four sea level index points (SLIPs), one upper limiting data point and 34 lower limiting data points. The database presented by Cooper et al. (2018) describes RSL change in southern Africa since the LGM using beachrock, *in situ* biological indicators, and geomorphological and sedimentological indicators, consisting of ~15 SLIPs. We use the same set of indicators and a similar protocol (Hijma et al., 2015), yet there are some fundamental differences between the two databases. The number of SLIPs is limited to four beachrock samples in the database presented here, as the indicative meaning of the *in situ* biological indicators described from this area only makes them suitable as limiting data points. The indicators described from paleovalley fills and storm beaches are likely to have been subject to sediment compaction or reworking, making them unsuitable for our purpose. The  $\Delta R$  used for reservoir age correction for samples dated using radiocarbon can also create a difference for a database. The  $\Delta R$  used in the databases is the same for the western coast but differs for the eastern coast, with an uncertainty of 175 years for our database. Although the broad RSL history is similar for both databases, with RSL rise between the LGM and ~8 ka followed by a highstand between ~7 ka and ~5 ka, the precise timing and elevation varies depending on the way sea-level indicators and their ages are interpreted. Specifically, replacing SLIPs by limiting data leads to much higher levels of uncertainty about the RSL history for a given region. Such differences in interpreting RSL change could have a significant effect on glacial isostatic adjustment (GIA) modeling because of its potential implications for quantitative data-model comparisons.

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O-0080

## Rapid sea-level rise and climate change: lessons from the early Holocene.

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### Abstract

The '8.2 ka cold event' is recognised as the largest magnitude Holocene cooling event in the North Atlantic region. Freshwater input from the retreating Laurentide Ice Sheet drove a slowdown of the Atlantic Meridional Overturning Circulation (AMOC) which subsequently caused the observed climatic shift. A 160 year period of temperature cooling of  $3.3 \pm 1.1$  °C and reduced precipitation are observed in Greenland, with contemporaneous climate shifts recognised in many other records around the North Atlantic region and further afield. In this presentation two new high-resolution sea-level reconstructions from both hemispheres will be presented with the aim of resolving the history of North Atlantic melt-water input prior to the 8.2 ka event.

Litho- and bio-stratigraphic data alongside high-precision radiocarbon dates have been collected from the Ythan Estuary (NE Scotland) and Swan Inlet (Falkland Islands) for the centuries prior to the 8.2 ka event. In the Ythan Estuary, two complimentary single core analyses utilise a foraminifera based transfer function and multiple high-precision radiocarbon dates to produce a robust high-resolution reconstruction. Swan Inlet is the first southern hemisphere location where a rapid flooding event preceding the 8.2 ka event has been discovered. Optically Stimulated Luminescence analysis shows that the observed sea-level rise, in the order of 2-4 m, occurred in Swan Inlet within a few centuries. This is further constrained by radiocarbon dating and a diatom-based transfer function to resolve the phase(s) and magnitude of this rise.

The combination of sea-level reconstructions from both hemispheres allows confirmation of a Laurentide melt-water source as the trigger of the 8.2 ka event by comparing the magnitudes in conjunction with sea-level fingerprint models. Identifying the freshwater source(s) and quantifying melt-water input allow climate models to be tested in order to apply them more confidently to future AMOC responses to scenarios of warming and ice melt. Thus, this work ultimately will help to improve understanding of the impacts of Arctic ice melt on oceanic changes and future climate, especially in the North Atlantic region.

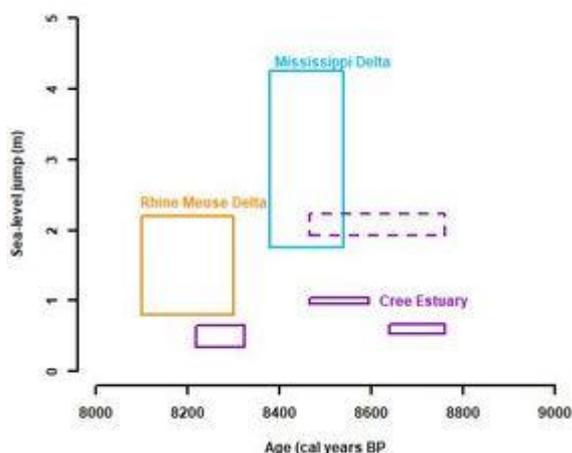


Figure 1. The timing and magnitude of previously observed sea level jumps from sites shown in figure 2, highlighting the current disagreement.

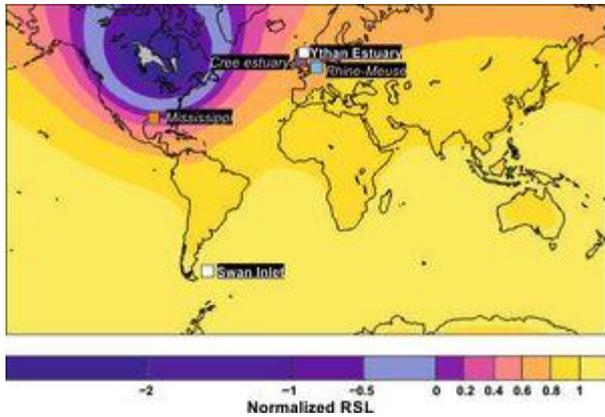


Figure 2. Numerically predicted sea-level fingerprint due to the melt-water input from the retreating Laurentide Ice Sheet at 8.4 ka, normalized by a eustatic rise (0.4 m). The coloured squares represent sites of previous sea-level measurements shown in figure 1 and the white squares are sites from this study. (Adapted from: (Kendall *et al.* 2008)

#### References:

Kendall, R. A., Mitrovica, J. X., Milne, G. A., Tornqvist, T. E. & Li, Y. X. 2008: The sea-level fingerprint of the 8.2 ka climate event. *Geology* 36, 423-426.

O-0081

## Holocene relative sea-level changes along the Atlantic coast of South America

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### Abstract

The spatial and temporal variability of Holocene relative sea level (RSL) changes along the Atlantic coastline of South America are assessed using a newly compiled Holocene sea-level database. The database covers a large spatial area from Suriname to southern Argentina. The southernmost region of the Atlantic South American continent is especially important because the Patagonian Shelf was fully exposed at Last Glacial Maximum and the reported very high mid-Holocene sea levels that could have been strongly influenced by the eventual inundation of the shelf during deglaciation and the expected sharp change in tidal range.

The database comprises sea-level index points and terrestrial and marine limiting data derived from a variety of geological and biological indicators including mangrove and salt marsh peat, beach rock, vermetids, and storm beach deposits. The data was compiled following newly outlined protocols in assembling published sea-level data allowing comparison of regional RSL trends after consideration of vertical and temporal uncertainties in the sea level data and local scale processes (e.g. sediment compaction). We estimated magnitudes and rates of RSL change and the amplitude and timing of the mid-Holocene highstand along a latitudinal gradient by applying a spatio-temporal empirical hierarchical model. Furthermore, we compare regional RSL trends with glacial isostatic adjustment predictions using the latest iteration of the Toronto model ICE-7G\_NA (VM7) of Roy and Peltier (2017).

The RSL records are characterized by higher rates of RSL rise during the early Holocene. The transition to the mid-Holocene period is characterized by spatially variable RSL rising to values higher than present level. For example, RSL records from Suriname and Guyana show RSL at 2.0 ( $\pm$  1.1) m at 3.7 ka. In central South America, RSL records from Brazil show RSL at 4.8 ( $\pm$  1.4) m at 5.3 ka while RSL records from the Beagle Channel show RSL at 6.6 ( $\pm$  2.1) m at 5.9 ka. Following the mid-Holocene highstand, the potential oscillatory nature of RSL changes towards the present is assessed after full consideration of the data uncertainty.

O-0082

## Investigating hydro-isostasy as a driver of Holocene sea-level variability in Northland, New Zealand

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### Abstract

Meltwater-driven ocean loading on the continental shelf is hypothesised to be a significant driver of spatial and temporal variability in Holocene sea-level (SL) changes around the New Zealand coast. The Northland peninsula, at the northern end of the North Island, is a key laboratory for examining the impact of meltwater loading on land deformation and SL variability in New Zealand: the coastline is convoluted with a variable-width continental shelf; the region is tectonically stable during the Holocene; was ice-free during the last glaciation; and contains a major sub-set of the population of SL index points assembled for the New Zealand palaeo sea-level database.

Glacial isostatic adjustment (GIA) modelling for sites along the length of the peninsula predicts significant variability in Holocene SL changes over relatively short distances. This variability is the product of spatial variations in solid Earth deformation driven by postglacial meltwater loading on the continental shelf and is controlled by the width of the shelf. At the southern end of the peninsula modelling predicts ~1 m of subsidence during the Holocene. The amount of subsidence increases to the north, with the northern end of the peninsula predicted to subside ~12 metres during the Holocene. The effect of this spatially variable subsidence on predicted RSL change is dramatic. Modelling predicts the southern end of the peninsula experienced a pronounced RSL highstand of +2.5 m above present beginning c. 8,000 years BP. With increasing distance to the north the magnitude of the predicted highstand decreases to ~1 m above present, with the onset of highstand conditions postponed until c. 4,000 years BP at the northern tip of the peninsula.

SL index points recovered from coastal environments around the peninsula show an overall moderate agreement with the GIA-model predicted spatial patterns in the timing and magnitude of SL changes. Ongoing work seeks to validate GIA model predictions with observational data, and new results obtained over the Southern Hemisphere summer 2018-2019 field season will be presented. New SL index points are being collected from localities around Northland where few or no index points currently exist, including Mangawhai, Pakiri, and Whangarei Harbour. Results from a study of the geomorphic evolution of the Hokianga Harbour will be presented: the Hokianga is hypothesised to have experienced SL rise until c. 4,000 years BP due to hydro-isostatic subsidence. This contrasts with other New Zealand estuaries that have been shown to experience a SL highstand beginning c. 7,000 years BP.

O-0083

## Holocene sea-levels and isostatic adjustment along the Mediterranean coasts. Where are we now?

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### Abstract

Glacial and hydro-isostatic adjustment (GIA) constitutes an important driver of past, present and future sea-level variability. For this reason, a major focus of current sea-level research is the continuous improvement of GIA geophysical models in an attempt to provide more accurate constraints for future sea-level scenarios.

GIA-related deformation in the Mediterranean Sea is mainly controlled by water loading, which has resulted in widespread subsidence throughout much of the basin at an average rate of RSL rise of  $\sim 1$  mm/y over the last 6000 years. However, available GIA models show discrepancy in the estimates of both variability and magnitude of the isostatic signal along the Mediterranean basin.

To solve these issues, comprehensive and quality controlled Relative Sea Level (RSL) databases were recently compiled for a large portion of Mediterranean coastlines. This included the re-evaluation of sea-level indicators from geological and archaeological investigations to produce a new suite of sea-level index points and marine/terrestrial limiting points. These are derived mainly from salt and freshwater marshes or adjacent estuarine sediment, fixed biological indicators, beachrocks and coastal archaeological structures.

I will outline some of the common difficulties and provide potential solutions to analyse sea-level data in such different depositional environments. In particular, I emphasize problems related to the definition of standardized indicative meaning (i.e., the relationship between the indicator and paleo mean sea level) and to the re-evaluation of old radiocarbon samples.

I will further discuss the results of the databases which allowed providing new insights into the anatomy of Holocene RSL changes of the Mediterranean basin. These data are particularly useful in the western portion of the basin that is relatively less affected by tectonic activity and where GIA was the major driver of the sea-level evolution in the mid to late Holocene period.

The isostatic pattern defined from newly assembled databases shows significant disparity with respect to those predicted by present GIA models, notably in the bulk of the basin where sea-level data suggests a general overestimation of the magnitude of the GIA contribution. This has implication in the definition of future scenarios of coastal inundation in the Mediterranean region being the GIA-related vertical motions a key parameter to quantify any possible post-industrial sea-level rise acceleration.

O-0084

## Algal rims as markers of late Holocene relative sea-level change and climate change in the northeastern Adriatic (Istria, Croatia)

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### Abstract

One of the best sea-level indicators on rocky coasts in the microtidal environment are bio-constructions formed by the alga *Lithophyllum byssoides*, called *Lithophyllum* rims. Their vertical precision ( $\pm 10$  cm) comes from the restricted environmental conditions of the alga as their living range is constrained around sea level. The alga thus creates the highest biogenic build-up in the Mediterranean. Consequently, the latest research on relative sea-level change along the eastern Adriatic has been centred on algal rims. Here we present new precise relative sea-level (RSL) reconstruction for the past 1500 yr based on the study of four algal rims on the Istrian peninsula. The chronology is based on 47 radiocarbon dates which were accurately calibrated in order to provide precise relative sea-level curve, to relate sea level changes to periods of climate changes and to try to distinguish land-level changes in the studied area. The RSL reconstruction was quantitatively analysed using an error in-variables integrated Gaussian process (EIV-IGP) model to identify sea-level trends with full consideration of the available uncertainty.

The data from the algal rims enabled the distinction of four phases of relative sea-level (RSL) changes. The rims from the southern Istrian coast show that RSL was almost stable during the Early Middle Ages. After AD 1000, during the Medieval Climate Anomaly (MCA) the RSL rise at a rate of  $\sim 0.8$  mm/y. The following Little Ice Age period, LIA I interval, is again characterised by the relative sea level stability which allows the rims at the southern coast to reach the width of  $\sim 40$  to  $\sim 80$  cm at its highest parts. After AD 1600 on the southern coast the major rim building phase is stopped. On the other side, along the eastern coast of Istria the rim building favourable conditions are achieved only after AD 1400 but the growth is very limited as favourable periods are obviously very short. Between AD  $\sim 1600$  and 1750, during the colder LIA II interval, algal rims do not form. From the second part of the 19<sup>th</sup> century the RSL rise again.

Following the correction for estimated land-level changes during the MCA the sea level rise at a rate of 0.5 mm/y assumed to be a consequence of the Medieval warmth. This increased RSL rise during the MCA was already previously observed in the Central Adriatic. Furthermore, *L. byssoides*  $\delta^{18}\text{O}$  records show that those periods of different sea-level changes are generally consistent with changes in temperature and with periods of rapid climate changes.

This research was supported by the Croatian Science Foundation (project no. HRZZ-IP-11-2013-1623, Reconstruction of the Quaternary environment in Croatia using isotope methods – REQUENCRIM) and by University of Zagreb Grants.

O-0085

## Droughts in the Czech Lands based on documentary and instrumental data in the 1501–2017 period

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### Abstract

Rich documentary and instrumental sources allow an analysis of droughts and their impacts in the Czech Lands during the 1501–2017 period. Reconstructions of mean monthly temperatures and precipitation totals created for the Czech Lands with use of documentary evidence (narrative sources, daily weather records, financial-economic reports etc.) and long-term instrumental measurements were used to calculate three different seasonal, summer half-year and annual drought indices (SPI, SPEI and Z-index). The resulting time-series reflect interannual-to-multi-decadal drought variability. Regression analysis of external forcings and large-scale climate drivers in drought series indicates the importance of the North Atlantic Oscillation phase and the aggregate effect of anthropogenic forcing (driven largely by increases in CO<sub>2</sub> concentration). Other factors, such as solar irradiation and the Southern Oscillation phase make only minor contributions to drought variability. Based on the calculation of return period for series of drought indices, extreme droughts were determined for seasons and summer half-year as cases when all three indices indicated a return period of  $\geq 20$  years. The years 1536, 1540, 1590, 1616, 1631, 1727–1728 were indicated as those with the most severe summer half-year droughts in the 16th–18th centuries (pre-instrumental period). Higher temperatures and lower precipitation totals during the extreme droughts resulted in impacts on agriculture (e.g. failure of harvest of grain, vegetables and fruits, dried pastures and meadows), water resources (e.g. lack of water, low water levels or drying of rivers, water-mills out of operation, decline of groundwater levels) or socio-economic patterns (increase in prices of goods, reduction of cattle, lack of flour and bread, forest fires, poverty etc.). (This work was supported by Czech Science Foundation, project no. 15-11805S “Windstorms in the Czech Lands during the past 500 years” and by the Ministry of Education, Youth and Sports of the Czech Republic, project no. CZ.02.1.01/0.0/0.0/16\_019/0000797 “SustES - Adaptation strategies for sustainable ecosystem services and food security under adverse environmental conditions”).

O-0086

## Historical and dendrochronological analysis of extreme climate years in Nunatsiavut between 1750-1950

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### Abstract

There are several Nunatsiavut historical sources of information, which provide valuable data in an area where instrumental records and proxy record reconstructions are sparse. In the present study, the Moravian archives were used as the main documentary sources. In addition, discursive information gathering textual products such as novels or traveler's journals were taken into consideration as they have the propensity to show extreme weather events that are unpredictable and most often variable in strength, time and place.

Moravian missionaries established several missions along the coast of Nunatsiavut. From 1771 to 1926, their main contact with the outside world was by the Mission ship – usually named the *Harmony* – departing from London in early June, every year. Periodical accounts relating major achievement of the missions, exceptional events and navigation conditions were sent back to London and Herrnhut, the Moravian headquarters in Germany. The mission ship arrival dates, along with descriptive climatic conditions, are used here as indicators of climate variations. For example, in the beginning of the record, 1824 was a joyful year as the ship had never arrived so early and exceptional cold conditions were experimented in 1826-1830 and 1836-1841, during which Moravians mentioned unusual quantities of ice and exceptional summer frosts.

Statistical analyses were performed on the mission ship arrival dates and the tree-ring data, which consisted in maximal wood density, as extracted from a Quebec-Labrador network of tree-ring analysis. Extreme values of both mission ship arrival dates (> 90<sup>th</sup> percentile) and maximal wood density (< 10<sup>th</sup> percentile) were identified in the time series. Among others, 1816 – known as the Year Without a Summer – related with the Tambora eruption in Indonesia in 1815 shows a strong correlation in historical and dendrochronological records. 1816 and 1853 were the only years during which the mission ship did not stop in Hopedale due to the dramatic quantity of ice. Dendrochronological analysis also demonstrated that such cold years had longer-term persistent effects on the ecosystem.

O-0087

## Hydroclimatic Variations over the eastern China during the past 1000 years

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### Abstract

Global warming has caused obvious changes in precipitation, especially altered the drought and extreme precipitation spatial patterns. The existing hydroclimate dataset is difficult to analyze the interannual-interdecadal variations of the hydroclimate and related East Asia monsoon activities before 1470. And several important teleconnected patterns at interdecadal time scale and the stability of internal variability in the climate system cannot be detected. Here, we reconstructed a hydroclimatic dataset derived from Chinese historical documents including 9 regions over the eastern China during the past millennium, and then analyze the spatial-temporal hydroclimate variations, extreme events, the teleconnection modes and their differences between the MCA, LIA and PWP. The results showed that Eastern China has significant 2-7a, 15-35a and 60-80a oscillation signals. On 60-80a time scale, the first EOF showed the same pattern in MCA and PWP, both have south-north opposite patterns divided by the Huaihe River; while in LIA, the first and second EOF showed the patterns with south-north pattern but divided by the Yangtze River, and longitude pattern divided by the 112°E. And on 15-35a time scale, more complex patterns are showed in the three periods. We found these patterns could have possible link with ENSO, PDO and PMO.

O-0088

## Combining historical documentary evidence and instrumental data to assess the severity of the 2015-16 drought in northern South Africa

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### Abstract

The rainy season of 2015-16 was a particularly dry one over large areas of the summer rainfall zone of southern Africa, with drought conditions related to El Niño prevailing from October 2015 into early 2016. Rainfall levels were, in places, less than 65% of the 1982-2011 average, with many areas experiencing their driest rainy season of the last 35 years. The densely-populated Gauteng province and adjacent areas of Mpumalanga were severely drought affected, with a number of municipalities requesting disaster management assistance from national government. This drought, and the more recent one impacting the Cape Town area, have raised questions of how unusual such dry periods are in the historical record. In this study, we combine instrumental rainfall data for the area encompassing Gauteng and southern Mpumalanga with documentary evidence from the late-19th century to address this question. With the exception of Joubert Park meteorological station in central Johannesburg, which has precipitation data back to 1889, rainfall series for the study area are restricted to the 20th and 21st centuries. We use statistical techniques to quality control and analyse the available data, and demonstrate that 2015-16 was one of the top 15 driest rainy seasons of the instrumental period, but certainly not the driest. Historical newspapers are used to provide insights into periods of drought prior to the instrumental period. We analyse titles including *The Transvaal Argus and Commercial Gazette*, *Transvaal Advertiser*, *The Standard and Transvaal Mining Chronicle*, *Transvaal Observer*, *Diggers' News and Witwatersrand Advertiser*, *Eastern Star* and *The Star* using standard historical climatology approaches, to reconstruct regional rainfall variability back to the 1876-77 rainy season. Only one severe drought season (1881-82) stands out during this period. We conclude by comparing our results against other rainfall series for the southern African subcontinent, to place our drought series in regional context.

O-0089

## A *ca.* 120 year-long record of variations in transboundary atmospheric pollution in tropical Asia

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### Abstract

Atmospheric pollution is a global problem, imposing serious adverse health and economic effects. This is particularly the case in parts of Asia, due to weak pollution controls. Atmospheric pollution in a defined geographical area comprises two components: locally produced, and non-local or transboundary pollution. Many atmospheric pollutants, such as heavy metals, have considerable atmospheric residence time, enabling their long-distance dispersal. Pollutants transported over jurisdictional boundaries can become sources of geo-political tensions, exerting potentially uncompensated, negative externalities on recipient jurisdictions. However, the same pollutants may be locally produced. Distinguishing, quantifying and determining the local and transboundary components over time is essential in linking pollution sources and sinks. A better understanding of source to sink pathways, and of pollution effects in receiving areas, can lead to the development and implementation of an effective regulatory response.

This paper describes a novel approach through which a *ca.* 120 year long (AD 1900-2016) record of transboundary atmospheric pollution is reconstructed for a site in tropical Asia, one of the world's most rapidly changing regions. In particular, the paper applies a combination of National Emission Inventory (NEI) and palaeolimnological data to reconstruct past local and transboundary chromium (Cr) contributions to the densely populated main island of Singapore. Concentrations and fluxes of Cr, a relatively poorly studied pollutant with potentially serious adverse health effects, were established from five radiometrically-dated sediment cores from a reservoir in the central catchment, Singapore. The sediment core data (total received Cr) were compared with NEI-derived Cr emission data (local Cr emission) for Singapore. The transboundary Cr pollution component was then established through mass balance: subtracting local Cr emission from total received Cr.

Results show that from *ca.* 1900 to 1960 CE, levels of Cr pollution increased slowly, but the quantities remained small. From *ca.* 1960 to 1970 CE, levels of Cr pollution accelerated, with local anthropogenic sources predominant due to rapid industrialization after Singapore's independence in 1965 CE. From *ca.* 1970 to 2000 CE, levels of pollution from local sources were gradually reduced, owing to a tightening of local environmental regulations. From *ca.* 2000 CE onwards, transboundary anthropogenic sources appear to have been dominant. This is demonstrated by a peak of total received Cr pollution in the palaeolimnological records, and the insignificant local emissions over the same period according to the NEI analysis.



This is the first research that differentiates and quantifies local and transboundary pollution over such a long time period in tropical Asia. The approach could be applied to other atmospheric pollutants or regions and has the potential to provide a basis for improved environmental governance and regional cooperation.

O-0090

## Reconstruction of the Southern Annular Mode from ships' logbooks and other historical observations

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### Abstract

We use historical pressure and wind data from land stations, and ships' logbooks, to reconstruct past variability in the Southern Annular Mode (SAM) with a focus on the inter-war period. The Southern Annular Mode is the major mode of circulation variability in the extratropical Southern Hemisphere, representing changes in the strength and location of the Southern Hemisphere storm tracks. In recent decades the SAM has moved to its positive phase (stronger and more poleward storm tracks) due to stratospheric ozone depletion. Extending the record back in time is important to put these human-induced changes into a longer-term context. Existing instrumental-based SAM reconstructions are based on teleconnections between mid and high latitudes, and contain very little high latitude data prior to the mid-20<sup>th</sup> century when regular meteorological measurements started at Antarctic stations.

Our reconstructions use newly-rescued pressure data from the project ACRE Antarctica (from both ships' logbooks and land stations), combined with pressure and wind data from ships' logbooks from the ICOADS (International Comprehensive Ocean-Atmosphere Data Set) dataset, to reconstruct past variability in the SAM. These reconstructions, and the rescued observations, will be used to evaluate the Twentieth Century Reanalysis at high southern latitudes, and to evaluate the influence on the quality of the Reanalysis of assimilation of new observations.

O-0091

## Wetter winters and drier summers in the UK explained by data errors and biases

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### Abstract

Long-term, quality assured records underpin our understanding of climate variability and change. Globally, few such records extend to the 18<sup>th</sup> Century, particularly for precipitation. The England Wales Precipitation (EWP) series is a notable exception that provides a continuous monthly record from 1766. EWP has found widespread use across diverse fields of research including; trend detection, evaluation of climate model simulations, as a proxy for mid-latitude atmospheric circulation, a predictor in long-term European gridded precipitation datasets, the assessment of drought and extremes, tree-ring reconstructions and as a benchmark for other regional series. A key finding from EWP has been the trends towards wetter winters and drier summers. We statistically reconstruct winter and summer EWP using independent, quality-assured temperature, pressure and circulation indices. Using a sleet and snow series for the UK derived by Prof. Gordon Manley and Prof. Elizabeth Shaw to examine reconstructions, we show that precipitation totals for pre-1870 winters are biased low due to gauge under-catch of snowfall and a higher incidence of snowfall during this period. When these factors are accounted for the trend to wetter winters in EWP is no longer evident. For summer, we find that pre-1820 precipitation totals are too high due to decreasing network density and uncertain data at key stations. A significant trend to drier summers is not robustly present in our reconstructions of the EWP series, with significance depending on start/end year and predictors used in model reconstructions. Our findings challenge current assumptions about historic climate variability and change in north-western Europe. It is also likely that the identified biases in EWP have distorted many other long-term European precipitation series.

O-0092

## Present-day Saharan dust deposition in the Atlantic Ocean and its marine-environmental consequences

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### Abstract

Mineral dust plays an important role in the ocean's carbon cycle through the input of nutrients and metals which potentially fertilise phytoplankton, and by ballasting organic matter from the surface ocean to the sea floor. However, time series and records of open-ocean dust deposition fluxes are sparse. Here, we present a two-year time series of the spatial and temporal evolution of dust-deposition fluxes from a trans-Atlantic array of dust-collecting instruments (surface dust collectors and moored submarine traps) directly below the core of the Saharan dust plume along 12°N. By combining observational data of actually deposited dust with model simulations and satellite observations, we argue that dust deposition in the Atlantic is strongly influenced by summer rains. Using *in-situ* incubation experiments we demonstrate that such wet deposition increases the release of nutrients up to an order-of-magnitude relative to dry deposition. As a result, we hypothesise that rain-amplified bioavailability of these nutrients may well be the key to increased surface-ocean productivity in remote and oligotrophic parts of the oceans and, potentially, continental ecosystems.

O-0093

## Chasing dust in Dronning Maud Land, East Antarctica: A Trace Element perspective

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### Abstract

For the last three decades, more and more attention has been drawn on mineral dust and anthropogenic airborne particles. The long-range atmospheric transport and deposition have become important processes that control and modify the biogeochemical cycles of many elements in the Earth system. In particular, dust plays a key role on the primary productivity in the “High Nutrient Low Chlorophyll” zones, like the Southern Ocean, providing essential elements (e.g., Fe) for the phytoplankton growth and therefore contributing to the global carbon cycle. Aerosol deposition can be found far away from their sources and hence, they are considered to be excellent paleoclimate proxies. In Antarctica, most of the studies dedicated to the dust tracing have mainly been carried out on ice cores extracted from Central East Antarctica and, based on elemental or Sr, Nd and Pb isotopic compositions, X-ray, magnetic properties, or single element analyses. The results of these studies have presented unequivocal evidence demonstrating that during glacial/interglacial periods, the dust trapped in Antarctic ice mainly originates from Southern South America (SSA). However, the aerosol fluxes and sources in Antarctica as a whole and specifically at the coast in the East Antarctica such the case of Dronning Maud Land, are still poorly constrained. Additionally, coastal wind conditions may provide different dust origins as what is observed on the high plateau. Addressing this, we collected atmospheric particles using Sigma 2 passive samplers and active collectors together with sub-surface snow samples. The sampling was performed following a ~250 km transect from the high plateau to the coast at six different sampling sites. Here, we present the preliminary results of the two first field campaigns accomplished during the austral summer of 2017-18 and 2018-19. Samples were analyzed for their physicochemical properties (SEM-EDS, Rare Earth and other trace elements by HR-ICP-MS) in order to define the geochemical signature that characterizes the present-day airborne particles in Dronning Maud Land, East Antarctica. Overall, this study will enhance our knowledge about the geochemical signature variations from the coast to inland plateau of this area and, improve the understanding of dust transport and deposition, atmospheric composition evolution and its close relationship with the southern Ocean and the lower latitude wind circulations.

O-0094

## Holocene southern westerly wind variability in the Southern Indian Ocean Sector: a dust record from Amsterdam Island

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### Abstract

Atmospheric dust production, long-distance transport and subsequent deposition are intricately linked to source conditions, climate and human activities [1]. Holocene dust origins and deposition processes are poorly understood in the Southern Indian Ocean, which limits our understanding of Southern Hemisphere (SH) climate change. An important feature of SH climate is the Southern Westerly Wind Belt (SWW), which influences Southern African, Australian and Southern American aeolian dust trajectories [2].

Here we use elemental and Nd isotope (denoted as  $\epsilon\text{Nd}$ ) proxies in a peat core from Amsterdam Island (AMS) to reconstruct past mineral dust flux, dust provenance, climate change and anthropogenic influence. The peat core covers 6600 years and provides a high-resolution record ( $0.76 \text{ mm yr}^{-1}$ ) of dust deposition from the mid to late Holocene. Two mineral dust flux minima occur during 6.2 - 4.9 cal. kyr BP and 3.9 - 2.7 cal. kyr BP, and may correspond to a strengthening/expansion of the SWW at its northern edge [3, 4]. Lower dust deposition on the peatland under higher wind speed can be explained by wetter local conditions (decreasing dust mobility), and removal of distal airborne particles by enhanced turbulent wind and enhanced wet deposition [5]. The  $\epsilon\text{Nd}$  and REE ratios show that mineral dust deposited at AMS is a mixture of local and distal sources. This highlights the influence of SWW transporting the dust particles. Using a multi-proxy mixing model,  $\epsilon\text{Nd}$  and REE ratios indicate that the peat received approximately 45% local, 15% Southern African and 50% Southern South American dust. Proportional dust contribution from these three sources were relatively constant for 6600 years, except during the last 120 years. Since 1890 AD, there is a distinct decrease in the local dust input (15%), while the contribution of Southern Africa doubled (32%). The contribution of Southern South America input is relatively constant (53%). Moreover,  $\epsilon\text{Nd}$  values shift from 0.5 to -9.6 over the last 120 years in parallel with a southward-shifted SWW. This suggests an enhanced dust mobilization in the distal sources due to land use, over-grazing and agriculture, especially in Southern Africa. Recent dust compositions therefore suggest that anthropogenic activities play more and more a key role in the SH dust cycle during the last 120 years.

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O-0095

## Iron oxidation in mineral dust from the Talos Dome Ice Core (TALDICE, Antarctica) and the Southern Hemisphere potential source areas.

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### Abstract

We performed X-ray absorption near edge structure (XANES) measurements at the Fe K-edge on aeolian dust samples extracted from the TALDICE ice core (Talos Dome, peripheral East Antarctica) and sediment samples from the major potential dust sources of the Southern Hemisphere.

We obtained the highest Fe oxidation levels from Australian sources, while South American sources interestingly show a progressive increase in Fe oxidation with decreasing latitude. Antarctic sources from Victoria Land show Fe oxidation levels higher than expected in such a cold polar environment, a feature which has been related to their very high exposure ages.

The Fe oxidation state of insoluble mineral dust particles from TALDICE are investigated for the last climatic cycle, from MIS 2 to the late Holocene (30-2 ka BP). A general trend from more oxidized to less oxidized values can be observed from the Early to the Late Holocene. This can be tentatively interpreted as a progressive change in the relative importance of different dust sources, with Antarctic local sources becoming progressively more important from past to present, but further studies are needed in this respect, in particular about *in situ* processes. During the Last Glacial Maximum, conversely, this trend seems interrupted by the input of dust from Patagonia and Tierra del Fuego.

Although these results and interpretations will be refined in future with additional studies on the TALDICE ice core, this research highlights the great potential of X-ray absorption spectroscopy applied to ice core samples for paloclimate and paleoenvironmental reconstructions.

O-0096

### **33 kyr records of continental dust fluxes in Hawaii: paleoclimatic implications**

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#### **Abstract**

Quartz in Hawaiian soils is significant evidence for continental dust flux into Hawaii because Hawaiian bedrock is quartz-absent mafic rock. Modern meteorological studies have demonstrated that climate changes linked to Asian dust processes affect dust deposition rates in Hawaii. Paleorecords from marine cores have contributed to detecting Asian dust-climate interactions, amplitudes and timescales beyond those available in modern observations. However, existing paleorecords are concentrated near the equator and mid-latitudes remote from Hawaii. In this study, we present the first paleorecord of continental dust flux (proxy: quartz accumulation rates) from Hawaiian peat sediments over the last 33,000 years. We investigate temporal correlations of the quartz flux data with potential climatic drivers most likely related to emission, transport and deposition pathways from East Asia and Hawaii.

O-0097

## Post-Glacial Lacustrine Records of Mineral Dust Deposition in the Uinta Mountains, Utah, USA

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### Abstract

The Uinta Mountains are a major component of the Rocky Mountain system in northeastern Utah, USA. Previous work has shown that eolian delivery of mineral dust to these mountains has influenced pedogenesis, soil nutrient status, and surface water chemistry. Lacustrine sediments are being used to develop a record of dust deposition in these mountains over the post-glacial period. Radiocarbon-dated sediment cores collected from three subalpine lakes extend from local deglaciation (ca. 13 ka BP) to the late Holocene. Passive dust collectors near each lake constrain the geochemical properties of modern dust. Samples of regolith, retrieved from below surficial soil horizons in hand-dug pits and tree-tip mounds, and bedrock constrain properties of the local material within the watershed. Geochemical analysis of the sediment cores allows the relative contribution of allochthonous dust and autochthonous regolith to the lake to be considered as a time series. XRF and ICP-MS analysis reveal that the abundance of Ca in dust is greater than in local material. Conversely, the abundance of Al is greater in regolith and bedrock than in dust. As a result, the ratio Ca/Al is a useful index for the dust content of the lake sediments. ICP-MS analysis of sediments from one lake was used to develop a preliminary record of Ca/Al over time. The 2-cm spacing of the samples corresponds to an interval of ~100 yrs per sample. In cores from two other lakes, XRF scanning was employed to develop a high resolution (2 mm, ~10 to 15 yrs per sample) Ca/Al record. All three lakes exhibit synchronous high values of Ca/Al between 6 and 5 ka BP, and values in 2 lakes were high again ca. 4 ka BP. A core from near the center of the range was truncated at 2 ka BP during collection, but in two other cores from the extreme west and east ends, values of Ca/Al rose between 2 and 1 ka BP. Synchronous high values of Ca/Al in multiple lakes in different parts of the Uinta Mountains are considered evidence of enhanced dust deposition over this region at these times. On the other hand, an interval of sustained low Ca/Al values between 8.6 and 6.5 ka BP in the easternmost lake is not seen in the others. Values of Ca/Al were also high in this lake ca. 9 ka BP. The significance of these inter-lake variations is not yet clear, however spatial patterns and other geochemical and sedimentological proxies may prove useful in interpreting these differences.

O-0098

## Provenance of Lower Volga loess: Using detrital zircon U-Pb ages to trace source material

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### Abstract

Loess contains an excellent terrestrial record of near-source aeolian mineral dust. Understanding past atmospheric circulation and dust dynamics can only be addressed through constraining the sources of this wind-blown dust yet in many regions the precise sources of loess and dust deposits are poorly constrained. Along the Lower Volga River in the Caspian Sea region in Russia, sequences of relatively under studied loess deposits crop out in sections along with Caspian Sea and Volga River sediments. Very little is known about the nature, source, transport and accumulation of these Late Quaternary dust deposits as well as their implications for understanding Caspian Sea and Volga River history. In comparison to the well-studied loess regions in Europe and East Asia the Lower Volga loess, located in the middle of the vast Eurasian loess belt, represents a missing link for developing full understanding of aeolian dust and Eurasian continental atmospheric circulation history. Hence, resolving the source and transport of this Volga loess is crucial for understanding climate and dust evolution in Eurasia.

U-Pb dating of detrital zircons from loess and potential source sediments represents a powerful tool to determine loess provenance and overcomes ambiguities in deciphering multiple sources from bulk sample geochemical data. Here we present high n zircon U-Pb age datasets from Lower Volga loess as well as from samples of possible source regions, obtained via multi collector laser ablation ICPMS.

Considering likely paleoclimate conditions, the possibility of multi-step fluvial transport and not least the amount of material an area would need to be able to supply when acting as source region, the following areas are considered as potential sources of Lower Volga loess: The floodplains of the Volga River and Don River, sands of the Caspian Sea, desert sediments from Central Asia, eroded bedrock material from the Caucasian and Crimea and moraine/loessic material from the East European/Russian plain.

The first results show that the zircon U-Pb age spectra of Volga loess are very similar at different stratigraphic levels, and show close similarities to Volga River sediments, strongly suggesting a close relationship between river and aeolian sediment material origin. The possibility of the Caucasus being a major source area to Volga loess is excluded based on this data. We will discuss these and further results from other potential source regions, as well as the implications for aeolian dust transport in the region.

O-0099

## A Holocene Sardinian history about nature, men and fire

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### Abstract

Paleoecological data have revealed that Mediterranean island landscapes are the result of complex long-term climatic and socio-environmental interactions (Beffa et al. 2015, Burjachs et al. 2017, Servera-Vives et al. 2018, Tinner et al. 2009, 2016). The Mediterranean islands have all their characteristic early Holocene ecological footprints. So does Sardinia, where treelike *Erica* species (*E. scoparia* and *E. arborea*) played a key role before 5000 cal. BP, whereas on other Mediterranean Island e.g. in Sicily or on Minorca, *Pistacia* or *Buxus* together with *Juniperus* were dominant (Beffa et al. 2015, Burjachs et al. 2017, Tinner et al. 2016). Here, using a multiproxy approach, three coastal lake sites on Sardinia (Sta Cucurica, Lago di Baratz, Chia) covering the past 8000 years are used to study the vegetation dynamics considering climate, land use, erosion, salinity and fire. A dynamic modelling approach helps to answer the question about the dominance of *Erica* species before 5000 cal. BP and to test the hypothesis that the today's dominance of evergreen oaks (*Quercus ilex*-type) is a consequence of intensive landuse and/or moisture seasonality changes.

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**O-0100**

## **Ecological legacies of the Amazonian rubber boom**

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### **Abstract**

Recent evidence suggests that pre-Columbian people living in Amazonia left a legacy on the vegetation that persists in today's forests. The post-Columbian era, including the time of European colonization and the Amazonian rubber boom (c. A.D. 1850-1920), has largely been omitted from the discussion of legacy effects from past human disturbances. Historical documents illustrating the locations of the early Amazonian settlers have yet to be digitized or quantified. Here, we examine the spatial distribution of early European colonists and the subsequent rubber boom period in Amazonian forests using a novel method that combines early collection records with species distribution modeling techniques.

We find that the distribution of people living in Amazonia after European colonization is similar to the pre-Columbian era. The locations of forest inventory and recensus plots, which are used to measure Amazonian biodiversity and carbon dynamics, are disproportionately located in areas that were likely disturbed during the post-Columbian era compared with random site selection. The probabilities of past disturbances at forest inventory plots increased by 29% between the pre-Columbian and post-Columbian era. By the population collapse at the end of the rubber boom, 20% of the forest inventory plots had likely been through at least two major disturbance and recovery periods due to past human activities, and 13% had likely experienced three major disturbance and recovery periods. The recurrent occupation or use of forest locations through time is positively related to accessibility via rivers. Our results suggest that Amazonian ecology is seen through the lens of a shifted baseline. Uncritical acceptance of forests as being mature, when they are actually early- to mid-successional, exaggerates the potential for the overestimation of the Amazonian carbon sink and has ramifications for global carbon budgets.

**O-0101**

## **The influence of cross-trophic associations on community structure at the end of the Quaternary**

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### **Abstract**

Climate influences the structure of both mammal and plant assemblages across space and time, seen most clearly in the emergence of no-analog mammal and plant assemblages coincident with no-analog climates at the end of the Pleistocene. Prior work has examined separately the influence of climate on mammals and plants, with little consideration of how these two taxonomic groups are integrated with and co-dependent on one another -- for habitat, dispersal, resources, and other important interactions. Including both assemblages within ecological models may be necessary to capture a fuller set of processes influencing spatiotemporal changes in species distributions and community structure. In this study, focused on assemblages occurring in eastern North America over the last 21,000 years, we used datasets of fossil faunal and pollen data from the Neotoma Paleoecology Database and generalized dissimilarity modeling to examine whether including cross-trophic associations, in addition to climate, as predictors in community-level models improved the explained amount of assemblage variation across space and time. We found that including mammal richness in models of spatial pollen assemblages influenced the amount of variation explained to only a small extent, and that mammalian assemblage turnover was not well explained by climate, with or without the addition of fossil pollen data. We further explore the magnitude of cross-trophic associations and determine which components of the mammal or plant assemblages most strongly influenced variation in community structure, as well as explore how modifications of the fossil mammal data may improve the ecological models.

O-0102

## Late Quaternary Megafaunal Extinctions in South America: assessing the role of environmental drivers using Species Distribution Models

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### Abstract

At the end of the Pleistocene the world lost most of the mammals weighing over 44 kg in what is known as the Late Quaternary Extinction event. In this context South America was one of the most affected places losing an 83% of all megafaunal genera that inhabited the continent during the Pleistocene. As for other regions of the planet, the discussion about the causes behind these extinctions revolves around the role of modern humans arriving into the continent and the one of climate changes proper of the last glacial-interglacial transition.

Analyses of the radiocarbon chronology of megafaunal extinction in South America show extinctions happening earlier in areas more sensitive to climate change (i.e. high latitude and high-altitude areas) and later in the lowlands near the Atlantic coast. In some regions, such as southern Patagonia and the Pampas, the timing of last appearance of some taxa coincides with the timing of major environmental changes, especially changes in vegetation. These observations open the question about how environmental changes could have contributed to drive some of these extinctions in the continent.

To address the role of environmental changes in driving megafaunal extinctions we use Species Distribution Models (SDM) to understand the dynamics of suitable environments for different taxa of megafauna between 21- 8 Ka. The selected taxa are 10 genera of extinct megafauna for which we have a robust record of presences consisting of radiocarbon and stratigraphically dated specimens. For some of these genera it was possible to explore the distribution of individual species as well. Climate conditions for the different time periods analyzed were extracted using the software Paleoview and the SDM generated using MaxEnt.

For those taxa with a distribution in the lowlands of the Atlantic coast (e.g. *Equus neogeus*) our results show broad areas of suitable conditions during most of the glacial maximum between 21-17 Ka. Suitable environments start to contract between 16-8 Ka. A similar situation is observed for taxa distributed in the high Andes. A very different result was obtained for megafauna with a distribution in southern Patagonia (e.g. *Hippidion saldiasi*). For taxa located there, suitable environments between 21-17 Ka were very reduced, becoming broader between 16-10 Ka and reducing again during the early Holocene. Areas of suitable habitat for the different taxa never completely disappear during the time interval analyzed.

The models presented here helps us to tackle the role of environmental changes in the process of megafaunal extinctions, showing how suitable environments probably became reduced during the Pleistocene-Holocene transition increasing the risk of extinction for these taxa at the time.

O-0103

## Modelling sixty millennia of human expansion throughout Sahul

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### Abstract

How the first people who entered Sahul (New Guinea, mainland Australia and Tasmania connected during periods of low sea level) and subsequently colonised the entire continent is still poorly understood owing to incomplete sampling and the antiquity of the event (50-60 ka). But quantifying the plausible demographic conditions of this rapidly expanding population is essential to determine how colonisation of Sahul occurred. We developed a stochastic, cellular-lattice model incorporating generationally scaled human population dynamics based on plausible rates of intrinsic growth with compensatory density feedback. We built cell-specific dynamic carrying capacities hindcasted with LOVECLIM global circulation model's net primary productivity for Sahul at 1000-year intervals from 60 ka to the present. The cellular-lattice model includes both nearest-neighbour immigration and emigration conditioned on relative carrying capacity and landscape rugosity, and finite-probability long-distance dispersal. Results show a peopling of the entire continent of Sahul within approximately 400 generations (~ 11,200 years) from initial colonisation, with dominant colonisation pathways southwards initially following the east and west coasts, and then easterly along the southern coast of Australia. Validated using reliably dated archaeological material, our model demonstrates for the first time the most likely pathways the first people of Australia took to colonise Sahul based on the ecological properties of their ancient environment.

O-0104

## Effects of climate and humans on lakes of continental interiors: Applications of the Energy-mass flux framework from seasons to millennia.

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### Abstract

The Energy-mass ( $Em$ ) flux framework predicts that climate transmits environmental variability to lakes via influx of energy ( $E$ ; irradiance, heat, kinetic energy) and mass ( $m$ ; water, solutes, suspended matter) through 11 direct and indirect pathways. This presentation applies the  $Em$  flux paradigm to lakes of central North America on time scales ranging from seasonal (spring plankton phenology), through decadal (ecosystem synchrony), to centennial (climate-agricultural interactions) and millennial (continental water sources) using an explicit combination of limnology and paleoecology. At seasonal scales, influx of  $E$  as irradiance and atmospheric heat regulated time series development within the lakes, except where unusual mass influxes as (cold) water intervened to reset the sequence. At annual scales, changes in nutrient influx and air temperature regulated overall ecosystem primary production. At longer time scales, the relative effect of climate and humans depended on the relative magnitude of forcing functions. Considered together, the findings confirm that the hierarchical relationships among climatic and human pathways depend mainly on the ratio of influx : ecosystem content of either  $E$  or  $m$ , rather than intrinsic susceptibility of lakes to specific  $E$  or  $m$  fluxes. Importantly, anthropogenic activities which mainly increase  $m$  fluxes usually overwhelm the unique effects of climate in basins where both human activity and climate change occur. Given that the rate of economic growth (~3% per annum) greatly exceeds that of global warming, the  $Em$  flux framework forecasts that anthropogenic factors may regulate lake ecosystem change in proximate future decades, whereas climatic controls may be paramount on longer time scales primarily when there are large state changes in climate systems.

**O-0105**

## **Simulating the Eurasian Mammoth Steppe using a coupled vegetation–megafauna model**

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### **Abstract**

Between the Last Glacial Maximum (LGM) and the beginning of the Holocene, ecosystems in northern high latitudes changed from graminoid-dominated steppe to taiga and tundra. Concurrently, populations of megafauna species collapsed, among them the three most important large grazers: woolly mammoth, steppe bison, and Pleistocene horse.

Our study focuses on two questions: In what numbers did these large herbivores populate the Pleistocene steppe biome? How did they influence their habitat and shape the ecosystem?

We approach these questions with mechanistic simulations using a new physiological model for the three big grazers. Our herbivore model is directly coupled with a dynamic global vegetation model, and for paleoclimatic driving data we used output of a global circulation model.

We present simulation results from Beringia and northern Eurasia after the LGM.

O-0106

## Multidecadal summer drought variability in Northwest Africa during the last 700 years: evidence for a circum-global oscillation in subtropical precipitation

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<sup>3</sup>University of Reading, Reading, United Kingdom

### Abstract

Northwest Africa is a key region for exploring the interaction of temperate (Atlantic) and tropical (Saharan) climate systems. The Atlas cedar (*Cedrus atlantica*, CEAT) is a long-lived and climate sensitive tree species facing extinction across its NW African range. A large body of work has explored the climate signal in CEAT tree rings, yielding long drought reconstructions and providing insight into the occurrence of past extreme drought years. These reconstructions have been integrated into multi-proxy reconstructions of the North Atlantic Oscillation (NAO), the dominant mode of Atlantic winter climate variability. To date, however, periodic dynamics in the CEAT records have been little studied and the drivers of low frequency change remain poorly understood. Here we show that the growth signal from the old growth forests of the Middle and High Atlas throughout the last 700 years is characterised by significant multidecadal fluctuations with periodic components of around 95, 60 and 21 yr. For the interval of historical climate data (1900 CE onwards), we do not find climatological support for significant influence of winter precipitation variability, but instead show that this signal reflects summer precipitation variability, associated with either enhanced convective activity at the Atlas-Sahara margin and/or enhanced moisture transport via tropical plumes (tropical-extratropical interactions). Weak explanatory power of NAO forcing at decadal timescales suggests that CEAT drought reconstructions should not be included in multi-proxy reconstruction of the NAO at the risk of confounding summer (tropical) and winter (temperate) climate signals. Multidecadal increases in the CEAT growth signal correspond to increases in proxies for monsoon precipitation over the Indian subcontinent and weakening of the El Niño Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO). As such, the signal from NW Africa points to a circum-global teleconnected pattern of precipitation variability at subtropical and low temperate latitudes. The wide spatial expression of the multidecadal pattern makes it difficult to distinguish driver and response regions from the climate proxies. Strong coherence, however, with multidecadal variability in ice core  $^{10}\text{Be}$  flux points to an external driver of the 60 yr climate oscillation.

O-0107

## When the dam breaks

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### Abstract

In many of the cores recovered from the Arctic Ocean during the YMER-80, ARCTIC OCEAN-96, and LOMROG expeditions, a gray layer of unknown origins is observed (eg. Jakobsson et al 2000, Löwemark et al 2008). This gray layer has heterogeneous thickness across the Eurasian Arctic areas spanned by the sediment cores, and is noticeably absent in the Canadian Basin side of the Arctic Ocean. In addition, previous studies on this gray layer show a sharp lower contact, indicating rapid onset of deposition. XRF scanning shows distinct Ti, Fe, Ca, and Mn signatures, which suggests unique provenance compared to adjacent sediments (Mellquist 2009). The Mn minima in particular suggests a redox front formed when the rapidly deposited gray layer created an anoxic environment (Mellquist 2009). Based on this it was hypothesized that the gray layer could be recording the sudden drainage of an ice-dammed lake along West Siberia (eg. Mellquist 2009, Eriksson et al 2012). These lakes form when the ice sheets expand over northern Siberia during the ice ages, blocking and rerouting the river drainages (Mangerud et al 2004), and can catastrophically release their waters when the blockage is compromised (Spielhagen et al 2004). A key test to this hypothesis is whether biomarker signatures also record a sudden change across the gray layer. An abruptly elevated brGDGT in the layer is expected, which could indicate a strong lacustrine input (Zell et al 2014). The catastrophic drainage of ice-dammed lakes can have severe consequences far beyond the Arctic realm. The most familiar example likely is the drainage of Lake Agassiz, which is believed to have triggered the Younger Dryas cold event (eg. Broecker et al 1989, Clark et al 2001). If the gray layer of the Eurasian Basin can be tied to a drainage event, then huge amounts of fresh water must have been injected into the Arctic and North Atlantic oceans, which could alter the thermohaline circulation (THC) significantly (Broecker et al 1989). The exact consequences of this fresh water input on mid- and low latitude climate remains elusive.

**O-0108**

## **Abrupt, global, synchronous megadrought at 4.2 ka BP**

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### **Abstract**

More than two hundred glacial, marine, lake, and speleothem cores provide high-resolution proxy data for the ca. 4.2 - 3.9 ka BP megadrought. The proxy data, displayed here with ERA-I Interim moisture vectors, are distributed across seven continents and the Atlantic, Pacific and Indian Oceans, and indicate regionally coherent and synchronous disruption of the westerlies, the Indian Monsoon, the East Asian Monsoon and the diverse monsoon systems of North America, South America and Africa. Decadal global synchronicity is observable with multi-proxy stacks of Greenland, European, west Asian, African, Indus, Chinese and Andean time series.

The megadrought appears in several regions as a cold, windy, three-stage event, two lengthy droughts separated by a brief wet interlude. Megadrought exceptions at 4.2 ka BP, however, are rare: at Mt Logan, Yukon ice core there is an abrupt wet event, while at Agassiz ice core and NoGRIP an abrupt warm spike is observed. Hypothesized proximate causes for the 4.2 ka BP event prominently include southward deflection of the ITCZ, but the subequatorial distribution of proxy records does not support this hypothesis. Despite the global proxy distribution and the robust atmospheric and marine linkages, ultimate explanations for the 4.2 ka BP event have not been identified.

O-0109

## The imprint of Heinrich Stadials and Dansgaard-Oeschger cycles on the latitudinal distribution of methane sources inferred from ice-core gas records

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### Abstract

Ice core records of atmospheric methane show that on orbital and millennial timescales methane closely follows changes in Greenland temperature, presumably driven by variations in tropical precipitation/hydrology. Over the last glacial period, warm events referred to as Dansgaard-Oeschger events or Greenland Interstadials (GI), noted in Greenland ice core  $\delta^{18}\text{O}$  records and other global climate archives, are characterized by a coeval rise in atmospheric methane. At the onset of these events, methane rises by 50-300ppb from cold Greenland Stadial (GS) concentrations. In addition to the GI/GS methane variations, there are distinct, though smaller, increases in methane during Heinrich Stadials (HS) 1, 2, 4 and 5. These Heinrich Stadial features in the methane record are unique as there is no coeval change in Greenland water isotopes.

Using the Inter-Polar Difference (IPD) of atmospheric methane, we investigate these periods and determine how latitudinal source distributions change between GS/IS cycles, to test a hypothesis that the Inter-Tropical Convergence Zone, normally positioned north of the equator, shifted southward during Heinrich Stadials, causing an intensification of monsoons and tropical wetland methanogenesis in the southern hemisphere and drying in the northern hemisphere.

We measured high-resolution records of  $\text{CH}_4$  from the GISP2 and WAIS Divide ice cores and calculated the IPD for the periods, GS 10 through GI 8 and GI 13 through GI 11. We also reanalyzed previous IPD measurements covering the LGM and Bølling/Allerød. For the first time, our records incorporate a correction for excess methane production associated with dust in Greenland cores. This correction implies an overall reduction in the IPD relative to previous studies. We furthermore resolve centennial-scale  $\text{CH}_4$  variability in both records for the first time, greatly reducing chronological uncertainties.

We show that the tropical to boreal source ratio between GS and GI periods remains relatively constant, indicating a coeval response in both regions during a GS warming event. Heinrich Stadials, by contrast, are characterized by a significant increase in the tropical to boreal source ratio, suggesting a likely shut down the boreal sources and a potential increase in Southern Hemisphere or tropical sources.

O-0113

## Glacial history of the Coats Land region, East Antarctica

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### Abstract

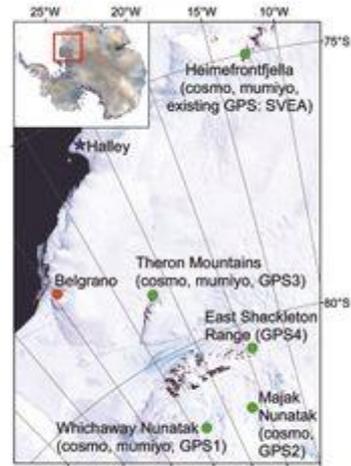
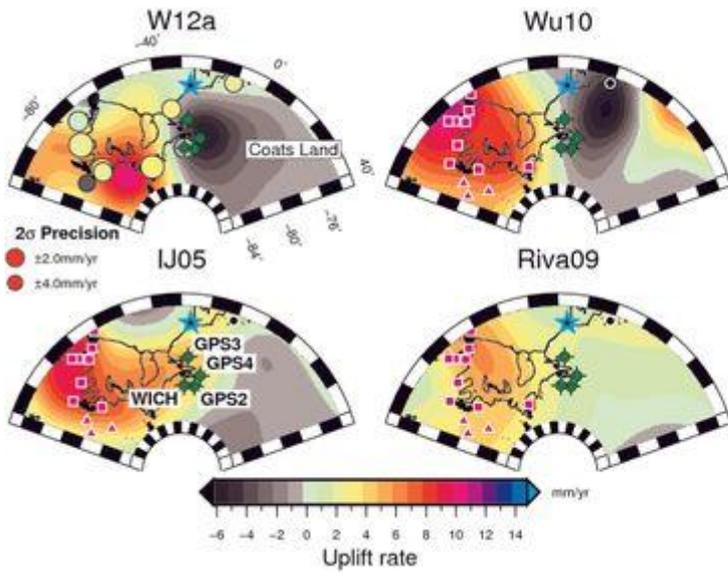
Satellite gravimetry is a widely-used technique of assessing ice sheet mass change. For its application it requires a correction for glacio-isostatic adjustment, which can be of an order of magnitude comparable to that of the 'raw' gravimetric signal. In order to improve these GIA corrections one powerful approach is to reduce uncertainties in the two main inputs: (i) the ice load history and (ii) the understanding of solid Earth structure in the loaded region. For the Antarctic ice sheet the largest differences between modelled GIA corrections occurs in Coats Land, that part of the East Antarctic Ice Sheet that drains into the north-eastern Weddell Sea Embayment (Fig 1). Here we report a multi-disciplinary study to improve our understanding of ice load and Earth structure in this region. We report here on a programme of glacial geology, GPS and seismometer deployment, and modelling; all aimed at improving GIA corrections and thus reducing the uncertainties in ice sheet mass balance in a key region.

We have mapped and sampled the glacial geological record of ice sheet fluctuations on a transect of nunatak sites stretching ~900 km from the Heimefrontfjella (74° 30'S) to the Whichaway nunataks (81° 30'). The glacial geomorphology is a consistent pattern of landforms and glacial deposits, which record a glacial (ice loading) history of the region that we have dated using two independent approaches of cosmogenic Be-10 surface exposure dating and by radiocarbon dating of mumiyo (preserved stratigraphic deposits of proventricular stomach oil from snow petrels, *Pagodroma nivea*). We have deployed GPS receivers in a network to record contemporary surface motion, and at some sites have installed co-located seismometers to provide data for tomographic reconstructions of Earth structure. The glacial history provides constraints for our ice sheet modelling. Once we have preferred data-constrained simulations of ice sheet (load) history then we aim to run GIA models to provide updated GIA corrections for improved satellite gravimetry measurements of this region.

Figure 1: The four left and centre panels show the different predicted uplift rates from four GIA models for the Coats Land region. The differences between models are larger than for any other region of Antarctica. The right hand panel shows the sites we have undertaken glacial geology work and GPS/seismometer deployments.



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O-0114

## Constraining Cordilleran Ice Sheet retreat in western Canada using cosmogenic $^{10}\text{Be}$ nuclide exposure dating

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### Abstract

Reconstructions of Cordilleran Ice Sheet retreat add to our understanding of ice sheet demise, sea level change and the peopling of the Americas. Recent work shows deglaciation along the west coast of North America was complex, with diachronous retreat of different ice margins, and there remain important chronological gaps along this coastline. Our own work reveals that ice retreat occurred by 18.1 ka, exposing low-lying islands by 17.7 ka, with significant implications for a coastal human migration route. However, the extent to which this pattern of ice retreat was indicative of the whole western margin remains unclear. Here, we present new data from Pitt Island (53.7°N, 130.1°W), Porcher Island (54.0°N, 130.6°W), Banks Island (53.3°N, 129.9°W) and Aristazabal Island (52.7°N, 129.2°W) on the west coast of British Columbia, Canada. Fifteen new terrestrial cosmogenic  $^{10}\text{Be}$  nuclide exposure ages from erratic boulders constrain lateral retreat and ice sheet thinning during deglaciation within this region. Importantly, our new data fill the gap between recent chronological campaigns around Calvert Island to the south (Darvill *et al.*, 2018) and Suemez Island to the north (Lesnek *et al.*, 2018). Radiocarbon dating of sediments from the island of Haida Gwaii to the west (Mathews & Clague, 2017) demonstrates ice advanced at 30.0 ka and retreated by 19.4 ka; our new ages complete the history of this sector of the Cordilleran Ice Sheet margin. With chronologies published in the last two years and our new exposure data, we present the most detailed reconstruction of western Cordilleran Ice Sheet retreat to date.

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**Figure 1. Sampling an erratic boulder for exposure dating on Porcher Island, British Columbia.** We present fifteen new exposure ages from similar erratics to constrain both retreat and thinning of ice between Haida Gwaii and the mainland during the last deglaciation.

O-0115

## Timing of cryosphere expansion across North Atlantic Arctic lands compared to a 2 ka CESM1 transient simulation: a data-model comparison

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### Abstract

Changes in late Holocene ice-cap dimensions around the North Atlantic Arctic are dominantly set by changes in summer temperature allowing us to compare time of ice expansion with modeled summer temperatures. We reconstruct times of ice cap expansion for the Eastern Canadian Arctic, Svalbard, and a portion of West Greenland using the radiocarbon ages of entombed tundra plants exposed as the cryosphere recedes under warming summers. Plant ages define when the cryosphere expanded, killing plants and preserving them for centuries to millennia. In most cases ice remained continuously over each site until the modern warming. Compositing the individual probability density functions of the calibrated ages defines periods of sustained summertime cooling in each region. Our summaries are based on 232 <sup>14</sup>C dates from the Eastern Canadian Arctic, 20 <sup>14</sup>C dates from West Greenland, and 37 <sup>14</sup>C dates from Svalbard, all <2 ka. We use changes in varve thickness from a high-resolution lake sediment core to track changes in the dimensions of Langjökull, second largest ice cap in Iceland. Almost all regions show an expanding cryosphere between 100 and 500 CE, a lack of expansion between 500 and 700 CE, followed by all regions recording cryosphere expansion between 700 and 950 CE. During Medieval times (1000-1250 CE) there is little or no evidence of an expanding cryosphere except for a few sites on Svalbard, but summer temperatures were not warm enough in any region to cause ice recession behind first millennium expansions. All four regions record renewed cryosphere expansion late in the 13<sup>th</sup> Century CE through the mid 15<sup>th</sup> Century CE, with the greatest ice extent occurring between 1450 and 1900 CE. We compare these results with a new 2 ka fully coupled climate transient using CESM1, with forcing data from PMIP4, including insolation, volcanic aerosols, land-cover, and GHG. The CESM results show a ~0.5°C reduction in summer temperature between 100 and 500 CE, consistent with widespread cryosphere expansion then. A second phase of persistent summer cooling in the model occurs between 800 and 950 CE, followed by slightly warmer summers between 950 and 1150 CE, although not as warm as early in the first millennium CE. Summers cool again in the model after 1150 CE, with stronger cooling after 1450 CE, reaching a minimum shortly after 1850 CE, ~1°C lower than at the start of the experiment. Orbitally driven declines in summer insolation appears to be the dominant forcing early in the first millennium CE, with volcanism and solar irradiance reductions increasingly important in the second millennium CE, but positive feedbacks from sea ice and the overturning circulation are necessary to explain the magnitude of peak LIA cooling.

O-0116

## Saltmarsh records of post Little Ice Age mass balance changes in Greenland

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### Abstract

Saltmarshes provide excellent archives of relative sea-level (RSL) changes over a range of different timescales. In Greenland they yield precise RSL data over the past few decades to hundreds of years that can help constrain Greenland Ice Sheet mass changes during and after the Little Ice Age (LIA). They are particularly valuable as they provide a longer term context upon which to evaluate recent tide gauge and GPS records which span only the past decade or so. In Southeast Greenland the current rate of crustal uplift recorded by GPS is approximately +7 mm/yr at the open coast and up to +18 mm/yr close to the ice sheet margin. At Ilulissat Isfjord on the west coast uplift rates are similarly 7.9 mm/yr at the open coast and 18.8 mm/yr at the head of the isfjord. These rapid crustal uplift rates reflect high rates of recent mass loss in west and southeast Greenland.

This study investigates fossil saltmarshes located within 5 km of the ice sheet margin at the head of Skjoldungen fjord in southeast Greenland, and just south of Ilulissat isfjord in west Greenland. The aim in both locations is to use RSL data to establish the timing and magnitude of mass loss since the end of the LIA. This is the first time that saltmarshes so close to the ice sheet margin, and close to the globally important Jakobshavn Isbrae ice stream have been utilised to create high precision proxy-GPS data for the last few hundred years.

Microfossil (diatom) evidence from saltmarsh sediments at the southeast site record a recent change from RSL rise to stable RSL, then RSL fall during the past 200 years. We interpret the change from RSL rise to stable RSL as evidence for the initial onset of mass loss locally from the Greenland Ice Sheet at the end of the Little Ice Age. Later RSL fall occurs as mass loss accelerates during the 20th Century. A similar pattern is seen in the west but with RSL rise interrupted by RSL fall caused by post-LIA mass loss, and changes in the rate of RSL change coincide with fluctuations in the frontal position of Jakobshavn Isbrae over the last few hundred years.

This study provides the first direct evidence that saltmarsh sediments from near-field sites can be used to reconstruct the timing of recent mass loss change from ice streams and other marginal areas of the Greenland Ice Sheet, extending direct GPS observations back to the end of the Little Ice Age and beyond using geological data.

O-0117

## Formal subdivision of the Quaternary System: a review and ongoing initiatives

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### Abstract

The Quaternary System was officially defined in 2009 following a struggle spanning two executive committees of the International Commission on Stratigraphy (ICS). The global boundary stratotype section and point (GSSP) for the Gelasian Stage, dated at 2.58 Ma, serves as its base. The Vrica GSSP, 1.80 Ma, which had earlier defined the base of the Pleistocene Series, was repurposed in 2011 to define the Calabrian Stage, effectively completing the Lower Pleistocene Subseries. A 10-year moratorium, stabilizing a now firmly rooted definition, lifts in 2019. The candidate for the Middle Pleistocene GSSP, dated at ~773 ka, is the Chiba section in Japan, having been selected by the Early–Middle Pleistocene boundary working group in 2017, and approved by the Subcommittee on Quaternary Stratigraphy (SQS) in 2018. The Chiba proposal (Chibanian Stage, Middle Pleistocene Subseries) will be submitted to ICS for approval in 2019. The Upper Pleistocene Subseries, with a base traditionally aligned with the onset of the last interglacial, is not yet defined by GSSP and a priority for the SQS. The Holocene Series was formally defined in 2008 using, for the first time, an ice core for the GSSP. In 2018, the Holocene was subdivided into the Greenlandian, Northgrippian and Meghalayan stages/ages and their corresponding Lower/Early, Middle, Upper/Late subseries/subepochs. The GSSP for the Greenlandian is that of the Holocene as previously defined in the NGRIP2 Greenland ice core, and dated at 11,700 yr b2k (before 2000 CE). The Northgrippian GSSP is located in the NGRIP1 Greenland ice core, and dated at 8236 yr b2k; that for the Meghalayan is in a speleothem from Mawmluh Cave, Meghalaya, northeast India with a date of 4250 yr b2k. This subdivision formally introduces the rank of subseries to the geological time scale, and incorporates by far the briefest of all stages. Defining a GSSP in a speleothem is another innovation, and this GSSP is appropriately displayed at the Birbal Sahni Institute of Palaeosciences, Lucknow, India. The Anthropocene is presently undefined, but the SQS Anthropocene Working Group is actively supporting research on prospective candidate sections. The rationale for formalization is compelling. The term is already used extensively in the scientific literature and, like Holocene subdivisional terms, its functionality will be enhanced by formal definition. To correct a misconception, the Anthropocene is not strictly anthropogenic: it reflects the Earth-system response to progressive human impacts, not the impacts themselves. As a concept, the Anthropocene is Earth-centric, not human-centric. The formal Anthropocene, as currently envisioned, would start in the early 1950s. It would hold the rank of series, terminating the Holocene but not interfering with its subdivision other than to terminate the Meghalayan Stage at a time when the Holocene is already evenly subdivided.

O-0118

## The Chiba Section, Japan: a proposed Global Boundary Stratotype Section and Point for the base of the Middle Pleistocene Subseries

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### Abstract

The Chiba composite section is a continuous and expanded marine sedimentary succession situated near the Pacific coast of the central Japanese archipelago. It contains well-preserved pollen, marine micro- and macrofossils, a tightly-defined Matuyama–Brunhes (M–B) paleomagnetic polarity boundary, and numerous tephra beds, allowing the establishment of a robust and precise chronostratigraphic framework across the Lower–Middle Pleistocene boundary. Its shallow-marine, open-ocean continental slope setting, coupled with sedimentation rates of 89 cm/kyr at the boundary with no evidence of abrupt deposition, has resulted in the capture of both terrestrial and marine environmental changes in and around Marine Isotope Stage 19 (MIS 19). We have performed ultra-high-resolution oxygen isotope analysis, as well as detailed sedimentological, geochemical, and biostratigraphic studies of the Chiba composite section, confirming the completeness of the stratigraphic interval spanning the Lower–Middle Pleistocene boundary. The M–B reversal serves as the agreed primary guide for the Lower–Middle Pleistocene boundary, and the Chiba composite section represents one of the most detailed marine sedimentary records yet obtained for this reversal, yielding an astronomical age of 772.9 ka with a duration of ca. 1.9 kyr. This section therefore offers an exceptional opportunity to calibrate the geological time scale as well as understand the dynamics of the geodynamo. The widespread Byk-E tephra bed lies close to the reversal, allowing precise regional lithostratigraphic correlation. The Chiba composite section is easy to access by public transport or car from international airports nearby. The section will be permanently preserved and maintained by the local government as a natural monument. Therefore, we propose the extensively studied Chiba section of the Chiba composite section as the Global Boundary Stratotype Section and Point (GSSP) to define the base of the Middle Pleistocene Subseries and Chibanian Stage.

O-0119

## Basal age for the Salawusuan Stage of the Upper Pleistocene Subseries in Chinese Quaternary chronostratigraphy

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### Abstract

The precise basal age of the Upper Pleistocene for the global Quaternary stratigraphy is important but has not yet been agreed. Here we report a dating study in the region where the stratotype section for the Salawusuan Stage which represents the Upper Pleistocene of the terrestrial Chinese Quaternary is located. We focus on the basal age of the lithostratigraphic unit of the Salawusu Formation. The stratigraphy in the region has been intensively studied since the seminal work by Pierre Teilhard de Chardin and Emile Licent nearly 100 years ago. The Salawusu (Sjara-Osso-Gol) Formation was proposed to describe a stratigraphic unit characterised by alternating fluvial/lacustrine sediments which are interbedded with aeolian sand. The age of this Formation has been determined by various methods. In this study, we date selected sand units using luminescence method. Both coarse-grained quartz and K-feldspar extracts were used and the single aliquot regenerative dose (SAR) optically stimulated luminescence (OSL) and the elevated temperature post-infrared infrared stimulated luminescence (post-IR IRSL) protocols were applied. Three sets of luminescence age estimates, based on quartz SAR, K-feldspar IRSL at 200°C and post-IR IRSL at 290°C protocols respectively, are markedly different from previously obtained age estimates. The base of the Salawusu Formation previously dated to ~130 -150 ka is shown to vary from ~80 ka to > 450 ka. Such great disparity for the base of the Salawusu Formation, hence the basal age for the Salawusuan Stage points to the complication in the regional stratigraphy apparently affected by the landscape evolution in the valley of the Salawusan River. Both require systematic investigation.

O-0120

## Prevalent known and cryptic extinctions in the Pleistocene have conservation lessons for the next century

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### Abstract

The growing field of conservation paleobiology provides a perspective on the range of species responses to global change beyond the limited scale of human observation. Given the challenges posed by future warming, ecologists are increasingly turning to natural experiments of the recent fossil record to characterize the risks to modern biodiversity. The Quaternary fossil record documents widespread shifts in species' ranges and abundances in response to glacial-interglacial cycles, but aside from the late Quaternary extinctions of large mammals, it is typically thought that climate-driven extinction was rare. This has resulted in the emerging paradigm that species may be more resilient than expected in the face of climate change. In contrast, our re-examination of the Quaternary fossil record indicates that the synergistic effects of climate change (both direct and indirect) and other landscape drivers put many species at greater risk than is currently appreciated. This is true both with respect to known, documented extinctions, but also to unidentified, or 'cryptic,' extinctions. Documented extinctions are more prevalent than commonly thought due to previous temporal, regional and taxonomic biases in the literature. Further, predominate attention paid to the species losses during the last glacial cycle misses pulses of extinction during the Plio-Pleistocene boundary, and during in the mid-Pleistocene, during which glacial cycles lengthened and intensified. Clade-based approaches tend to integrate taxa from different regions or habitat types, down-playing the mechanisms that drive extinction risk. Cases of rapid speciation within habitats that are ephemeral relative to glacial-interglacial cycles provide a model for "cryptic" extinctions, which were likely common during the Pleistocene but also provide context for processes that could also drive extinction risk today. By linking the mechanisms behind both known and cryptic extinctions, we identify processes by which climate change contributes to past and future extinction risk, providing a new framework for identifying climate-driven threats to biodiversity going forward. We argue that the fossil record has yet to be fully marshaled to document extinction risk associated with climate change or to draw lessons from these extinctions for conservation challenges going forward. Our Quaternary casualty list is likely incomplete, representing an opportunity for conservation paleobiology.

O-0121

## Reconstructing two million years of *Gigantopithecus blacki* fossil teeth geochemical record

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### Abstract

*Gigantopithecus blacki* (Giganto) was the largest ape ever recovered from the fossil record. So far only known by a few hundred teeth and three mandibles. Giganto was an important species part of the Asian megafauna, along with other large mammals that appear about two million years ago to disappear (for most species) in the late Pleistocene. While the timing and circumstances of the disappearance of Giganto remain abstruse, it has been hypothesised that modification of the environment around 350ka might have led to a deterioration of the species ecological niche. The large body mass animal would have been particularly prone to depleted food source and shrinking habitat. Our current effort to establish a comprehensive chronology of the extinction window for *Gigantopithecus blacki* is providing also key understanding on the palaeoenvironment changes at the time. Yet, in order to comprehend better what may have happen to the only apes that went extinct in the Quaternary, our project is combining an accurate timing for the species with a meticulous study of the early life history of several specimen. By studying Giganto's fossil teeth from 2 million years ago all the way to the extinction window, we are able to investigate the evolution of key adaptive strategies of the animal.

In this talk, we will show the evolution of important adaptive traits of the species, such as a potential change of diet, change of habitat, migration pattern, seasonal dietary adaptation, stress related markers and potential breastfeeding change of pattern of the Quaternary period. By combining the chronology, palaeoenvironmental record and the geochemical mapping of the teeth, our research will shed light on the potential reason for the demise of *Gigantopithecus blacki* in southern China.

O-0122

## Megafauna extinction, faunal turnover, terrestrial vegetation and climate change during the Last Glacial termination in Hungary: leads and lags

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### Abstract

Absolute dating of formerly analysed mammal faunas from two cave localities in Hungary (Jankovich Cave, Rejteck Rock Shelter) combined with AMS <sup>14</sup>C dating of the Hungarian Natural History Museum's Late Quaternary mammoth bone collection allowed us to determine the approximate extinction time of several rodent and large mammal species in the Carpathian Basin. These extinctions occurred in the Late Pleniglacial and Late Glacial period (c. 26 500 - 11 600 cal yr BP). In this presentation we compare the faunal changes with pollen, plant macrofossil and coprophilous fungi records from 5 localities in the Carpathian Region (Kokad, Nagymohos, Lake St Anne, Lake Brazi, Kardoskút Fehér Lake). Biome and quantitative climate reconstructions are used to compare the timing of the faunal changes in connection with the ongoing vegetation reorganization of the Carpathian Region. Our results suggest that the population size of large herbivores decreased in the Great Hungarian Plain (GHP) considerably after 17 700 cal yr BP, when *Artemisia* steppes and steppe tundra vegetation declined, while boreal forest tree abundance increased rapidly in the lowlands. The same boreal forest expansion was delayed, and took place around 16 200 cal yr BP in the surrounding low Carpathian mountain zone. Our results suggest that the vegetation responded quickly to the initial warming after the LGM. T<sub>JJA</sub> reached 14-15 °C already at 19 000 cal yr BP. Cave sediments from central Hungary show the decline of *Microtus gregalis* and *Dicrostonyx torquatus* populations at 16 200 cal yr BP and the expansion of *Microtus arvalis*. The Heinrich-1 cooling was discernible both in the pollen and mammal records: *Juniperus communis* expansion, boreal forest retreat and resurging dominance of *Dicrostonyx torquatus* characterised this period between c. 16 200 - 16 800 cal yr BP, while the pollen based T<sub>JJA</sub> reconstruction suggested ~1.5 °C summer cooling. The Late Glacial showed the expansion of deciduous forest trees (*Corylus*, *Tilia*, *Ulmus*, *Quercus*) in the GHP and minimal vegetation response to the YD cooling in the lowlands.

Absolute dating suggests that *D. torquatus* disappeared from the Carpathian Basin at ~ 16 640 cal yr BP, *Mammuthus primigenius* at ~ 16 125 cal yr BP, *Rangifer tarandus* at ~15 195 cal yr BP and *Microtus gregalis* at ~13 340 cal yr BP, while *Ochotona pusilla* survived into the Early Holocene, but likely disappeared around 11 000 cal yr BP.

These data overall suggest that the collapse of the large herbivore fauna slightly preceded the terrestrial vegetation change and thus likely facilitated it via restricted grazing and the accumulation of plant biomass.

O-0123

## Ecological flexibility of the Pleistocene Sumatran serow and the possible cause of local extinction of the Himalayan goral in Thailand

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### Abstract

Two taxa within the subfamily Caprinae: Sumatran serow (*Capricornis sumatraensis*) and Chinese goral (*Naemorhedus griseus*) are common today in the mountainous areas and forests of Southeast Asia. The co-occurrence of these two species, in addition with a locally extinct Himalayan goral (*N. goral*) that is restricted to the Indian subcontinent and China today, is documented from several Pleistocene fossil sites in Thailand. In some Pleistocene Southeast Asian sites, previous studies on the carbon isotope composition have shown differences in dietary signatures, either pure C<sub>3</sub> or C<sub>4</sub> plants, for the species of *C. sumatraensis*, leading to the question of whether it was a grazer or browser. Moreover, diet and habitat preferences of both species of *Naemorhedus* (*N. griseus* and *N. goral*) have never been isotopically investigated. Here we reconstructed the diets and habitats of these three Pleistocene sympatric taxa through the isotopic analysis of carbonate in tooth enamel in order to identify the exact habitat of *C. sumatraensis* and to test the species co-occurrence patterns. For a long-term history perspective, we analyzed caprine fossils from four sites in Thailand, ranging from a Middle Pleistocene (Pha Bong, undated fauna), Khok Sung (≈200 ka, MIS7), and Thum Wiman Nakin (>169 ka, MIS6) to latest Pleistocene age (Tham Lod Rockshelter, 32 to 12 ka, MIS2), as well as some Holocene specimens. Our carbon isotope analysis reveals different ecological patterns between *Capricornis* and *Naemorhedus*. During the Pleistocene glacial-interglacial cycles and the Holocene, *C. sumatraensis* had a wide range of diets and habitats varying from pure C<sub>3</sub> to C<sub>4</sub> vegetation, while both *Naemorhedus* species from all Thai fossil sites fed on pure C<sub>4</sub> plants or a mixture of both types and shared chiefly an open landscape habitat. The isotopic results suggest that *C. sumatraensis* has been a greater ecological generalist than *Naemorhedus*, in both diet and habitat. The Sumatran serow *C. sumatraensis* was more ecologically flexible in diet and habitat during the Pleistocene, compared to its recent population, reflecting that the modern wildlife habitat is likely constrained due to the human impact on the Thai ecosystems. In addition to the human hunting and besides the interspecific competition, the loss or reduction of grasslands after the latest Pleistocene, when rainforests became dominant, certainly contributed to an extirpation of *N. goral* in Thailand.

O-0124

## Holocene history of 'non-native' tree taxa in Ireland

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### Abstract

The occasional occurrence of pollen of *Abies*, *Acer*, *Carpinus*, *Fagus*, *Juglans*, *Picea*, and *Tilia* in Holocene deposits from Ireland has largely been attributed to sample contamination, reworking of older pollen, or long-distance transport. Therefore, these tree taxa are generally considered as 'non-native' to Ireland. To test this assumption, we examined more than 500 Holocene pollen records from across Ireland for the occurrence of 'non-native' tree pollen types. The palynological evidence was summarized in a database, using G.F. Mitchell's Irish pollen zones for biostratigraphic assignment. The Holocene presence of 'non-native' tree pollen types was recorded in over 38% of Irish pollen archives. *Carpinus* and *Tilia* pollen were documented since the Boreal period. Pollen of *Acer* and *Fagus* were first recorded in the Irish Neolithic, whereas *Juglans* pollen has occurred since later prehistoric times. Both *Abies* and *Picea* pollen occur since the Afforestation period. The palynological evidence presented here implies that the presence of individual 'non-native' tree pollen in Holocene records from Ireland cannot be simply explained by contamination, reworking, or long-distance transport. Although the 'non-native' tree pollen do not show closed pollen curves or high pollen abundances prior to the Afforestation period, the large number of pollen archives from across the island suggests that 'non-native' trees formed part of the Holocene vegetation. Based on these results, a revision of the phytogeographic status of the 'non-native' tree taxa in Ireland is proposed. *Carpinus* and *Tilia* are considered as being native, while *Acer*, *Fagus*, and *Juglans* represent archaeophytes. *Abies* and *Picea* are neophytes.

O-0125

## Spatiotemporal trends in subfossil chironomid diversity: A robust recorder of climate and environmental change?

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### Abstract

Anthropogenic activities have led to a global decline in biodiversity, and monitoring studies indicate that insect communities have been particularly affected. There is a need for long-term (centennial or millennial scale) data to better understand natural dynamics and the processes that govern the observed trends in insect diversity. Chironomids (Insecta:Diptera:Chironomidae) are among the most abundant insects in lake ecosystems, are sensitive to environmental change, and as parts of their larval exoskeleton preserve well in lake sediment records, they provide a unique resource of centennial to millennial-scale information on insect population dynamics. Here, we analyse spatial and temporal trends in chironomid diversity, exploring the applicability of both taxonomic and functional diversity.

Our results show that July temperature (Tjul) is the environmental factor that is most strongly correlated to spatial trends in modern-day taxonomic diversity in regional datasets from Canada, Finland, Norway, Russia and Switzerland. We observe a strong increase in subfossil chironomid alpha diversity with increasing Tjul between 2.5-14°C, whereas in areas with Tjul >14°C alpha diversity stabilises or even declines, potentially due to human-related factors such as lake eutrophication.

A compilation of subfossil chironomid diversity records that span the last glacial-interglacial transition (LGIT), the most recent interval characterised by notable climate variability, further illustrates the sensitivity of chironomid faunas to summer temperature. We observe decreasing diversity during millennial-scale to centennial-scale cold intervals in the majority of the LGIT records. A compilation of records that span the current interglacial (Holocene) show that during intervals when the amplitude of temperature change was relatively muted, site-specific factors such as vegetation and soil development have a more pronounced influence on chironomid fauna, obscuring the chironomid diversity-temperature relationship.

These results illustrate the effects of regional climate change and local natural factors and anthropogenic activities on subfossil chironomid taxonomic diversity in both space and time. However, they do not enable determination of whether the impact of climate variability on chironomid community composition is limited to changes in number of extant species, or if there were fundamental changes to community composition, e.g. through changes in the food web. Analysis of diversity trends within functional classes related to feeding- or habitat-preference shows no class-specific relationship to temperature in the Norwegian training set, and we gained little additional information on past ecosystem dynamics when analysing functional diversity trends in a subset of our LGIT records. To move forward with analysing functional diversity using subfossil chironomids, we need to: (a) increase the count sums of our samples; (b) better link our subfossil taxonomy to the Linnaean taxonomy; and (c) produce more data on modern-day chironomid ecology.

O-0126

## Greater tree species richness in eastern North America compared to Europe is does not translate to functional trait space differences

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### Abstract

Our aim in this study was to determine if differences in species richness between currently climatically similar regions correlate to dissimilarities in functional diversity. Using classic functional traits defining distinct ecological strategies, we described the trait spaces of European and eastern North American tree floras. The trait space of each region was described based on the occupied area, species accumulation pattern, and the trait-space size, dispersion, and clustering. We then evaluated if the species richness differences between these two climatically similar regions correlate to the dissimilarities in occupied areas and species accumulation pattern; as well as differences in the trait-space attributes. Differences in species richness between climatically similar regions do not necessarily result in functional dissimilarities. Regardless of eastern North American having a larger trait-space, occupied areas and species accumulation patterns converged. Although in both regions species clumped towards the trait-space centroid, we observed statistically significant differences between Europe and eastern North America in the dispersion and clustering but not in size the trait space. Positional convergence between European and eastern North American trait spaces suggests that this species richness anomaly does fully translate to the functional space. Our results suggested that species accumulation within a region occurs within a climatically restricted trait space, and not via trait space expansion. Moreover, the consistent aggregation of species towards the trait-space centre aligns with the idea of a directional selection towards a generalised morphology, which might provide the best way to interact with a broad array of environmental conditions.

O-0127

## The Cameron Hills ice streams of southern Northwest Territories, Canada: a closer look

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### Abstract

The Cameron Hills ice streams in southwestern Northwest Territories and northern Alberta are unique for the western sector of the Laurentide Ice Sheet in that unlike other ice stream corridors in the region, they formed atop an upland instead of within topographic lowlands (e.g., Great Slave Lake and Hay River ice streams). Two distinct, cross-cutting sets of megascale glacial lineations (MSGSL) occur in the Cameron Hills upland; an earlier south-southwest flow largely preserved along the southeastern flank of the upland that was then crosscut by the southwest flow (IS #145 of Margold et al., 2015). Spectacular bedforms commence at the eastern leading edge of the Cameron Hills and many extend >15 km in length, and have impressive length:width ratios of 75:1 or greater. There are conflicting interpretations on the nature and formation of these bedforms in terms of ice bed hardness and their erosional versus depositional nature of the MSGSL formation. Previous interpretations on the Cameron Hills MSGSL were wholly derived from remote sensing data.

A field investigation was conducted in 2018 within a single elongate bedform on the Cameron Hills to determine the strain signature and associated microstructures imparted by the palaeo-ice stream on the laterally extensive till formed at its bed. Micromorphological samples were collected to document the nature of sediment deformation, the spatial variations in the microfabrics, and the ductile shear zones and deformation fronts within the till. Samples were also collected from the Hay River ice stream (IS#176 of Margold et al., 2015), a lowland till plain adjacent to the Cameron Hills near the Alberta-Northwest Territories border, for micromorphological fabric comparison between the upland and lowland ice streams. A detailed micromorphological study of the till sequences beneath the Cameron Hills and Hay River ice streams is used to unravel the complex deformation histories recorded by these glacial sequences, and investigate the potential factors controlling fast ice flow in these contrasting palaeo-ice stream settings.

On a macroscale, the tills formed beneath many palaeo-ice streams are massive, lacking any visible signs of stratification and/or glacial tectonic deformation structures. As a consequence, micromorphology is increasingly being used as a primary tool for the analysis of these subglacial sediments, which provides far greater detail on their depositional and deformation histories recorded by these sediments than previously obtained from just macroscale studies.

O-0128

## Microsedimentology of tills near Ainet, Austria -were palaeo-ice streams in the European Alps underlain by soft deforming bed zones?

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### Abstract

Fast moving palaeo-ice masses within the European Alpine Ice Cap (EAIC) during the Last Glacial Maxima within the large valleys of the European Alps can be compared to ice streams that drained the larger Quaternary Ice Sheets in Europe and North America and the modern East and West Antarctic Ice Sheets. Unlike these continental-style ice sheets, the ice inundating the European Alps flowed first through confined bedrock valleys that, at close to the glacial maximum, acted in similar manner to ice streams in the North American Cordilleran Ice Sheet. Knowledge of the subglacial environments illuminates controls in basal ice activity in terms of overall ice sheet mass balance based upon a grasp of basal thermal regimes, sediment availability and rheology, as well as subglacial hydrological conditions.

Debate continues as to basal ice temperatures and sliding velocities as well as basal interface conditions whether on hard or soft beds in many inner and marginal zones of EAIC. Little mention exists as to the extent of soft sediment basal deformation although increasingly such conditions are known from several parts of the EAIS. In particular, in the Drau (Drava) ice stream, an upper branch of the large Sava Ice Stream, appears as a fast-moving ice mass that would likely be underlain by soft deforming sediment. It is the underlying microsedimentology of parts of the Drau Valley in the Lienz area of Austria that is the focus of this research.

Past research on tills has demonstrated that the use of microsedimentology and the examination of multiple microstructures reveals details of till sedimentology surpasses most macroscale examination of tills. The tills of the Drau Valley at Ainet occur from the valley bottom to high up on the valley side. Thin section examination of these tills reveals a detailed depiction of soft sediment deformation processes throughout the basal zones of this ice stream illustrative of temperate basal ice conditions. The tills exhibit the characteristics typical of ongoing active deformation while being emplaced and post-emplacment stress effects such that the evidence from Ainet supports the contention that most likely ice streams in the palaeo-EAIC were similar to those today in Antarctica and in the Quaternary ice streams of the Laurentide and North European Ice Sheets.

O-0129

## Why you should sweat the small stuff: microsedimentology and Snowball Earth

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### Abstract

Microscopic analyses of glacial sediments are well-developed and increasingly widely utilised techniques in Quaternary studies, exposing a wealth of additional sedimentological and structural data which may not be visible at the outcrop scale. However, these techniques have been comparatively under-utilised in the ancient glacial sedimentary record. Here, we use numerous examples from Cryogenian (c. 700 million year old) glaciomarine successions in Namibia, Australia, Scotland and the USA to illustrate the successful application of traditionally Quaternary analysis techniques to pre-Quaternary glacial sedimentary rocks. In northern Namibia, beautifully preserved shear structures and plasmic fabrics provide the first evidence of subglacial deformation in the region, and attest to mobile, warm-based ice masses on the 'globally frozen' Snowball Earth. These deformation structures also aid in unpacking longstanding debates regarding the glacial origin of diamictite-rich facies versus accumulation via rift-related mass flows. In northern Scotland, similar debates ensue, where normally-graded facies do attest to sediment gravity flow emplacement, but ice-rafted debris only visible at the micro-scale confirm a direct glacial input as well. Ice-rafted debris are also only detected microscopically within iron formations in South Australia, demonstrating that these are syn-glacial as opposed to the post-glacial rusting of the seas argued under traditional Snowball Earth hypotheses. Meanwhile, in the western USA, microsedimentology is essential in distinguishing sediment gravity flow deformation from proglacial glaciotectonic deformation, and in identifying the first regional evidence of ice-contact conditions during Cryogenian glaciation. These microscopic data can therefore shed light on the primary mode of deposition of glacial sediments, on the dynamics and basal thermal regime of depositing ice masses, and on the location of grounded ice margins in the pre-Quaternary record, demonstrating the importance of sweating the small stuff even when exploring potentially global scale ice ages.



Sheared clast and enveloping plasmic fabric in the subglacially deformed Chuos Formation, from the Cryogenian record (~720 Ma) of northern Namibia.

O-0130

## Lateglacial lacustrine sediments in Peary Land, northernmost Greenland

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### Abstract

During reconnaissance Quaternary geological mapping in northernmost Greenland we encountered substantial lacustrine sediments, dated to between 16 and 12 KA BP. These sediments started to accumulate in inland embayments of an ice shelf in the Lincoln Sea between Ellesmere Island and northern Greenland.

Micromorphological analysis of a set of thin sections from the lacustrine sediments revealed that they should be classified as rhythmites, not annual varves. The sedimentology is quite complicated. Most astonishing is the widespread occurrence of organic material (most likely mosses) in the sediments, associated with widespread bioturbation. Astonishing, because it is not clear where the plant material came from so early in the lateglacial and which organisms are responsible for the bioturbation.

We will present further sedimentological data on the lacustrine sediments and a comparison with other, non-lacustrine rhythmites.

O-0131

## Dynamic retreat of the Eden-Stainmore palaeo ice stream of the last British-Irish Ice Sheet

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### Abstract

During the Last Glacial Maximum, ice streams of the last British-Irish Ice Sheet (BIIS) controlled the discharge of ice and sediment from various dispersal centres. Deglaciation was characterised by shifts in ice-divide location and internal ice-sheet dynamics resulted in flow switches and dynamic changes in the configuration of ice streams, and hence significant modification of their landform signatures. We present new geomorphological mapping and 11 <sup>10</sup>Be cosmogenic nuclide ages from the Stainmore Gap and Eden Valley, constraining regional dynamic ice-stream retreat following the LGM in northern England. These data allow us to provide temporal constraints on glaciodynamic ice-flow phasing, by linking ages to flow-sets and stillstands recorded in the glacial geomorphological. In our new palaeo ice-sheet reconstruction, we identify complex decoupling of ice in the Vale of York/Mowbray, which was characterised by early retreat of the North Sea Lobe and a minor re-advance of Stainmore ice into the space vacated prior to ~20 ka. This was followed by rapid recession of the central Stainmore Gap, which was ice-free by  $18.0 \pm 0.5$  to  $19.8 \pm 0.7$  ka. The Stainmore Gap Ice Stream retreated contemporaneously with the Tyne Gap Ice Stream, which became ice-free in its eastern sector by  $18.4 \pm 0.8$  ka and in its central sector by  $17.4 \pm 0.7$  ka and the Vale of Eden, with the southern edge at Crossby Ravensworth Fell becoming exposed between 19.2-20.3 ka. The implication is that the northwards ice-flow reversal in the Vale of Eden, which became a fast flow tributary of the Irish Sea Ice Stream, occurred while the Stainmore and the Tyne Gap ice streams were still active and therefore must have been associated with the development of a N-S ice divide down the western spine of the northern Pennines and then across Howgill Fells. This ice divide migration likely triggered the rapid collapse of eastward ice flow corridors as their catchment areas contracted. Our new age constraints suggest that the central sector of the BIIS rapidly collapsed back up into upland dispersal centres between 20 - 17.5 ka.

O-0132

## New Constraints on Late Pleistocene Sea Levels across Western Scotland with Implications for the Wester Ross Readvance

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### Abstract

Reconstructing the past behavior of ice sheets through the Late Pleistocene provides a means for understanding how ice sheets respond to climate change. Following the last glacial maximum, the British Ice Sheet retreated in response to warming and global sea-level rise. The retreat of the ice sheet over northwest Scotland is partly reflected in local records of sea-level change as well as moraines left behind within the landscape. We provide new constraints on the relative sea-level record of northwest Scotland based on two newly cored isolation basins. A record of magnetic susceptibility from one of these basins closely tracks climate changes recorded in the Greenland ice cores and is used to tune our age model from one of the basins. The new sea-level index points suggest sea level was  $17.26 \pm 0.10$  m at 14.9-15.8 ka within Glac Bhuidhe and  $12.65 \pm 0.05$  m at 15.7-16.1 ka with Loch Bad n h-Aclaise, both near the town of Gairloch in northwestern Scotland. Neither basin provides evidence for a “double-dip” in sea level during meltwater pulse 1-A as some models of glacial-isostatic adjustment predict for northwestern Scotland. As both basins lie within the limits of moraines associated with a regional readvance known locally as the Wester Ross Readvance, they constrain the age of the glacial event to greater than 15.8 ka. This age is within error of some rescaled cosmogenic ages and older than most previous models and point to a pre-Bølling Allerød age for the readvance, suggesting it may correlate to the Killard Point Readvance in Ireland and/or Heinrich Event 1. Furthermore, the basin stratigraphy records other regional climate events including the Younger Dryas and Bølling Allerød.

O-0133

## Geomorphological and seismostratigraphic evidence for multidirectional polyphase glaciation of the northern Celtic Sea.

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### Abstract

A Quaternary stratigraphic succession preserved offshore Southeast Ireland (between Dungarvan to Hook Head) records a sequence of depositional and erosional events that supports regional glacial event models derived from nearby coastal sediment stratigraphies and landforms. Multichannel seismic and Sparker data are presented and reveal a five-fold event stratigraphy. A regionally widespread, largely acoustically massive facies (SU2) interpreted as the 'Irish Sea Till' infills an uneven, channelized bedrock surface overlying irregular mounds and discontinuous pockets of weakly stratified deposits (SU1) in bedrock lows that are likely remnant, earlier Pleistocene diamicts and associated sediments. SU2 is truncated throughout the study area by a strong, horizontal reflector and overlain by a thin, stratified acoustic facies (SU3), suggestive of the development of a regional ice dammed palaeolake or smaller ponded water bodies after the recession of ice. On the near shore bedrock platform to the north, a north to south oriented linear narrow ridge at seabed is interpreted as an esker, and represents southward flowing subglacial drainage associated with a restricted ice sheet advance onto the Celtic shelf postdating the SU1-SU3 seismostratigraphy. Onshore LIDaR data reveal drumlin orientations that corroborate the southerly advance of ice into the Celtic Sea from the mainland. The evidence supports palaeoglaciological models derived from nearby coastal localized sediment sequences comprising an LGM-aged cross-shelf Irish Sea Ice Sheet flow from the east, followed by proglacial subaqueous deposition, and finally an episode of offshore-directed Irish Ice Sheet ice flow at a regional scale. The offshore topography marks a new limit for a restricted Late Midlandian Irish Ice Sheet advance from an inland ice dispersal centre onto the Celtic Sea shelf offshore County Waterford.

**O-0134**

## **Cultural Dynamic at the Initial and Early Upper Palaeolithic of Altai Mountains**

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### **Abstract**

This article presents the results of determining the technological and typological characteristics and the general trend of the Kara-Bomian and Ust-Karakolian cultural tradition's development at the IUP and EUP of Altai Region (50,000–30,000 uncal yrs BP). One of the priority areas of research was the study of the structural organization of the cultural deposits of the Kara-Bom (excavation area 4) and Ust-Karakol-1 (excavation area 2) Upper Paleolithic sites, which were used as a reference for the reconstruction of cultural dynamics. The analysis of these complexes opens up the possibility for the study of homogeneous stone industries, the specification of their technical and typological variability and the subsequent verification of regional cultural and chronological schemes.

As a result of the study, we proposed new schemes of the cultural and stratigraphic division of the Upper Paleolithic deposits of Kara-Bom and Ust-Karakol-1 sites. We found that layers 6–4 of Kara-Bom include two horizons with archaeological material (cultural horizons UP1 and UP2) instead of the six habitation levels noted earlier. Lithological layers 11–8 of the Ust-Karakol-1 site contain a single horizon with archaeological material (cultural horizon EUP1), instead of the four levels noted earlier. We have proved that the content of the elements of blade-point Middle Paleolithic technology in the EUP1 cultural horizon of Ust-Karakol-1 site is a consequence of the disturbance and mixing of cultural deposits of the Middle and Upper Paleolithic. The analysis of archaeological complexes of the Kara-Bom site shows that the list of technological and typological characteristics of the industries of the early stage of the Kara-Bomian tradition's development is significantly reduced in the industry of the later stage. This was manifested in the disappearance of the volumetric component in the blade production (flat-faced cores) and a series of tool-markers and technologies (points with ventral base thinning, truncated-faceted pieces, pecking technique etc.).

New data clarify the existing cultural and chronological model of the cultural tradition's development in the early stages of the Upper Paleolithic of the Altai region. We found out that the Kara-Bomian and Ust-Karakolian traditions represent evidence of generally different episodes of human habitation, rather than synchronous ones, as previously supposed. The Kara-Bomian assemblages belong to a chronological interval of 46,000–31,000 uncal yrs BP. The industries of the Ust-Karakolian tradition are clearly fixed in the region not earlier than 35,000 uncal yrs BP and find similar analogies in assemblages of the middle stage of the Upper Paleolithic of the region. The technological tradition's development of this period was aimed at the microlithization of stone tools, the disappearance of non-volumetric elements in the blade production and the improvement of prismatic technology.

We are grateful to the RFBR (grant 18-39-00167) for supporting our research.

O-0135

## New data on Initial Upper Paleolithic in Central Asia: Ushbulak site (Kazakhstan)

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### Abstract

Initial Upper Paleolithic assemblages were initially identified on the basis of the archaeological materials from the sites of Boker Tachtit and Ksar Akil in the Levant. Nowadays, such assemblages have been reported from many regions of Eurasia including Near East, and Central Asia: Altai Mountains, Transbaikalia, Mongolia, and North China. A typical IUP assemblage has been recently found in Kazakhstan (Ushbulak).

Ushbulak (the northeastern part of the Shilikty Valley) is a stratified site (8 lithological layers; 7 cultural layers). According to recovered lithic assemblage and its features, as well as the stratigraphic position of the complexes, and associated faunal remains, three major cultural and chronological units have been tentatively established, including the Holocene assemblage (layer 1), the UP assemblage (layers 2–4), and the IUP assemblage (layers 5–7).

The most significant number of artifacts was discovered in the layers 5–7 (14000 items). The debitage assemblages from these layers represent primary knapping targeting blade production by parallel uni- and bidirectional methods of prismatic core reduction. Blade cores with the opposite semi-tourné platforms predominate in core collection. Core trimming elements correspond well to the available cores. The majority of core trimming elements (crested and semi-crested, plunging, and marginal laminar spalls) illustrates laminar prismatic and sub-prismatic reduction.

The tool assemblage includes several types, such as end-scrapers on large blades, including those with ventral thinning of the base, notched tools, truncated-faceted tools, truncated blades, burins on blades, point with basal trimming, strangled blades, biface and burin-cores.

Based on the composition of the lithic industry, layers 5–7 can be defined as a lithic workshop near raw material outcrops.

These features, supplied by dates 45250–44000 calBP from layer 6 allow us attributing these layers 5–7 to the Initial Upper Paleolithic and considering Eastern Kazakhstan as a region between synchronous sites of the Initial Upper Paleolithic in Altai Mountains (Kara-Bom site, Ust-Karakol-1 site and others), Dzungaria (Loutoshi site, Tongtiandong site) and Northern Mongolia (Tolbor-4 site, Tolbor-21 and others).

O-0136

## Chronological sequence of the Initial and Upper Paleolithic in Mongolia and its relationship to ecosystem changes during MIS3

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### Abstract

In this paper, we investigate the possible correspondence between the chronological sequence from the Initial to Early Upper Paleolithic (IUP-EUP) and the ecosystem changes during MIS 3 in Mongolia. With progress of Upper Paleolithic research across Eurasia and beyond, in the last decade, we are beginning to gain a clearer picture of even the IUP-EUP phenomenon at the onset of the Upper Paleolithic. IUP in its broad sense can be summarized as follows: (1) IUP assemblages are distributed extensively from North Africa to Northeast Asia, (2) the dates likely fall within the range of 50,000-40,000 Cal yr BP, and (3) the stone tool technology is characterized by blade-based primary reduction with elements of the Levallois technique. In northeast Asia, following the period with extensive distribution of IUP assemblages with many common cultural characteristics found across continents, the EUP assemblages appeared displaying higher regional diversity continuing until about 30,000 Cal yr BP. Therefore, one of the main current research objective is to reconstruct the variability and chronology of relevant assemblages of several smaller regional IUP-EUP clusters that are discovered, for example, in southern Siberia and northern Mongolia. IUP-EUP sites found in these regions, at the northeastern tip of their distributions, challenge our current understanding of lithic technology as having broad similarities and local evolutions.

Recent fieldwork in northern Mongolia conducted in the Selenge River Valley System provides relatively high-resolution datasets for reconstructing the origin and evolution of local IUP-EUP assemblages in Mongolia. The ages of IUP-EUP sites in Mongolia fall within the interval of 45-33,000 Cal yr BP, though the change of cultural phenomena are not yet clear. Those ages seem slightly younger than those from other regions, but this age-estimate may still contain several thousand years of error due to the difficulty in accurately determining ages at these sites. The difficulties are mainly derived from its preservation condition because these sites are subject to several agencies of post depositional disturbance; these sites are situated at higher terrace or colluvium slope-wash. Obtaining site-based geochronology with careful examinations of the geological contexts will provide a better platform for us to obtain reliable chronological sequence. This will also allow us to understand change in past human-behaviors during IUP-EUP in Mongolia, providing a local perspective. On the other hand, high-resolution datasets to reconstruct the local paleoenvironment have been compiled recently in Southern Siberia and even in Mongolia although they are not sufficient to cover the entire area. Our comparisons of those data show clear association between the chronological sequences and regional environmental and landscape changes in Mongolia, while awareness of problems and limitation.

O-0137

## The presence and absence of IUP in China: Implications for modern human dispersal across Eurasia

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### Abstract

The emergence of Initial Upper Paleolithic Industries in China is a very complicated research issue, regional variability is obvious in archaeological records in the vast area during the transition from the Early to the Late Paleolithic. While the presence of Levalloisian-like technocomplexes and large blade assemblages from a few Paleolithic sites in North China, such as the Shuidonggou in Ningxia, Luotuoshi and Tongtiandong in Xinjiang, Jinsitai and Sanlongdong in Inner Mongolia, signaled the beginning and existence of Initial Upper Paleolithic industries in part of the region, lithic assemblages from many other sites in North China were largely dominated by traditional simple flake tools. In Central and South China, Levalloisian and blade products are totally absent throughout the Paleolithic, leaving the vast space for the prevailing of pebble-tool-tradition until the Neolithic. What is the dynamic for such technological variation? Environmental restrictions? Different adaptation strategies? Occupation by different human groups? These questions have puzzled archaeologists for a long time. This paper will summarize the diversity of the early Late Paleolithic industries in China and try to offer some interpretations to the complexity of Paleolithic development in the region, including the possibility of different trajectories of modern human origins and evolution.

O-0138

## Variations in core reduction strategies in the IUP assemblage at Shuidonggou locality 1, northern China

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### Abstract

The term Initial Upper Paleolithic (IUP) is generally used to describe the earliest Upper Paleolithic assemblages with Levallois elements in blade production in many regions of western Eurasia, Central Asia, and China. Many researchers consider the IUP techno-complex as transitional from Middle Paleolithic to Upper Paleolithic, primarily on the basis of the Levallois-like features of blade production. In fact, IUP assemblages may contain evidence for multiple strategies for manufacturing blades, including prismatic, Levallois, and burin core methods. Little attention has been paid on the relations of different core reductions within IUP assemblages. Are they independent reduction strategies employed with varying frequencies, or could cores have transitioned from Levallois to prismatic (or vice versa) during reduction? Shuidonggou locality 1, one of the few IUP sites in northwestern China, has yielded a large assemblage of cores and blades, and has figured prominently in discussions of technological diffusion and modern human dispersals in northern Asia. In this paper, we analyze the 3-D models of cores from Shuidonggou locality 1, constructed using a CT-scanner. We apply simple metric as well as geometric morphometric approaches to investigating the relationship between Levallois and non-Levallois cores and core reduction. In addition to casting new light on the nature of blank production at Shuidonggou locality 1, our findings are relevant to research on “transitional” lithic technologies in general.

O-0139

## MIS3 Flake production at the site of Shuidonggou (loc. 2), North China

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### Abstract

A specific blade technology associated with the Initial Upper Paleolithic (IUP) suddenly occurred in Central and Northeast Asia during the Greenland Interstadial 12 (Kuhn and Zwyns, 2014), but where, how and why this phenomenon emerge is still unclear. In Siberia and in Mongolia, the IUP marks a definitive shift toward blade and bladelet-based lithic assemblages that overall characterize the onset of the Upper Paleolithic in the steppe belt and to the farther north. In the Yellow River Basin, at the southeastern edge of this phenomenon and also at the southern border of the northern biogeographic zone in China, the site of Shuidonggou (SDG) tells a different story. Although a handful of loci have yielded evidence for IUP technological systems (SDG1, SDG2 and SDG9) (Brantingham et al., 2002; Li et al., 2013; Peng et al., 2014), human occupations that followed the IUP occupations show the return of a flake-based assemblage configuration at the expense of the blade technology (Li et al., 2013). Here we present a techno-typological analysis of the SDG2 assemblages (cultural layers 3 to 1a) excavated between 2014 and 2016 and that cover the time span between ca. 32 ka cal BP to 20 ka cal BP. In the material studied, none of the defining features of the IUP blade technology subsists, and instead we see the rapid re-establishment of technological practices commonly observed in the region preceding the appearance of the IUP. On the one hand, a closer look at flaking patterns shows that although technological change occurred through time, it does not lead back to blade productions. Finished products remain poorly standardized, although significant temporal variations are illustrated by the import/export of semi-finished products (Lin et al, 2019). Also, method and flaking techniques illustrate a degree of diversity that contrast with the use of a generic label such as 'core and flakes'. However, our analysis also underlines similarities in the selective treatment of raw material types that may reflect long-lasting regional signatures (e.g. specific use of the SDG resources). At the regional level, our results provide insight that helps clarify the temporal changes in the lithic technology at SDG2, with evidence for versatile subsistence strategies but also convergence in raw material exploitation. At a more global level, the SDG2 sequence help illustrate a complex history of technological changes at the border between two strikingly different paleoenvironmental ecozones (Dennell, 2008; Norton et al., 2010)

**O-0141**

**Lost in Space? Current trends, challenges and potentials in strontium isotope archaeology**

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**Abstract**

More than thirty years after the first ground-breaking work in the field, strontium isotope applications are ever-increasing in the archaeological sciences, and in particular in bioarchaeology. From larger studies tracking the mobility of past populations to individual (and even seasonal) movement histories, strontium isotope analysis is proving to be a valuable means of exploring the past and answering archaeological enquiries at a range of scales. In addition to numerous studies on human remains, isotope zooarchaeology has flourished as a sub-field, including diverse strontium isotope applications to both domestic fauna and remains of wild animals from Pleistocene sites. In this talk, the highlights and challenges of strontium isotope applications in archaeology will be explored, with a particular focus on the difficulties of translating isotope ratios into spatial data within a meaningful, archaeological interpretive framework. The position of strontium isotope analysis in bioarchaeology now and into the future will be contemplated, and key research priorities discussed.

O-0142

## The PleistoHERD model: Linking intra-tooth strontium isotope profiles and isoscapes using computational modelling to reconstruct *Rangifer* palaeomigrations

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### Abstract

Reconstructing the movement palaeoecology of archaeologically-important prey-species, such as reindeer, is crucial to the study of ancient landscapes and ecosystems, and for gaining a better understanding of the decisions, movements and hunting strategies of past human groups. Traditionally inferred from the behaviour of modern analogue species, our ability to reconstruct ranging behaviours and seasonal movements in the past has greatly improved with the development of isotope techniques that target incrementally developed tissues preserved in the archaeological and palaeontological record, such as tooth enamel. Strontium ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotope provide information on the location individuals foraged during tissue formation. Isotope analysis of sequentially-sampled tooth enamel can be used to evidence seasonal migratory behaviour of ungulates, and to provide an indication of possible seasonal ranges (e.g. summer or winter range). However, more nuanced approaches that link intra-tooth isotopic profiles and isoscapes, are required in order to reconstruct past migratory routes across landscapes and seasonal range use. Here, we present the methodological framework for an isoscape-based model which will assess the distribution and migratory movements of *Rangifer* from their intra-tooth  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}$  isotope data, the PleistoHERD model. Our model integrates intra-tooth and landscape isotope data using GIS analysis and movement modelling methods from modern ecology. In developing the model, we use intra-tooth isotope profiles from modern migratory caribou from the Rivière-aux-Feuilles herd, Québec, Canada, alongside creating a working  $^{87}\text{Sr}/^{86}\text{Sr}$  isoscape, based on the age and nature of the lithology of Québec, supplemented by bioavailability strontium isotope data from modern plants, and refined using Random Forest modelling. Preliminary isotope analyses of the second and third molar indicated variations in  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope values, reflecting the seasonal migratory behaviour of the individuals during their first 18 months of life. A Bayesian spatial assignment approach is used to identify the origin of every intra-tooth sample from each individual, and produce a time-series probability distribution map for each caribou. Caribou movements are then modelled throughout the time-series distribution map to identify potential winter and summer ranges and migration routes. Finally, in order to refine and discriminate potential migration routes, we use habitat suitability models to take into account the impact of topography, hydrography and landcover on caribou movements. The comparison of reconstructed seasonal movements with real migratory movements, assessed from 30 years of telemetric survey of the Rivière-aux-Feuilles herd, will allow us to validate the model. The implications of the PleistoHERD model, and its interdisciplinary approach, for the use of strontium isotope analysis in both archaeology and palaeoecology will be explored.

O-0143

## Strontium-scapes, cultural change, and human life histories in the southern Andes

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### Abstract

The main goal of this paper is to reconstruct the spatial scales and patterns of organization of human mobility across a diverse array of ecological and altitudinal settings across the southern Andes (32°-34° S) during the last 2500 years. This project is designed to sample different biogeographic regions from the Pacific coast in Chile to the eastern Andean lowlands in Argentina (Figure 1). To achieve this long-term goal, we present advances in the following two specific goals of the project.

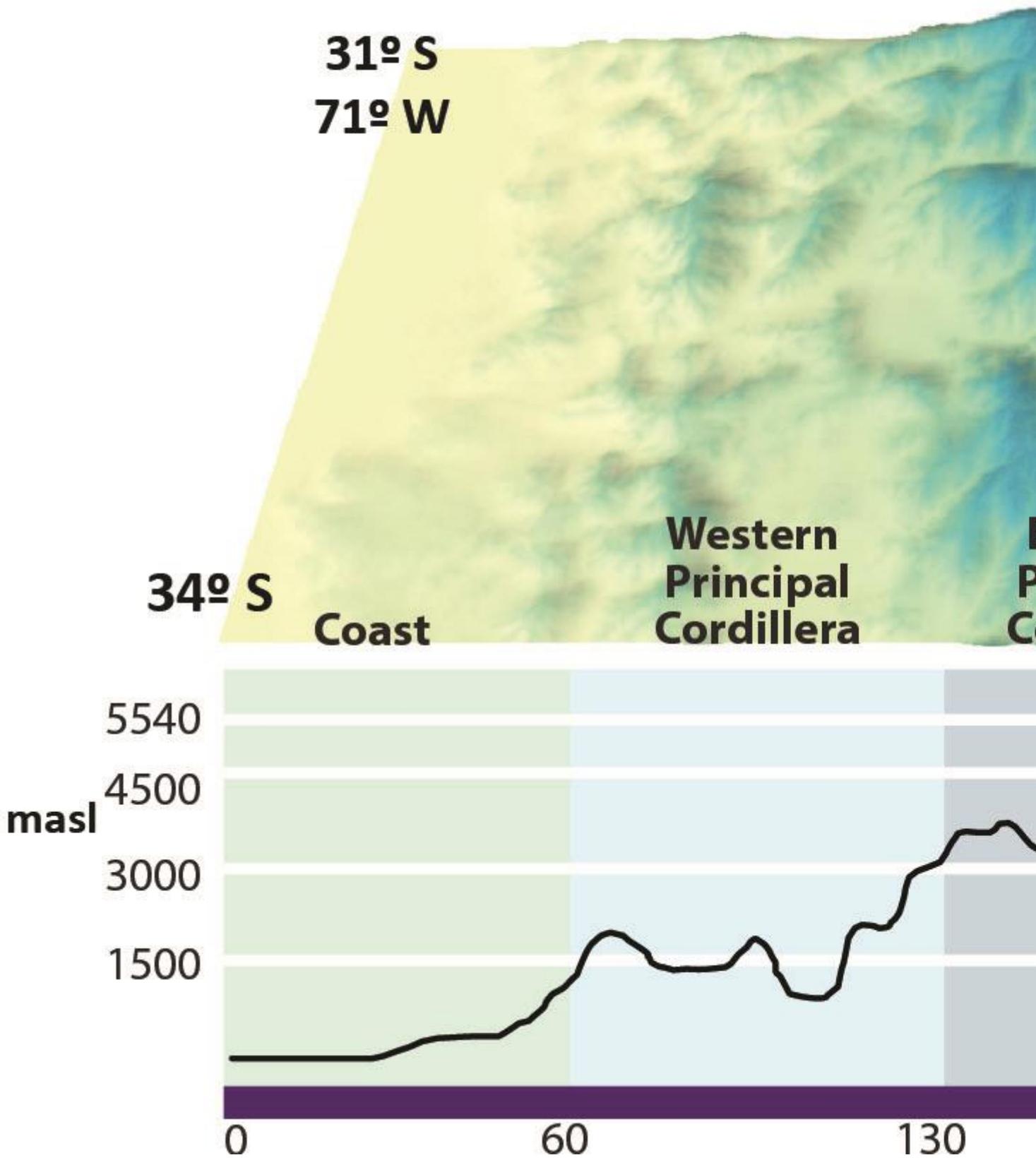


Figure 1. Cross-section of the southern Andes.

Firstly, we seek to build a framework of bioavailable strontium isotopes ( $87\text{Sr}/86\text{Sr}$ ) as expressed in the main Andean geological units, which span from the Pliocene to the Lower Paleozoic: a) marine Sr in the Pacific coast; b) Coastal Cordillera (Cretaceous); c) Western Principal Cordillera (Miocene-Oligocene); d) Eastern Principal Cordillera (Cretaceous-Jurassic); e) Frontal Cordillera (Permian-Triassic); f) Precordillera (Lower Paleozoic); and e) Active Foreland (Quaternary) (Figure 2). To achieve this goal, we analyze plants and rodent samples from modern and archaeological contexts. This is the first attempt to apply such an approach in the southern Andes.

Figure 2. Geological framework for the southern Andes.

Secondly, by analyzing strontium isotopes in human bone and teeth samples from archaeological contexts, we reconstruct place of origin and death, providing an analytical window for the study of individual life histories, combining the realms of quotidian ranges of human movement and social processes, such as conflict and migration, which disrupt this pattern of daily life. We focus on the analysis of human remains from the last 2500 years, witnessing the most intense processes of socio-demographic and economic change, including an apparent reduction in the intensity of mobility, first presence of archaeological cemeteries, the origins of agro-pastoral economies, and the geographic expansion of the Inka Empire.

From a methodological perspective, we develop a preliminary comparison of strontium and oxygen isotopes ( $18\text{O}/16\text{O}$ ), revealing a divergent pattern: while oxygen isotopes for human samples from distant regions in western Argentina overlap widely, there are important differences in strontium isotopes, hence suggesting that strontium provides a finer tracer of human mobility across this geologically complex Andean landscape. Our strontium results will be briefly compared to those produced by colleagues for the south-central Andes of southern Peru, northern Chile, and western Bolivia, in an attempt to learn about the spatial resolution achievable in different Andean geological settings. In synthesis, by integrating the results for bioavailable strontium and human tissues in the context of a biogeographic framework, this project (National Geographic HJ-136R-17) presents the first assessment of sociocultural variation, scales of human territories, and patterns of social interaction across the southern Andes.

**O-0144**

## **Traveling monastic paths: A study of mobility and religion in medieval Ireland using radiogenic strontium and oxygen isotope analysis**

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### **Abstract**

Monasteries were powerful social institutions in early and late medieval Ireland that took drastically different forms over time. Medieval historical records, such as annals and Saints' Lives, and archaeological data, such as the layout of monastic buildings, suggest that small communities of monks at early medieval Irish monasteries followed ascetic or austere ways of life. Contrastingly, historical and archaeological sources indicate that monks at late medieval monasteries, founded by English and continental religious orders, lived in large communities and interacted with lay or non-religious people. Historical texts also record that high-status Irish monks and nuns traveled throughout Ireland, Scotland, England, and continental Europe. However, documents record little information about lower status monks and lay people. Thus, it is unknown how frequently people traveled as part of monastic life and how frequently local individuals participated in monasticism. This study leverages unique burial contexts of 88 individuals at five Irish monastic sites spanning nine centuries (8<sup>th</sup>-16<sup>th</sup> centuries AD) through biogeochemical analysis of human bones and teeth based on two isotopic systems (radiogenic strontium and oxygen) compared to a geological baseline of plant samples, to uncover patterns of medieval Irish mobility in connection to the changing practices of Irish monasticism.

O-0145

## The building of Qin-Han Empire: insights from strontium isotopes of sacrificial animal tooth enamel

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### Abstract

The domesticated cattle and horses were introduced to north China as early as the second millennium BCE, and played vital roles in subsequent China's wars and farming. However, supplies of these livestock are still hampered by the lacks of direct evidence and suitable methods. A newly excavated Xuechi site, a state-level ritual venue for the Qin-Han dynasties, exposed abundant sacrifice animals, providing a valuable opportunity to approach this issue. Here we analysis the enamel  $^{87}\text{Sr}/^{86}\text{Sr}$  value of 10 cattle and 19 horses from different sacrificial pits of the site. As the whole, the cattle and horses bear the similar  $^{87}\text{Sr}/^{86}\text{Sr}$  values and no statistically significant differences are found between pits. By contrast, the  $^{87}\text{Sr}/^{86}\text{Sr}$  values of the livestock are obviously higher than those of local snails and surface water, strongly suggest that the analyzed livestock were not raised on the immediate locality of the site. Inferred from river water  $^{87}\text{Sr}/^{86}\text{Sr}$  values, the regional baseline map for bioavailable  $^{87}\text{Sr}/^{86}\text{Sr}$  values further suggests that some livestock (cattle 7/10, horse 5/19) probably derived more than one hundred kilometers away. These extensively consumed livestock found from the Xuechi site suggests a social network behind them, as supported by historical documents. Moreover, the increase in standard deviation of  $^{87}\text{Sr}/^{86}\text{Sr}$  values of cattle tooth enamel shows robust correlation to the trajectory of Chinese states, implying that the variability of  $^{87}\text{Sr}/^{86}\text{Sr}$  values of sacrificial tooth enamel is a potential tool to track the formation of empire.

O-0146

## Origins of the people in the Iron Age Levänluhta water burial, western Finland.

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### Abstract

With ~100 exceptionally well preserved skeletons, the Levänluhta water burial (ca. 400-800 CE) is one of the foremost Iron Age sites in Finland, situated ca. 50 km inland from the Baltic Sea coast in western Finland. Since 2011 it has been the target of multidisciplinary studies including modern archaeological (Wessman et al. 2018), osteological, isotopic and genetic investigations (Sikora et al. 2018; Lamnidis et al. 2018) aiming to arrive at a holistic understanding of the site and those buried there.

To study the origins of the people buried in Levänluhta, who are almost entirely women and children, tooth enamel from 16 individuals was sampled for  $^{87}\text{Sr}/^{86}\text{Sr}$  analysis. Local bioavailable  $^{87}\text{Sr}/^{86}\text{Sr}$  values (0.7238-0.7384) were evaluated using environmental sampling of surface waters and small mammal bones. Some of these data are included in the aDNA study of Sikora et al (2018). The studied humans yielded  $^{87}\text{Sr}/^{86}\text{Sr}$  values from 0.7103 to 0.7313. Six individuals showed  $^{87}\text{Sr}/^{86}\text{Sr}$  values (0.7268-0.7313) consistent with local Sr levels. Ten individuals showed lower values (0.7103-0.7207), out of the range of local environmental samples. Four of these had  $^{87}\text{Sr}/^{86}\text{Sr}$  values <0.715, distinctly different from the observed local baseline and the relatively high  $^{87}\text{Sr}/^{86}\text{Sr}$  levels common for the Levänluhta area bedrock.

Three scenarios are considered in the interpretation of the origins of the apparent “non-local” individuals. Their  $^{87}\text{Sr}/^{86}\text{Sr}$  levels are consistent with origins from e.g. the Baltic countries, northern Poland and Germany, southern Sweden, and Denmark, all underlain by Phanerozoic sedimentary rocks. However, immigration within Finland can't be excluded. Although high  $^{87}\text{Sr}/^{86}\text{Sr}$  values typical for the Precambrian rocks constituting most of the Fennoscandian Shield are expected throughout Finland, also regions with bedrock  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios <0.715 have been modeled to occur. A third, alternative scenario arises from the possibility of heavy usage of aquatic resources from the brackish northern Baltic Sea with current  $^{87}\text{Sr}/^{86}\text{Sr}$  values at 0.7094-0.7096. Due to the influence of strong isostatic uplift, the coastal waters were only at a ~25 km distance from the site during the Iron Age and attainable via the Kyrönjoki river. Incorporation of Baltic fish and seals, would result in lower  $^{87}\text{Sr}/^{86}\text{Sr}$  values of consumers than expected based on local terrestrial/freshwater resources only. Despite the site's inland location, Baltic resources were likely significant for prehistoric subsistence in the area highlighting the need to carefully consider how we determine values defining “local”.

### References:

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O-0147

## Strontium isotopes reveal new insights into the complex life history of modern and ancient fish in California

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### Abstract

The San Francisco Estuary is the largest estuary along the west coast of the United States and a vital link in California's water supply. It provides a complex, dynamic and productive habitat but over the last centuries has been highly altered and degraded by human impacts. This resulted in the loss of numerous ecosystem functions and in the rapid decline of many native fish species, causing significant conflict about the use of limited freshwater resources.

Comprehensive life history and migratory patterns of impacted species are needed to guide future conservation and water management efforts. Fish otoliths (ear bones) consist of continuously-accreted calcium carbonate, thus providing a life-long archive of the environmental conditions each individual has experienced. Strontium isotopes ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) in fish otoliths can be used to reconstruct the use of different watersheds in freshwater systems and the use of habitats with varying salinities in estuaries. Thus, they can be used as a powerful tracer to reconstruct migration, habitat utilization, and life history diversity in both modern and ancient fishes (Fig. 1).

We applied strontium isotope analysis to several threatened and endangered fish species in the San Francisco Estuary, including the iconic Chinook Salmon and the threatened Longfin and Delta Smelt to quantify and reveal their life history diversity across the recent drought and flood periods. We have also examined similar patterns in archaeological Chinook Salmon otoliths collected from Native American middens to examine life history complexity in the Estuary prior to the Gold Rush in the 1850s.

Our findings show that strontium isotope analysis greatly enhances our understanding of the diversity of live histories utilized by each species. Furthermore, by combining life history reconstructions with environmental data (temperature, fresh-water outflow), we can investigate the underlying drivers and mechanisms of movement patterns, which can lead to more effective water management and conservation efforts.

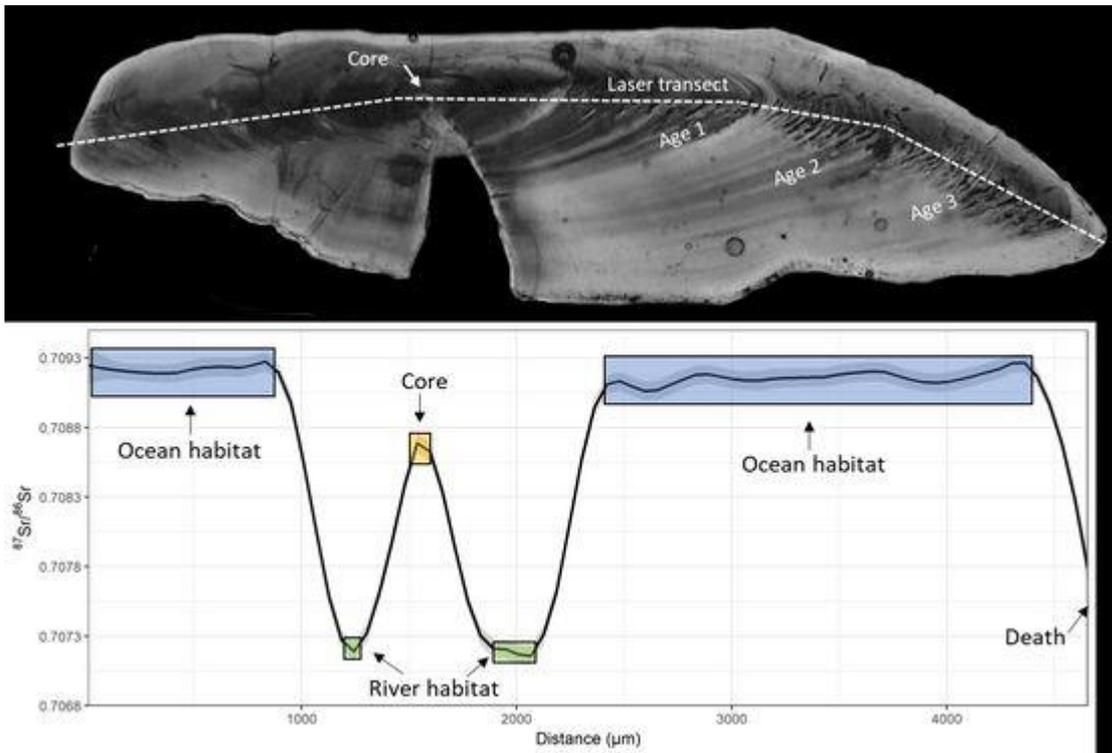


Fig. 1: Otolith cross-section and strontium isotope profile of a 3-year-old Chinook Salmon (*Oncorhynchus tshawytscha*). Variation in strontium isotope values reflects natal riverine habitat, rapid migration through the estuary, multiple years spent in the coastal ocean as an adult, and a return to freshwater habitats to spawn prior to death.

O-0148

## Collaborative RESPONSE to Rapid Climate Change Impacts on Greenlandic Heritage

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### Abstract

Both the scientific record and local and world cultural heritage are threatened by accelerating climate change, especially evident in the circumpolar north. Science and Heritage organizations are joining with local communities to respond to these threats and this paper presents one such partnership building upon multiple seasons of archaeological and paleoecological research and a community focused field school in SW Greenland. The RESPONSE Project Greenland is an international collaborative project sponsored by the *North Atlantic Biocultural Organization* (NABO, [www.nabohome.org](http://www.nabohome.org)), the *Integrated History and Future of People on Earth* program (IHOPE, <http://ihopenet.org/global-environmental-change-threats-to-heritage-and-long-term-observing-networks-of-the-pas/>) and the *Humanities for Environment Circumpolar Observatory* program (<https://hfe-observatories.org/observatories/circumpolar-observatory/>) with funding support from the US National Science Foundation. It involves an international interdisciplinary team of researchers from Greenland, US, Canada, Denmark, Norway, Poland and the UK, host Greenlandic institutions, field school students and indigenous scholars in a coordinated effort to rescue an archaeological and paleoecological record threatened by both accelerated marine erosion and rising soil temperatures. The “melting middens” phenomenon is now well documented by the Danish REMAINS project which has established the biochemical tipping point that transforms excellent organic preservation in stratified archaeological sites into unrecoverable mush in a few years. The work of the 2011-18 NSF NABO Comparative Island Ecodynamics project has underscored the extent of the damage: of 97 sites tested only three retained significant organic preservation. The new NABO RESPONSE project will work to rescue excavate archaeological midden deposits, Norse cemeteries, and Colonial era mission settlements while expanding the ongoing Greenland National Museum and Archives site survey and documentation program. The RESPONSE project also will work to extend the paleoecological record through bog and lake coring and extensive geo-archaeological sampling of home fields to reconstruct long term human ecodynamics. It will also work to build Greenlandic capacities for further heritage rescue and conservation work and aid early career Greenlandic and international student engagement. The Swedish Bifrost (<https://hfe-observatories.org/projects/bifrost-online/>) environmental media project will document the work to provide professionally-produced digital resources for public communication and education on climate change.

**O-0149**

## **When you can't save them all: cultural heritage loss on Alaska's North Slope**

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### **Abstract**

Archaeological sites are important sources of data on past human behaviour, as well as valuable resources for paleoenvironmental reconstruction. They can also inform attempts to strengthen resilience and to adapt to environmental change in a sustainable and culturally appropriate way. Just as new methods increase our ability to access information from these sites, accelerating environmental change poses a dire threat.

Equally importantly, they are part of the tangible cultural heritage of descendant communities, and of humanity writ large. For indigenous peoples, many of whom have been subject to extremely rapid cultural change, often imposed from the outside, sites can be an important part of sustaining and even revitalizing cultures under pressure. This too is threatened by site loss.

The scale and urgency of the global threat requires new models for funding, education and recruitment of staff, engagement with the public and long-term curation of rescued samples.

This paper will describe the situation in the area of Utqiagvik (formerly Barrow), Alaska, where multiple important sites are under threat and some have already been lost entirely. Responses (both current and planned) will be highlighted, as will the challenges that are magnified by remote location and extreme climate.

O-0150

## Multiple approaches to investigating climate change impacts on coastal heritage in Ireland and Wales: The CHERISH project.

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### Abstract

The winter of 2014 was exceptionally stormy in the British Isles, with major damage on coasts exposed to the North Atlantic. Combined with the impacts of subsequent individual events, such as Ex-Hurricane Ophelia in October 2017, this recent stormy period has highlighted the vulnerability of coastal communities to current and future climate change. Attention has generally focused on impacts to infrastructure, property and communities, with less emphasis on implications for coastal heritage that are important from both a cultural and economic perspective. CHERISH (Climate, Heritage and Environments of Reefs, Islands and Headlands) is a five year, multi-disciplinary project supported through the Ireland-Wales Territorial Co-operation Programme (2014-2020) which is focusing on past, present and future climate change impacts on coastal heritage in Ireland and Wales.

Aerial survey, including high resolution LiDAR imagery is providing new details of the nature and extent of historic assets in understudied, remote areas such as the Welsh islands. Crop marks produced during drought conditions of summer 2018 have revealed previously unrecorded coastal archaeology within our study areas. The combination of aerial and ground-based survey, which includes high-resolution laser-scanning and geophysical survey enables detailed recording and monitoring of sites at risk from coastal erosion and storm impacts. Palaeoenvironmental records from coastal lakes and bogs are being developed to investigate long term patterns of storminess across the study area. Integration of palaeoenvironmental evidence with archaeological excavations and documentary records at key sites is revealing valuable insights into human-environment interactions in these dynamic coastal environments at a range of timescales. High-resolution mapping of the seabed around islands and headlands and detailed monitoring of selected submerged cultural heritage assets is being undertaken, representing an integrated approach to investigating onshore and offshore heritage and landscape change.

Data gathering on land, at sea and from air to investigate coastal heritage around the Irish Sea provides valuable baseline data for monitoring of risks to historic assets, helps to determine rates of loss at vulnerable sites, and sets contemporary risks within a long term framework of North Atlantic Holocene climate variability. Detailed evidence from selected case study sites offers mitigation towards the likely future loss of heritage assets, archaeological, and palaeoenvironmental archives. These case studies also represent opportunities to raise awareness of the implications of climate change for coastal communities, and provide an evidence base to inform management and policy decisions.

O-0151

## Understanding the Impacts of Climate Change on Cultural Heritage Buildings: A Case of UNESCO World Heritage Site, India

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### Abstract

Cultural heritage is not only an important part of a country's cultural identity but also a key driver of economic activity which can play an important role in a nation's economic and social resilience. Nevertheless heritage buildings are gradually becoming more vulnerable, due to physical decay and deterioration, effects of climate change, and human-induced impacts, such as poor or ineffective maintenance. An increased number of climate events, many of which are associated with the impacts of climate change, are posing considerable problems in managing and preserving cultural heritage around the world. Being exposed to a number of climate hazards and having a great cultural heritage, The Nalanda University ruins in state of Bihar in India presents a case study that provides the basis for the consideration of the strategies required for losing legacy of cultural heritage buildings. Through the commitment with practitioners responsible for the management of a range of cultural heritage sites, this paper identifies the challenges faced when considering climate change adaptation measures. It discusses that enhanced climate change adaptation and improved hazard mitigation strategies, involving a broad range of rightly trained stakeholders, are extremely important considerations when it comes to the assessment, maintenance and conservation of UNESCO World Heritage site.

O-0152

## Sea Level Rise, Predictive Modeling and Heritage Resources in Delaware's Inter-Tidal Zone: Indicators from Shepard's Island

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### Abstract

The Delaware Bay is the second largest estuary along the U.S. Atlantic coast and is experiencing some of the gravest effects from Sea Level Rise. Most of the estuarine shoreline is fringed by salt marshes that have been developing for the past 2,000 years but are now being lost at a rate of up to an acre/day. The trend suggests that much of the Delaware Bay wetlands may convert to open water at a variable rate, and that about 10% of documented archaeological and historic resources will soon be inundated or surrounded by salt marsh. A multi-disciplinary pilot project targeted the Milford Neck portion of the Delaware Estuary. Sediment cores were extracted from the marsh adjacent to Shepard's Island, a dryland hummock surrounded by salt marsh, to document marshland border changes over time and to estimate future changes. An archaeological survey on the hummock itself yielded evidence for human occupation. Using stratigraphic data, ArcGIS modeling, and paleo-environmental and SLR history, we reconstructed the Holocene coastal landscape at Sheppard's Island and developed predictions for future changes. Existing predictive models suggest these hummocks within the intertidal zone are low probability for archaeological recovery. The Shepard's Island survey results contradict this and reveal that sites in these locations are on the front-line for experiencing adverse effects from SLR. These landscapes serve as harbingers for the impacts of environmental changes on cultural resources along the estuary.

O-0153

## Research on plant utilization and adaptation to environment of human of Yahuai cave site during the latest 20 ka BP

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### Abstract

It is an important scientific problem in the study of the relationship between man and land to select the key areas and important periods of human evolution. South China has a unique geographical landscape pattern and unique vegetation and climate background, which is not only an important channel for the diffusion and migration of ancient humans but also an ideal refuge to avoid climate changes. It preserved the rich archaeological remains of the evolution and development of human beings, and provided a rare place for the adaptive strategies of human survival and the early environment. However, few plant utilization research works have so far been done in this area. In this paper, the Yahuai cave from Guangxi Zhuang Autonomous Region, South China is selected for investigation. The Yahuai cave site is a very important site in the prehistoric archaeology in South China and Southeast Asia, where a well-preserved ancient human skull fossil is found. We analyzed the continuous accumulation of ancient cultural and natural remains, and utilized AMS<sup>14</sup>C dating to reconstruct the chronological framework. Flotation and pollen analysis were first conducted to identify these samples. However, few macroremains and pollen were recovered from this site. Therefore, phytolith analysis was employed as an important research method in this project. By phytolith analysis of soil samples, we extracted the plant information and analyzed the human usage of plant resources. It is the first time that wild rice was found at 16000BP based on the phytolith record. The presence of wild rice is one of the essential elements for identifying the origins of rice cultivation and domestication. This finding provides a prerequisite for the origin of rice. Besides, Bambusoideae, and palm were also identified at different periods. A wide collection and utilization of plant resources from Yahuai cave site revealed the ways and strategies of human being's adaptation to the environment during the latest 20000 years.

O-0155

## Quaternary stratigraphy solves engineering geology problems; two case histories from Utah, USA

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### Abstract

Two geologic hazard case histories from Utah, USA show the importance of understanding Quaternary stratigraphy in engineering geology investigations. The Eaglepointe landslide occurred on 05-AUGUST-2014 in a developed area of North Salt Lake City, Utah, USA and measured 150 m wide and 175 m long. The failed slope is underlain by ~ 20 m of lakeshore sands and gravels from pluvial Lake Bonneville (15.5 to 18 ka), which overlie altered Tertiary volcanic rocks. The style and orientation of the landslide are not compatible with the strike-and-dip of bedding in volcanic rocks (i.e., a translational slide or wedge failure). Four geotechnical boreholes had been drilled on the slope prior to 2014, and another 16 after failure. Boreholes revealed that a 2 m-thick weathering zone (paleosol) had developed on the volcanic rocks prior to their burial by the Bonneville shoreline sediments. The paleosol has lower shear strengths than the in-situ bedrock, and also forms a perched water table beneath the permeable Quaternary sandy gravels. At the landslide site the paleosol slopes north, in the direction of today's surface slope (not in the direction of bedrock dip), and forms the 2014 failure plane. The failure plane is thus controlled by a thin Quaternary paleosol (not bedrock), developed on a complex paleotopography of the Wasatch Range front (basal faceted spurs eroded by gullies), all buried by 20 m of Quaternary gravels. This subsurface complexity was not detected in pre-development geotechnical studies.

In the same year but 350 km farther south, the Chief Toquer [earthfill] Dam was being constructed on the footwall of the active Hurricane Fault. The cut-off trench exposed numerous normal faults in bedrock, but site engineers could not determine if the faults were active by regulatory definition (movement younger than 35 ka), which if true would have posed a major constraint. The dam footprint overlaps the active channel of a fault-parallel stream and three higher Quaternary terraces. Our soil chronosequence suggests Terrace 1 (oldest) is >125 ka, Terrace 2 >35 ka, and Terrace 3 Holocene, whereas OSL ages indicate T1 is ca. 50 ka, T2 35 ka, and T3 19 ka. None of the hundreds of bedrock faults visibly displace alluvium >35 ka, which covers 85% of dam length (therefore, faults there are not active). In the remaining 15% of the dam alluvium over the faults is <19 ka, so even though alluvium is not displaced, fault movement younger than 35 ka (but older than 19 ka) cannot be precluded. This example shows a weakness of using age-based definitions of hazard "activity", because the critical Quaternary isochron may not exist at your project site.

O-0156

## Study on spatial-temporal distribution characteristics and forming mechanism of landslides in the Meigu River basin of China

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### Abstract

The Meigu River basin, which is located in the uplift area of the Qinghai-Tibet Plateau, is characterized by the development of fault and folds. Due to special landform patterns, a large number of large scale landslides with complex genesis mechanisms that caused heavy damage. In order to reveal the temporal and spatial patterns and formation mechanisms of landslides controlled by this special landform with oblique valleys and anticline mountains, on the basis of investigation and comprehensive analysis in the Meigu River basin and using the interdisciplinary ways of Quaternary geology, engineering geology and tectonic geology, the temporal and spatial distribution characteristics of landslides in the basin, the relationships between the development position of landslides and active faults, folds, joints *etc.*, the main controlling factors of the engineering geological rock groups are susceptibility to landslide were all systematically studied, then have achieved the following conclusions: 1) The Meigu River Basin belongs to the coincident tectonic landform under the control of tectonic uplift, with typical features of oblique valleys and anticline mountains. There were 18 faults and 27 folds with a certain scale in the basin by field investigations, and there is a good correlation between the occurrence time of landslide and the active period of fault. 2) There are 161 landslides in the basin which is the most important types of geohazards in the basin, and the development and distribution characteristics of landslides are significantly different due to the differences in topography and geomorphology of the upper, middle and lower reaches of basin. These landslides are spatially distributed "along the river", "along the fault zone", and "oblique core". And there are mainly five development stages: middle and late Pleistocene, late Pleistocene, 200 a B.P., 1980s and 1990s and modern times. 3) Fracture activities, folds, joints, and soft interlayer in rock mass have unique control patterns over the landslides development process since the mid-late Pleistocene. Fault fractures and folds are the main controlling factors over landslides in the region. 4)  $T_{3xj}$ 、 $J_{2S}$ 、 $T_{1-2d}$  of soft interlayer in sand-mudstone are the most prone sites for landslides (easy-slide rock mass groups), therefore, they are also the key areas for preventing landslide hazards in the future. All these results provide new technical theoretical support for landslide research and disaster prevention and mitigation in the similar regions of the plateau and surrounding areas.

O-0157

## Unprecedented riverbank collapse during Australia's 'Big Dry': a spin-off consequence of the River Murray's late Quaternary depositional history

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### Abstract

Much of Quaternary science is about the genesis of sedimentary deposits and interpreting the depositional histories of environments to the present-day form. These are the deposits and legacy environments that civil engineers then work and build in (e.g. floodplains, coastal deposits, slope-deposits). In the northern hemisphere, there is a long relationship between engineers and Quaternary scientists around glacial and peri-glacial deposits, where Quaternary science helps to explain the spatial distribution, properties and mechanical behaviour of engineering materials (Groot & Griffiths, 2001). In Australia, this intersection is less common and obscured by nomenclature, with much of the overlap found in the 'regolith' literature (e.g. Taylor & McNally, 2001). Here we provide an example of an intersection between engineering and Quaternary science where a thorough understanding of geomorphology and depositional histories helped to solve a modern-day riverbank collapse problem.

During very low river levels in the Millennium Drought (1997-2011), known colloquially as Australia's 'Big Dry', long sections of river bank along the lower River Murray in South Australia collapsed, threatening many social and economic assets. Not only did these failures represent rapid geomorphic change in a reach that is normally considered very stable, but they also occurred during long periods of extremely low flows. This phenomenon is unusual and unprecedented as bank failures are typically associated with the recession of high-energy floods rather than with prolonged drought.

Geotechnical investigation found a soft clay deposit in the riverbank stratigraphy at four sites along the River Murray, concluding that "during periods of low river level it should be assumed that riverbank collapse could occur where the riverbanks are underlain by the soft clay" (SKM, 2010; Coffey, 2012). The origin of this geotechnically problematic unit and its regional extent was unknown. Subsequent drilling by our team revealed a fine-grained soft clay deposit dominated the Holocene upper valley-fill as a single stratigraphic unit over an 80km reach of river, between 10 to >50m thick in its down-valley extent. When placed within the context of the late Quaternary environment and the depositional history on an incised valley system, interpretation of physical and mechanical properties of the deposit identified a central basin environment evolving under highstand conditions. Mapping the extent of the stratigraphic unit/central basin within this geomorphic framework allowed us to determine and constrain the extent of the riverbank collapse hazard and predict where future bank-failures will take place along the lower River Murray, focussing management strategies during future low flows. A thorough understanding of Quaternary environments and their depositional histories is particularly useful to engineers at the interface of coastal and fluvial environments, considering that these environments and often complex stratigraphic units form the building foundations for most of the world's cities.

O-0158

## **Geological anomalies within the London Basin, United Kingdom; their engineering impact, morphology and possible formation theories.**

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### **Abstract**

Engineering projects in London are increasingly using the subsurface, making it essential to understand the geological context. A number of geological anomalies within the London Basin have commonly been grouped together and named “drift-filled hollows” (DFHs). These are typically interpreted as closed depressions, developed into the local rockhead (mainly the London Clay Formation) and infilled with a melange of unconsolidated, superficial deposits, including Quaternary fluvial sand and gravel. DFHs are challenging to engineers due to the difficulty in identifying the features from the surface, the risk of missing the features during site investigations due to the limitations of boreholes, and their differing geotechnical properties compared with the predicted and surrounding clay strata. Potential risks include: differential settlement, possibly to nationally significant infrastructure and during sub-surface construction; tunnel face collapse; water ingress; and delayed timelines due to machine breakages. This can lead to increased costs and potential loss of life.

Information on over 80 DFHs within Central London has now been collated and assessed - the largest dataset compiled to date. The features range in size from 5-500m in width and up to 75m deep. Many of the deeper features breach to the local bedrock and have evidence of faulting associated within or surrounding the feature. Some also have a diapir of lower strata upwelling within the depression. A major outcome has been identifying the spatial and vertical variability between and within features using both CPTu and borehole samples, suggesting they reflect a range of processes.

The features are not just of significance to Civil Engineers, but to the earth surface processes community due to both uncertainty about the processes which led to their formation and their potential for palaeo-environmental reconstructions (Collins et al., 1996). Three main hypotheses have been proposed: fluvial scour at river confluences (Berry, 1979), periglacial activity through the formation of pingos (Hutchinson, 1980) and dissolution-related subsidence (Collins et al. 1996). These explanations remain problematic due to a lack of diagnostic physical evidence identified within borehole samples. This talk will focus upon the limitations of existing hypotheses, further possible formation hypotheses and the difficulties in studying these features due to both their variability and samples only being available through boreholes.

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O-0159

## The Anthropocene and environmental sustainability: An investigation of rural to urban watersheds Black Hawk County (Iowa, U.S.A.)

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### Abstract

Two rural to urban tributaries, Dry Run Creek (DRC, HUC12) and Black Hawk Creek (BHC, HUC10) Watershed, to the Cedar River are located Northeastern Iowa. These streams are heavily influenced by agricultural runoff in its upper reaches then become heavily urbanized as they travel through the cities of Cedar Falls and Waterloo (pop. 109,157) before draining into the Cedar River. The streams are perennial, however most first-ordered segments have been agriculturally tiled increasing base-flow in second and third-ordered stream segments. A previous, 2005, DRC study identified factors that led to DRC being placed on Iowa's 303(d) impaired streams list, lack of aquatic diversity (2002) and high bacteria levels (2008). Recent, DRC and BHC watershed evaluations identified changes to their urban and rural reaches. As the watersheds' urbanization (population and/or agricultural) continues land use and bank stability are becoming significantly impacted/compromised. Comparative findings over the past twelve years indicate: Bank stability improved slightly, canopy cover decreased by 10%, point source drainage increased by 7%, urbanization increased by 22%, and stream variability decreased by 8%. Further laboratory investigations seek to characterize DRC's, physical (particle-size analyses) and chemical properties (aqueous - ICP-MS). Black Hawk Creek baseline stream data were also recorded for comparative analyses every two years.

Work by the Black Hawk County Soil and Water Conservation District, the Dry Run Creek Advisory Board, Iowa Department of Natural Resources, University of Northern Iowa and others have made positive impacts on local watersheds. Native vegetation (shade tolerant – prairie grass plugs), May 2018, were planted near the UNI Water Monitoring Well site, creating a natural buffer that seeks to decrease runoff and reduce bank erosion, increasing bank stability. The UNI bank stability site provides local communities an opportunity to view 'best practices'. Watershed (DRC and BHC) citizens are encouraged to participate in geologic and water monitoring or other conservation efforts: rain barrels, permeable pavers, rain gardens and prairie strip. One climate change outcome appears to be the intensification of precipitation events; three of the highest/intensity rainfall events in the past forty years were recorded in 2018. As urbanization and agricultural practices continue to reshape our watershed, understanding how these activities accentuated by a changing climate will alter DRC and BHC processes and habitats. Our primary goal is to build meaningful relationships between the Dry Run Creek Watershed Advisory Board, University of Northern Iowa, local preK-12 schools, local Water Management Authorities (WMA) and communities/citizens within the Middle Cedar Watershed. These efforts seek to improve our watershed's geo-ecological health through applied geoscience, education outreach, and political engagement; ideally leading to an environmentally sustainable present and future.

O-0160

## Assessment of flood vulnerability using GIS tools: A case study of the central High Atlas of Azilal (Morocco)

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### Abstract

Climate change has increased the severity of weather-related natural disasters such as flash flooding, riverine flooding, coastal erosion, lightning and fires (IPCC,2012). The occurrence of extreme meteorological events is increasing as well in the area of the mountains of Morocco. Thus, this research considers the support provided by remote sensing and GIS data for the delineation of potential sites susceptible to natural hazards such as flash floods, storms, droughts, and landslides.

The present study focuses on an assessment of flood hazard areas in the High Atlas of Azilal (Morocco) where it has suffered from flood in every year with different extents.

Spatial analysis in GIS environment has been applied for the estimation of flood risk zones in which seven relevant physical factors have been selected namely, rainfall, slope, aspect, elevation, distance from stream, land use and lithology. The relative importance of physical factors has been compared in pairwise matrix to gain the weight values during the process of Analytical Hierarchy Process (AHP). The flood hazard zones have been mapped according to their weights. It has been Tillouguit, Tabant and Rbat region are identified as the high risk zones of flood.

Proposed methodology for the assessment of flood hazard and elaboration of maps of flood vulnerability by Analytical Hierarchy Process in GIS environment is a first step in development of the information system for integrated risk assessment from natural disasters.

O-0161

## Remote sensing application to the mapping of built-up areas exposed to flood and runoff hazards in sedimentary basin in Benin

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### Abstract

The sedimentary basin made up of bar earth with a high clay content is subject to flooding and runoff phenomena despite significant investments made by donors, the Beninese government and local authorities to set up several stormwater treatment facilities. This research aims to determine the cause of the persistence of flooding and runoff in the sedimentary basin despite the existence of large stormwater treatment facilities. The methodological approach is based on remote sensing and the Geographic Information System (GIS). To this end, Quickbird images with a resolution of 0.6 m in panchromatic and 2.4 m in multispectral were used to extract the "built-up area" class using Ecognition software. The mapping of the areas exposed to flood and runoff hazards was carried out by simulating a ten-year return period rainfall (2-hour rainfall with an intensity of 50 mm/h) with the HEC RAS 2D modelling software on the basis of a Digital Elevation Model (DEM) developed from Shuttle Radar Topography Mission (SRTM) data at 1 arc/s. The intersection of the "flood and runoff hazard zone" layer with the "built-up zone" layer using QGIS software identified the built-up areas established in flood and runoff hazard areas. In total, 62% of built-up areas are built in natural stormwater flow paths and areas exposed to runoff. Flooding and runoff problems are then more related to the uncontrolled occupation of urban space than to the inadequacy of stormwater treatment facilities and the geological characteristics of the sedimentary basin.

Keywords: sedimentary basin, remote sensing/GIS, floods, runoff, Benin.

**O-1000**

## **Dynamic of glacial to interglacial transitions inferred from multi-proxy analysis in ice cores**

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### **Abstract**

Polar ice cores are unique climate archives providing continuous stratigraphy for the last 800 000 years with a relatively high temporal resolution (annual for the last 60 000 years). They are particularly well adapted to study the dynamic of the glacial to interglacial transitions and link with external and internal forcings (orbital configuration, greenhouse gases concentration). Indeed, they provide direct access to the past atmospheric concentration through air trapped in ice cores and a wealth of dating tools are available. Finally, the recent developments of ice core proxies now permit to have access to low latitude proxies in polar ice cores hence providing sequence of high vs low latitude events without chronological uncertainty on the same archive.

I will present recent developments for ice core dating and combination of low and high latitude proxies in ice cores. The sequence of events over several key transitions between glacial and interglacial periods (Termination I, Termination II, Termination III and Termination V) will be discussed based on recent and new ice core records showing the interplay between orbital forcing, greenhouse gases concentration and millennial scale variability at low and high latitude.

O-1001

## Human-induced marine ecological degradation: historical ecology and the Anthropocene

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### Abstract

We analyzed published downcore microfossil records from 150 studies and reinterpreted them from an ecological degradation perspective to address the following critical but still imperfectly answered questions related to the Anthropocene: (1) How is the timing of human-induced degradation of marine ecosystems different among regions? (2) What are the dominant causes of human-induced marine ecological degradation? (3) How can we better document natural variability and thereby avoid the problem of shifting baselines of comparison as degradation progresses over time? The results indicated that: (1) ecological degradation in marine systems began significantly earlier in Europe and North America (~1800s) compared with Asia (post-1900) due to earlier industrialization in European and North American countries, (2) ecological degradation accelerated globally in the late 20th century due to post-World War II economic growth, (3) recovery from the degraded state in late 20th century following various restoration efforts and environmental regulations occurred only in limited localities. Although complex in detail, typical signs of ecological degradation were diversity decline, dramatic changes in total abundance, decrease in benthic and/or sensitive species, and increase in planktic, resistant, toxic, and/or introduced species. The predominant cause of degradation detected in these microfossil records was nutrient enrichment and the resulting symptoms of eutrophication, including hypoxia. Other causes also played considerable roles in some areas, including severe metal pollution around mining sites, water acidification by acidic wastewater, and salinity changes from construction of causeways, dikes, and channels, deforestation, and land clearance. Microfossils enable reconstruction of the ecological history of the past  $10^2$ – $10^3$  years or even more, and, in conjunction with statistical modeling approaches using independent proxy records of climate and human-induced environmental changes, future research will enable workers to better address Shifting Baseline Syndrome and separate anthropogenic impacts from background natural variability.

O-1002

## The impact of watershed restoration on marine sediment dynamics in coastal and coral reefs environments, US Virgin Islands

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### Abstract

Terrigenous sediment derived from unpaved roads is a significant stressor to coral reefs in the high-relief island of St. John, US Virgin Islands. The 10.7 km<sup>2</sup> Coral Bay watershed was the focus of a NOAA-ARRA watershed restoration program completed in 2011, which included: sediment retention structures, road drainage improvements, and limited road paving. A seven-year terrestrial-marine monitoring program to assess the effectiveness of this restoration at multiple spatiotemporal scales measured: (a) terrestrial erosion and runoff-sediment yields; (b) time integrated (sediment traps) and high resolution (nephelometers) marine terrigenous sedimentation and turbidity at shoreline and coral reef sites; and (c) sediment “residence time” using short-lived radioisotopes (SLR) in developed/restored and minimally developed sites.

Watershed erosion, sediment yields, terrigenous sedimentation, and coral exposure to sedimentation stress were significantly greater below developed compared to minimally developed watersheds. Restoration program paving reduced road-segment-scale erosion rates to 4-29% of pre-paving rates, but watershed modeling showed that ~90% of the ~110 Mg yr<sup>-1</sup> reductions were due to sediment retention ponds. In the marine environment, resuspension contributed more to turbidity and deposition than shorter lived (hours) runoff plumes, and limited the ability to resolve changes post-restoration in the potential exposure of corals to sedimentation stress. However, <sup>7</sup>Be activity measured in offshore reef sediment traps suggests that a relatively short (months) time scale of connectivity between watershed and reef sedimentation.

Due to resuspension, statistically significant pre- vs. post- restoration reductions in marine sedimentation were not measured. However, significant decreases in % clay and terrigenous sediment were found below the restored watersheds post restoration. These data suggest that % clay (rather than reduced total sedimentation) may be a more sensitive tracer of effective restoration, which targets sediment input from unpaved roads.

Lessons learned from the Coral Bay watershed restoration and monitoring program may serve to inform the development of effective management and monitoring strategies that may be applied to other areas with similar ephemeral hydrologic behavior. Long term (several seasons) integrated terrestrial- marine monitoring is essential to quantify the habitat impact of watershed restoration and must include regular coordination and data sharing between a multidisciplinary team of scientists, community members, and the sponsors.

O-1003

## Climatic and human impacts on Si cycling in the Chesapeake Bay

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### Abstract

Coastal marine ecosystems form the transition zone between the terrestrial and marine Si cycles. Short residence times make the nutrient cycles in coastal zones sensitive to local to global changes in environmental conditions and human disturbances. Si isotopes help us to link variations in the terrestrial Si cycle triggered by climate change and/or human activity.

The Chesapeake Bay, an estuary on the North American East Coast, is a well-suited study site with a constrained settlement history (European settlement around 250 a BP). Different sedimentary proxies record the influence of climate variations, land-use changes and altered nutrient fluxes since ~12,000 a BP. To investigate variations in Si fluxes during the Holocene we measured biogenic silica (BSi) concentrations and  $\delta^{30}\text{Si}$  in hand-picked centric diatoms from two sediment cores: one located proximal to the main inflow Susquehanna river, the other closer to the Atlantic.  $\delta^{30}\text{Si}_{\text{diatom}}$  varies between 0.8 and 1.7 ‰ in both sediment cores.

Calculated Si budgets for the modern Chesapeake Bay suggest 90% of Si consumption by diatoms, a much higher rate than previously assumed for estuarine systems. However, different trends at both core sites indicate the importance of regional influences like water-mixing conditions and Si inputs from the watershed. BSi fluxes for both sediment cores are mainly coupled with erosion events caused by sea-level rise and deforestation. Human activity modified Si cycling in the Chesapeake Bay: Variations in  $\delta^{30}\text{Si}_{\text{diatom}}$  together with an increase in BSi fluxes since European settlement ~250 a BP indicate a distinct influence on the coastal Si cycle. Land-use changes in the watershed are likely to be the major cause altering Si budgets in the Chesapeake Bay.

Superimposing processes linked to climate change (precipitation, vegetation, sea-level) or human activity (agriculture, damming and nutrient supply), are difficult to disentangle in the complex Chesapeake Bay system. Lake sediments hold a great potential to provide high resolution-records of terrestrial Si fluxes to better distinguish individual processes influencing terrestrial Si fluxes.

O-1004

## Benthic foraminifera as potential proxies for environmental monitoring: A study from parts of south east coast of India

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### Abstract

India has 7,516 km of coastline, of which the mainland accounts for 5,422 km. As the coastal environments across the World have become very friendly for human development and diversity hence the high degree of pollution is expected in these places. Rivers which debouch into the Bay of Bengal after flowing long distance along the course collecting huge outlets of various domestic, industrial, agricultural and aquaculture contaminants from the estuaries at the Bay. Contaminants derived from river runoff have been shown to accumulate in estuarine sediments, reaching concentrations potentially capable of causing biological. Demonstration of effects, however, is difficult due to strong natural environmental gradients and the effects of past and present point source of contamination. The increased usage of pesticides and fertilizers in both agriculture and aquaculture sectors along the coastal tract of Andhra Pradesh has been one of the reasons for this environmental stress. The abundance, diversity, temporal and spatial distribution and test morphology of foraminifera in this environment can provide a proxy to reveal the present degree of pollution in the coastal environments of the study area, when related to the concentrations of heavy metals (Fe, Mn, Pb, Ni, Co, Cu). Recent benthic foraminiferal assemblages have been used as proxies to monitor the effects of pollution on the marine marginal waters. Benthic foraminifers are increasingly used as bio-indicators of environments at different levels of investigation. Community structures provide information on ecological conditions, especially in the highly changing parallel environments while some species are sensitive to species environmental parameters. Distributions of benthic foraminifers were significantly related to those of environmental variables and were ordinated along the axes that correlated both natural environmental variables and pollutants. Test morphology may also be related to environmental characteristics and is sometimes used as bio-indicator. For example, the size and density of the pores are considered as an indicator of the dissolved oxygen concentration. Recently, morphological abnormalities are increasingly taken as proxies. Morphological abnormalities of fossil and recent foraminiferal tests have long been reported. This paper is to monitor the pollution effects on biota of the parts of south east coast of India. In order to avoid further damage to this coastal fragile ecosystem immediate safety measures have been suggested to the policy makers, public etc.,. This paper attempts to provide action plans for the policy makers to frame ideologies for the protection of the coastal environment.

O-1005

## Stable strontium isotopes ( $\delta^{88/86}\text{Sr}$ ) as a salinity proxy in the lagoon-estuarine environments

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### Abstract

Strontium (Sr) isotopes have been widely used in large-scale ecosystem and hydrological studies. Specifically, the  $^{87}\text{Sr}/^{86}\text{Sr}$  is commonly used for tracing radiogenic processes such as water source mixing, while the newly employed stable  $^{88}\text{Sr}/^{86}\text{Sr}$  (noted as  $\delta^{88/86}\text{Sr}$ ) is sensitive to isotope fractionation processes such as carbonate formation. Combining the two isotope signatures in carbonate sediment archives and ambient water adds potential to reconstruct paleo-hydrology in carbonate-producing coastal environments. Importantly, the stable  $^{88}\text{Sr}/^{86}\text{Sr}$  has been applied in recent years in coastal environments with fresh to marine salinity conditions, very few studies were conducted in hypersaline environments.

The Coorong hydrological system (Fig. 1), located ~100 km southeast to Adelaide, represents a unique 'natural laboratory' to calibrate novel and traditional isotope tracers in due to its unique geomorphology and large salinity gradient in water bodies ranging from fresh to hypersaline (from ~0 PSU to ~120 PSU, Fig. 2). This study aims to assess the radiogenic and stable Sr isotope ratios (i.e.,  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{88/86}\text{Sr}$ ) in the Coorong lagoon waters, inorganic carbonates and bivalve shells *Arthritica helmsi* from sediment cores, and hence explore the potential of these isotope tracers to be used to reconstruct the paleo-hydrology in the Coorong throughout the recent thousands of years.

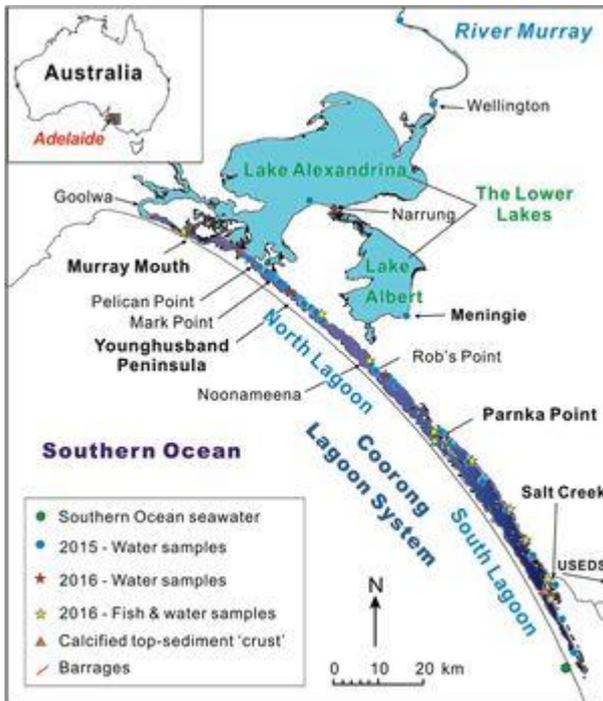


Figure 1: A map showing the Coorong Lagoon and Lower Lakes at the terminal end of the Murray River (i.e. Murray Mouth estuary) in South Australia (modified from Shao et al., 2018).

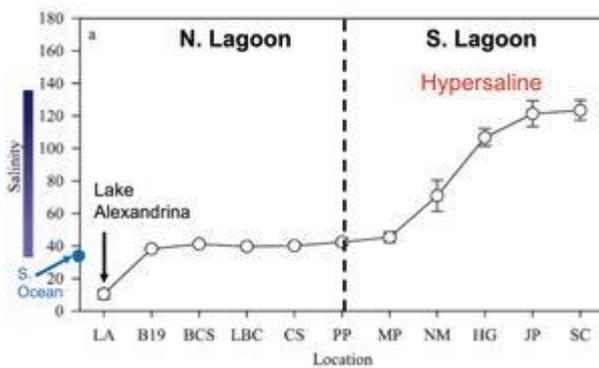


Figure 2: Salinity gradient along the Coorong (Gillanders and Munro, 2012).

O-1006

## Hydro-geochemical signatures for the identification of seawater intrusion in paleobeach aquifer of Cox's Bazar city and its vicinity, Bangladesh

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### Abstract

In order to better understand the encroachment of seawater into the groundwater system a total 115 groundwater samples were collected in an area of  $\sim 7\text{km}^2$  in Cox's Bazar paleobeach and its vicinity, from different *types of tubewells, which included hand pump fitted bore wells (<50m depth), moderately deep energized bore wells (50-100m depth) and deep bore wells (>100m depth)* during June 2013. A combined hydro-geochemical indicators, selected trace elements (Sr and B) and in addition to  $\text{d}^{18}\text{O}$  and  $\text{d}^2\text{H}$  were used in this study. Results show that the high values of EC (202 to  $6730\mu\text{S}/\text{cm}$ ) and TDS (135 to  $4509\text{mg}/\text{l}$ ) are found in groundwater of wells closer to the coast and few wells from the northern and central part of the study area. The cross plot of  $\text{HCO}_3/\text{Cl}$  and TDS shows that groundwater along the paleobeach and some isolated areas are saline with  $\text{TDS} > 1000\text{mg}/\text{l}$ , associated with high ratios of  $\text{Cl}/\text{TDS}$  (0.065). The groundwater facies generally evolves from freshwater ( $\text{Ca-Mg-HCO}_3$ ) to saline water ( $\text{Na-Cl}$ ) type with an intermediate  $\text{Ca-Mg-Cl}$  type indicating that the aquifer system interacts with seawater and undergoes cation exchange. Results also reveal that the area affected by marine water intrusion has ionic ratios of  $\text{Br}/\text{Cl}$  (0.0006 to 0.0021) similar to seawater (0.0015) with some higher values. Groundwaters along the paleobeach and some isolated areas, low ionic ratios of  $\text{SO}_4/\text{Cl}$  (0.01 to 6.53) and  $\text{Na}/\text{Cl}$  (0.20 to 152.09), relative to marine ratios (0.05 and 0.86 respectively), are also observed. Groundwaters with Seawater Mixing Index  $> 1.0$  and  $\text{TDS} > 1000\text{mg}/\text{l}$  constitute about 20% of the studied groundwaters and have relatively high  $\delta^{18}\text{O}$  ( $> -4.0\text{‰}$ ) values and the linear relationships between TDS and most of the ions, including B and Sr, and the chemical signature of the saline plumes (e.g., marine  $\text{SO}_4/\text{Cl}$ ,  $\text{Na}/\text{Cl}$  and  $\text{Br}/\text{Cl}$  ratios) suggest that mixing processes control the chemical composition of the seawater within the aquifers. However, these geochemical variations also reveal that the quality of potable water has deteriorated to a large extent due to seawater intrusion along the paleobeach, migrating inland toward the heavily groundwater exploited areas from the coast line and may entail various future health hazards.

**Key Words:** Cox's Bazar, Paleobeach, Coastal groundwater, Seawater intrusion

O-1007

## Climatic and anthropogenic controls on sediment sources, fluxes, and transport pathways to and across a formerly glaciated coastal zone

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### Abstract

Climate change and human modifications of linked riparian and coastal landscapes have altered the provenance, temporary storage reservoirs, and transport rates of sediments delivered to the coast, causing time-varying sediment fluxes to estuaries, wetlands, and beaches. This study explores the role of changing climate, sea level, and anthropogenic land use on sediment delivery to, and across, the formerly glaciated Merrimack River drainage basin and Plum Island barrier-backbarrier system (northern Massachusetts, USA) across multi-decadal to multi-millennial timescales. Using a suite of sediment cores collected across this barrier island and associated estuary, sedimentologic, bulk organic, biomarker, and organic and inorganic stable- and radio- isotopic proxies were used to reconstruct paleo-environmental changes and quantify time-varying sediment fluxes to the coastal zone following de-glaciation. Our results document that the source of sediment ( $\sim 850 \times 10^6 \text{ m}^3$  total) delivered to the backbarrier bays, tidal flats, and marshes of Plum Island shifted from direct fluvial, to mixed estuarine and marine during a period of gradual deceleration of sea-level rise throughout the Holocene. This barrier-island system has remained relatively stable (progradational, aggradational) throughout the last 3500 years in response to continued sand inputs from the Merrimack River. However, low sediment accumulation rates (0.2 – 2.8 mm/yr) throughout the mid-to-late Holocene in the Merrimack River estuary and low modern total suspended sediment (9.0 – 15.0 mg/l) in the modern Merrimack River reflect an upstream landscape stripped of fine sediment by repeated Pleistocene glaciations; this presents a threat to continued health of backbarrier marshes as sea-level rise accelerates. In recent centuries, it is the human impact that has controlled coastal sediment delivery: for example, land clearing and river/coastal engineering increased estuarine sediment accumulation rates by an order-of-magnitude during the 17<sup>th</sup> to 19<sup>th</sup> centuries in response to enhanced terrestrial sediment inputs. However, this effect was muted by sediment trapping behind artificial rock walls and dams. Most recently, urbanization and suburbanization of the watershed led to the accumulation of mixed-grain sediment with different terrestrial and marine influence across the estuary. Simultaneously, continued delivery of sand to the ocean-side beach, allowed the island to remain in equilibrium with rising sea level. Together, these data demonstrate the complex and time-varying patterns of sediment delivery to, and across, the paraglacial, river-influenced coastal zone in response to natural and anthropogenic changes in drainage basin sediment production and transport, and downstream changes in sea level, coastal morphology, and land use. Further, they highlight the need to develop feasible sustainable paths for management that balance natural processes and societal needs and constraints.

**O-1008**

## **North Atlantic radiocarbon constraints on ocean circulation and air-sea gas exchange over the last deglaciation**

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### **Abstract**

Paleoclimate records from the North Atlantic show some of the most iconic records of abrupt climate change during the ice ages. Here we use radiocarbon as a tracer of ocean circulation and air-sea gas exchange to investigate potential mechanisms for the abrupt climate changes seen in the North Atlantic over the last deglaciation. We have created a stack of surface radiocarbon reservoir ages over the past 20,000 years from the North Atlantic, using new synchronized age models from five sediment cores refined with thorium normalization between tie-points. This stack shows consistent and large reservoir age increases of more than 1000 years from the Last Glacial Maximum into Heinrich Stadial 1, dropping abruptly back to approximately modern reservoir ages at the onset of the Bolling-Allerod. We use the intermediate complexity earth system model cGENIE to investigate the potential drivers of these reservoir age changes in order to further our understanding of the climatic changes occurring at these times and improve regional radiocarbon calibration.

O-1009

## Exploring the phase relationship and mechanics of Dansgaard-Oeschger signals between the Northern and Southern hemispheres

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### Abstract

At present, the matter of the connection between the Northern and Southern hemisphere in regards to Dansgaard-Oeschger (D-O) events during the MIS3 period and the deglacial interval itself are still far from clear. Our interest is in the mechanism whereby these intensely fluctuating temperature signals, evident in Greenland ice cores, are transmitted southwards to their Antarctic counterparts.

Recently Peltier and Vettoretti succeeded in producing a comprehensive model of glacial climate variability [1] which correctly captured the Dansgaard-Oeschger mode of millennial timescale climate change. This employed the CCSM4 global climate model with unique modifications, allowing for further understanding of this mechanism involved. A major result of this paper is the identification of what is apparently the correct bipolar seesaw behavior. In particular it is noted that there is an essentially perfect correlation between the sea surface temperature variability in the Southern Ocean encircling Antarctica and that of the air temperature above Antarctica (Figure 3e of [2]) as it shows that the signals are propagating from the Northern hemisphere to the Southern hemisphere via an oceanographic pathway as one would expect. In this paper we compare the air temperature signals over a series of D-O cycles predicted for both the Northern and Southern hemispheres by the comprehensive model at the locations of ice core extraction: NGRIP site on Greenland and the Epica Dronning Maudland (EDML) and WAIS divide (WDC) sites on Antarctica. The phase lag of the signal between the hemispheres is noted and we comment on the differences, if any, between our model results and those obtained by other groups based upon the data. [3]

Using this successful model, we are in the process of tracking these predicted D-O signals from the Northern to Southern hemisphere in order to illustrate the mechanism involved in the transmission of the signal. The mechanism potentially involves the Deep Western Boundary Undercurrent: an extensive southward flowing channel hugging the Eastern coast of the Americas. Whereby the signal is thought to travel from the tip of Greenland into the Southern Ocean. At which point it would be captured by the strong Antarctic Circumpolar Current (ACC), transporting the signal around Antarctica and thereby extending the time before the signal emerges at the surface of the southern ocean and thence via an atmospheric pathway into the Antarctic ice cores. This paper will report upon our progress in understanding this oceanic transportation mechanism.

References in supporting material.

O-1010

## Data and Modeling Evidence for multiple Episodes of abrupt Mass Loss from the Antarctic Ice Sheet during the last Deglaciation

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### Abstract

Global mean sea level rose ~134 m (Lambeck et al., 2014) during the last deglaciation (~19,000 and ~8,000 years ago). A better understanding of the contribution of the Antarctic Ice Sheet (AIS) to this sea-level rise may inform projections of global mean sea-level rise in a future, warming world. Earlier sea-level projections for the 21<sup>st</sup> century (IPCC, 2013) did not include potentially large contributions from the AIS, however, recent ice-sheet models (DeConto and Pollard, 2016) indicate that future AIS collapse could be substantial, approaching deglacial dynamics. Although modeling evidence suggests that once initiated, ice retreat may continue for centuries (Feldmann and Levermann, 2015; Golledge et al., 2015), there has been no direct evidence; neither is it clear how fast those dynamics would unfold.

Here we summarize data from Iceberg Alley that indicates repeated and rapid AIS mass loss during deglaciation, dubbed Antarctic Ice Sheet Discharge (AID) events (Weber et al., 2014). Similar behavior was simulated independently by ice-sheet modeling (Golledge et al., 2014), and geologic and glaciological records suggest step-wise retreat of 400 km in the Ross Sea sector of the West AIS (Bart et al., 2018), and ice-elevation drawdown in the Weddell Sea sector of the East AIS in excess of 600 m (Fogwill et al., 2017). Major retreat events occurred during times of global meltwater pulses, indicative for a possible AIS contribution of Meltwater Pulse 1A of several m. Flux rates of iceberg-rafted debris indicate that onset of each AID happened very fast, usually within one or two decades, and continued for centuries. Accompanying ice-sheet modeling indicates a close relationship of iceberg calving and grounded ice-mass loss on decadal to multi-decadal time scales.

This newly detected, substantial deglacial dynamics of the AIS contradicts earlier assessments (Bentley et al., 2010; Mackintosh et al., 2014) and the postulated rapid pace challenges current ice-sheet and climate models (Feldmann and Levermann, 2015; Golledge et al., 2015) and needs to be tested against them. Our findings for the changing past raise concerns that current instabilities observed for large parts of the West AIS (Rignot et al., 2014) may indeed indicate irreversible retreat that is already on the way.

Also, we will show first results from upcoming IODP-Expedition 382 (Iceberg Alley; March 20 to May 20, 2019); during with a number of new, high-resolution sediment sequences will be recovered to provide novel insight into ice-sheet ocean interactions and to constrain the findings obtained so far.

O-1011

## **Collapse of Eurasian ice sheets 14,600 years ago was a major source of global Meltwater Pulse 1a**

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### **Abstract**

Rapid sea-level rise caused by the collapse of large ice sheets is a global threat to human societies. In the last deglacial period, the rate of global sea-level rise peaked at more than 4 cm/yr during Meltwater Pulse 1a, which coincided with the abrupt Bølling warming event ca. 14,650 yr ago. However, the sources of the meltwater have proven elusive, and the contribution from Eurasian ice sheets (EIS) has until now been considered negligible. Here we revisit the deglacial chronology of the marine-based sectors of the EIS using a new reconstruction of the radiocarbon content of Norwegian Sea surface water. We utilize the <sup>14</sup>C reconstruction as a regional calibration curve to recalibrate marine <sup>14</sup>C dates from the EIS deglaciation. We show that marine-based sectors of the EIS abruptly collapsed at the Bølling transition and lost an ice volume of between 4.5 and 7.9 m sea level equivalents (95% quantiles) over 500 yr. During peak melting 14,650 - 14,310 yr ago, Eurasian ice sheets lost between 3.3 and 6.7 m sea level equivalents (95% quantiles), thus contributing significantly to Meltwater Pulse 1a. A meltwater flux of 0.2 Sv over 300 yr was injected into the Norwegian Sea and the Arctic Ocean during a time when proxy evidence suggests vigorous Atlantic meridional overturning circulation. Our new reconstruction of the EIS deglaciation shows that a marine-based ice sheet comparable in size to the West Antarctic ice sheet can collapse in as little as 300-500 years. The new precise deglacial chronology enables us to address the chain of events leading to the EIS collapse, and to evaluate the influence of meltwater runoff on ocean circulation and climate.

O-1012

## Using simplified physical models to predict ice sheet melting and response as climate changes

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### Abstract

Over the last few decades, large-scale ice sheet models have improved dramatically and are now being used to accurately hindcast recent ice sheet mass loss from the Greenland and West Antarctic Ice Sheets, and also the collapse of the Laurentide Ice Sheet. However, while these large-scale models attempt to include much of the known physics relevant to ice mass loss, the complexity of these processes often requires a number of key processes to be modeled with empirical relations or data assimilation rather than with equations based on first-principles physics. While such an empirical approach is useful within the range over which data is available, it is unclear how accurate these models are when applied to either future or past warming scenarios or geometries unlike those observed. Here, we discuss three ways in which simplified but physically motivated models can be used as alternatives to help make less precise but potentially more accurate predictions of ice sheet mass loss. First, we describe a simple two-equation model of two ice sheets intersecting in a saddle and show that this simplified system predicts acceleration of ice mass loss due to the positive height-mass balance feedback and saddle geometry; the model can therefore explain saddle region collapse of the Laurentide-Cordilleran system that more complex models have shown could be responsible for Meltwater Pulse 1A. One benefit of the new simplified model is that it makes straightforward predictions as to what parameters most affect the speed of collapse. Next, we describe a simple alternative to the positive degree day (PDD) model based on a simplified one-dimensional energy conservation equation; despite the simplicity of this PDD alternative, it performs better than the PDD model while still only using surface air temperature as an input and thus does not require the numerous parameters of a typical energy balance model. Finally, we describe how simple physical considerations of friction near a marine grounding line suggest that the standard Weertman sliding parameterization of basal sliding should be modified in a very specific way that is at odds with how it is done in most ice sheet models; instead of water pressure modifying Weertman sliding directly, it should be accounted for in a separate frictional equation. In all three of the models described, simplified but physically motivated reasoning leads to qualitatively different predictions of ice sheet mass loss with climate change as compared with when more traditional empirical laws are used, suggesting that these simplified models provide useful insight about ice sheet behavior in future or past climates very different from what has been observed.

O-1013

## Nature and timing of deglaciation in Changme Khangpu valley, Sikkim Himalaya, India

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### Abstract

The Changme Khangpu (CK) glacier in the Sikkim Himalaya has been selected for study the palaeoclimate through proxy of glacial landforms and glacial sediment assemblages. The main axis of CK valley trends N-S and modern glacier restricted at an altitude between 5900 and 4810 m a.s.l. (27.9583 N, 88.6844 E). Lack of previous studies and spectacular preserved landforms within the 4.5 km downstream from the present glacier snout of CK captivating, and raises the importance to portrait the glacial geomorphology and reconstruct the palaeoclimate of this monsoon dominated valley. We used SRTM DEM, Sentinel-2A satellite imageries, GPS, sedimentological analysis and field technique to map the glacial landforms and glacial sediment assemblages. The <sup>14</sup>C isotope AMS dates of glacio-fluvial and glacio-lacustrine deposition were obtained to reconstruct palaeo phases of climate. Two main glacial phases have been identified by latero-frontal moraines from the mapping. The sedimentation in a form of rhythmite archives were dated to be  $31.47 \pm 0.15$  Ka Cal BP, situated at 1.7 km from present glacier snout. This indicates that this glacier retreated at a slower pace, similar to in present-day glacier snout variability. This retreating phase was appears to be interrupted by the local glacial cooling phase, demarcated prominently by a huge latero-frontal moraine, enclosing the present glacier periphery. Primary glacial sedimentation was continuously redistributing under the paraglacial slope processes, signifying an inverted age of dated sedimentation. The younger talus scree, younger debris rampart are major paraglacial features overlying the palaeo-rhythmites, enhancing the modification of primary sedimentation. Chronological analysis of glacio-fluvial archive from a trench indicate towards oscillating nature of environment from  $14.05 \pm 0.17$  to  $3.45 \pm 0.06$  Ka Cal BP. The sediment grain size variation during the period of  $7.75 \pm 0.05$  ka to  $5.49 \pm 0.04$  Ka Cal BP signifies interrupted environmental condition. This study suggests that valley slope derived paraglacial processes inhibited the preservation of primary glacial sediments and geomorphic features in such environments.

**O-1014**

## **Episodic massive acceleration of Northern Hemisphere ice sheet retreat during the last deglaciation caused by the marine ice sheet instability**

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### **Abstract**

During the last deglaciation (19 ka BP-11 ka BP) sea level rose by about 120 m with a mean rate of a few centimetres. However, natural archives for past sea level change record episodic abrupt sea level rises as fast as 4 metres per century (e.g. Deschamps et al., 2012).

Several mechanisms can explain such accelerations in ice sheet retreat: i) ice stream surges due to internal thermo-mechanical oscillations (e.g. MacAyeal, 1993; Calov et al. 2002) ; ii) strongly negative surface mass balance due to surface elevation feedbacks (e.g. Gregoire et al., 2012; Abe-ouchi et al., 2013) ; or iii) oceanic destabilisation of the grounding line position for marine ice sheets (e.g. Pollard et al., 2016). If the first two processes have been generally put forward to explain Northern Hemisphere retreat, the role of marine ice sheet instability have not been quantified yet, despite the fact that models used at the millennial timescale have considerably improved the representation of this process (Schoof, 2007; Tsai et al., 2015).

Here, using a coupled ice sheet – climate model (Roche et al., 2014; Quiquet et al., 2018), we show that we reproduce episodic massive accelerations of Northern Hemisphere ice sheet retreat during the last deglaciation due to the marine instability. Both the Laurentide and the Eurasian ice sheets are potentially affected by these instabilities which are strongly re-inforced by bedrock deflection. If ice sheet geometry evolution is largely sensitive to climate forcing, such events systematically occur in the course of the deglaciation. Our results suggest that the marine ice sheet instability is an important mechanism to explain Northern Hemisphere ice sheet waning, highlighting the major role of oceanic forcing for ice sheet evolution.

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O-1016

## Human adaptive responses to abrupt climate change in western Iberia during MIS 3 and 2

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### Abstract

During the Upper Pleistocene (MIS 5-2), abrupt climate changes repeatedly altered paleoenvironments across the Iberian Peninsula. Within this context, humans adapted and transformed their environment. Artifact and bone assemblages from palimpsests and high-resolution sites reflect human-environment interactions. Polar ice cores record global scale temperature and sea-level changes on annual time scales for the entire Upper Pleistocene. Deep-sea sediment cores off Iberia record regional and continental scale climate and environmental changes at centennial and millennial time scales. Terrestrial sediment traps, including lakes, bogs, and caves, record local and regional scale records at similar temporal scales. For western Iberia, Lapa do Picareiro, a cave site in central Portugal, provides a diachronic record of MIS 3 and 2 human occupation and environmental change. The cave contains a unique, continuous, 10.5 m stratified sedimentary sequence spanning 60,000 years of the Upper Pleistocene, making it an ideal locale to track long-term human response to paleoenvironmental change. The sedimentary sequence of Picareiro contains Middle and Upper Paleolithic occupations, extremely rich faunal assemblages, and subtle variations in particle size and geochemistry that record changes in the climate, hydrology, and morphology of the cave environment. Age control is provided by over 60 radiocarbon dates. Sedimentological analyses including magnetic susceptibility link the cave deposits with global scale records of Upper Pleistocene climate from the Greenland ice cores and regional-scale ones from deep-sea cores off Portugal. Stratified lithic artifact assemblages reveal technological changes that correlate with climate and environmental shifts recorded in the North Atlantic. Taphonomic analyses of the faunal remains inform on local paleoenvironments and human diet choice during MIS 3 and 2. We draw on these data to synchronize abrupt climate changes and human adaptive responses during the Upper Pleistocene.

O-1017

## Symbolism in late European Neandertals: Paleoenvironmental and evolutionary contexts

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### Abstract

Discussions of Neandertal behavior tend to focus on the identification of species characteristics in what we might refer to as an “ethological” approach. This is understandable because such an approach is both conservative and objective. At the same time, given the close biological relationship of Neandertals to modern humans and the likely complexity of their behavior based on this relationship, a broader, more “ethnographic” approach may be useful. Reconstructions of Neandertal population structure, behavior, and lifeways rarely take into account the possibility – or rather, probability – that Neandertal populations were themselves structured by cultural or ethnic distinctions, like all known modern human populations, past or present. Based on a detailed review of the archaeological, paleoenvironmental and genetic evidence, we argue that (1) the capacity for symbolic behavior was shared by Neandertals and modern humans, and therefore may also have characterized the Last Common Ancestor of these hominins (with concomitant implications for our understanding of the Denisovans); and (2) that the apparent increase in archaeologically-visible symbolic behavior after ~48,000 BP may reflect increased needs for social differentiation among late European Neandertals due to environmental and within-group pressures, and not necessarily changes in cognition or in response to encounters with anatomically modern humans. We conclude that while Neandertals exhibited many aspects of “modern behavior” throughout their lifespan as a species, it is only after 48,000 BP that a unique confluence of environmental and social pressures may have prompted them to codify their inter- and intra-group behavioral and cultural variation in a more durable visual media.

O-1018

## Environmental changes and cultural adaptations of human populations during the Middle-to-Upper Palaeolithic transition in southwestern France (44,000 and 35,000 BP)

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### Abstract

One of the joint issues in archaeology and paleoenvironment is the impact of climate changes on human populations and their means of adaptation. Determining the impact of climatic changes on past human populations is difficult and aims to do try to find coincidences between a climatic event and a cultural transition. However, the identification of a concomitance is undermined by the uncertainties inherent in the chronologies of archaeological sites (dating methods) and by the resolution of environmental data. Our study focuses on improving the temporal resolution of these environmental data for southwestern France, a region that has provided abundant studies on cultural traditions since the Middle Palaeolithic.

Pollen grains and spores preserved in marine sediments are good tracers of environmental changes and our study was carried out using a deep-sea core collected in the Bay of Biscay. This analysis made it possible to study at very high-resolution (100-300 years), the environmental changes in southwestern France between 44,000 and 35,000 years before the present. We then compare our results with the chronology of cultural transitions in the southwestern France to detect a coincidence between both, and see whether climate changes may have been really a part in the development of these cultural transitions.

Our very high-resolution pollen study and other climate tracers preserved in the same samples allowed us to detect several climate phases and associate them with the main climate events in the North Atlantic Ocean and Greenland, i.e. Dansgaard-Oeschger cycles and Heinrich events. In addition, we were able to observe three phases during the Heinrich 4 stadial, which were identified in very high-resolution studies of Greenland ice cores, but also in deep-sea cores from the Iberian margin. In the current state of research and despite the difficulties mentioned above, we can begin to see possible concomitances emerge. This work will be continued during the thesis.

**O-1019**

## **The causes and effects of the earliest Levallois in Britain**

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### **Abstract**

The change from Acheulean technology to the use of the Levallois technique is often used to define the Lower-Middle Palaeolithic transition (c. 300,000 – 250,000 BP) and is considered the only major technological innovation during the Middle Pleistocene. The correlation of MIS 9 and MIS 7 with the terrestrial record in Britain has revealed that this is not a static division in the archaeological record but a longer and more dynamic process. This has allowed a more detailed examination of the changing environments of Britain and its effects on the archaeology found. Research into MIS 9 is examining the Proto-Levallois phenomenon alongside some of the earliest Levallois evidence at sites such as Purfleet and explores whether the new technology was ubiquitous in Britain during the interglacial or if its presence is geographically or temporally constrained. Key elements in this discussion include the timing of early Levallois technology and its relation to the preceding Acheulean. This was previously thought to have been a rapid transition, but evidence from MIS 9 reveals a period of overlap with the Acheulean similar to patterns seen in other regions.

This paper will examine why the change in technology occurred after a long tradition of handaxe manufacture. MIS 9 is often considered to be a turning point for Palaeolithic technology, but the paper will ask whether this can be linked to environmental changes during the MIS 9 interglacial and what effects Britain's glacial cycles might have had on the development of Levallois technology.

O-1020

## To change or not to change... Mesolithic societies in the Wojnowo Region, western Poland

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### Abstract

The problem with the perception of past societies as being largely dependent upon environmental conditions and climate changes is especially significant in reference to hunter-gatherers. For a long time these groups were treated as technologically undeveloped and focused mostly on procuring food. But numerous recent studies show that hunter-gatherer societies were able to apply various strategies for survival in constantly changing natural conditions, i.e. the development of Federmesser groups on the North European Plain during almost the entire Late Glacial. Moreover, these communities were likely to affect local surroundings.

In our paper we focus on the Wojnowo Region, located in the western part of Poland. The richness and diversity of excavated settlement remains located along the edge of the Odra river valley allow the region to be defined as a 'persistent place', an area occupied through centuries or even millennia because of the extremely favorable settlement conditions. Detailed analysis of multi-proxy data – archaeological, palaeobiological (pollen, plant macroremains, Cladocera, diatoms), geomorphological and geochemical - enabled reconstruction of both environmental conditions and human impact on the landscape. From the radiocarbon dating of burnt bones we were able to observe multiple occupation episodes which were completely invisible in the archaeological record.

Moreover, the aforementioned region is an extremely good example of an area where Mesolithic hunter-gatherers "survived" deep into the Late Neolithic. This phenomenon was observed on several archaeological sites and confirmed by radiocarbon determinations.

We would like to discuss the factors affecting human behavior in the distant past, both environmental and cultural (i.e. cultural transmission, transformation). Why, on the one hand, did some societies, witnessing frequent and sharp environmental shifts, show flexibility, apply different subsistence strategies, and develop? And, on the other hand, why did other societies not change their hunting-gathering way of life, even though around them completely different patterns had prevailed?

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O-1021

## Climatic reconstruction between Bond events 4 and 3, implicating the rise/fall of the society at the Sannai-Maruyama site

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### Abstract

The Sannai-Maruyama site (5.9–4.2 cal. kyr BP), one of the most famous and well-studied mid-Holocene (mid-Jōmon) archaeological sites in Japan, existed in Bond events 4-3. The north Mesopotamian civilization and the Yangtze River civilization in China showed similar decline. It was characterized by the exceptionally largest settlement community by the hunter–fisher–gatherers of 90,531 Jōmon sites in Japan.

Temperature is an important environmental parameter. At a glance, 2 groups of proxies for temperature estimates may give contradicting implications. For example, alkenone sea surface temperature and the assemblage of pollen suggest that warm (cold) and cold (warm) environments in the former (latter) half in the period of Bond events 4-3, respectively. Food availability influenced by the climate might control the prosperity/collapse of the site. Chestnuts and horse chestnuts were important food in the Jōmon people and proposed to be protected by *hansaibai* (the word is *hanand Saibai*, half and cultivation, respectively) (Nakao, 1976; Kitagawa and Yasuda, 2004). Especially northernmost Honshu is close to the northern limit of *Castanea* distribution.

Sedimentary cores were collected in Mutsu Bay near the Sannai-Maruyama site. Proxy #1, including alkenone temperature and assemblage of Ostracoda and coccoliths, generally suggests that the temperatures in early-summer peaked around 4.8-4.3 cal. kyr BP with minima in 5.9 and 4.1 cal. kyr BP. Proxy #2, including  $\delta^{18}\text{O}$  value of benthic foraminifera, alkenone flux and relative abundance of pollen, suggested annual-based warm environments in 6.0-5.0 cal. kyr BP. In whole, both proxy groups propose that Jōmon people at the Sannai-Maruyama site generally enjoyed improved life in warm climate between Bond events 4 and 3.

Northward shift of westerly jet, in association with strengthened East Asian Summer Monsoon, influencing prosperity/collapse of the human societies in Far East Asia, could bring relatively warm climate in 6.0-4.3 cal. kyr BP, when the Sannai-Maruyama site flourished between Bond events 4 and 3.

It is suggested that high population density at the Sannai-Maruyama site could be supported by effective *hansaibai* in *Castanea crenata* (chestnuts) and *Aesculus turbinata* (horse chestnuts) to the less amount. Actually the production density per area of chestnut, one of the highest of fruits a tree produces in calorie, is as high as one quarter of the rice production density. Effective *hansaibai* in *Castanea* dominated forest could support high population density at the site. Cooling episodes at Bond event 3 could result in the decline of *hansaibaion* chestnuts, leading to the collapse of the site. Recent results from compiled archaeological-site map with the number of ruins and pit dwellings and from mitochondria DNA haplotype are in more favor of the contention that people were dispersed without no/little change of population across the Bond event 3.

O-1022

## Four millenia of vegetation and lake ecosystem changes recorded in sedimentary ancient DNA from the Bale Mountains, Ethiopia

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### Abstract

Reaching to over 4000 m in altitude, the Bale mountains of south-central Ethiopia comprise the most extensive area of Afro-alpine and sub-alpine Ericaceous vegetation in Africa and host an exceptionally high number of endemic species. Previous pollen analyses of a sediment core of the glacial lake Garba Guracha, located at 3950 m altitude, indicate shifts of the Ericaceous and the Afroalpine belt in relation to climatic changes during the Holocene and imply that the ecosystem has been shaped by natural expansion and contraction of vegetation zones (Umer et al. 2007). At the same time, the significance and timing of the onset of anthropogenic impact, e.g. through grazing and through cutting and burning of *Erica* scrub, is debated.

From Lake Garba Guracha we have retrieved sedimentary ancient DNA targeting the last 4000 years and focussing on plants and diatoms. Positive results were retrieved from nearly all samples. The vegetation revealed by the DNA is characterized by Afro-alpine species in all but the lowest sample, which shows a high number of reads assigned to *Erica arborea* - absent in the younger samples with ages less than 4000 yrs BP. This supports the previously postulated timing of the contraction of the Ericaceous zone, while, in contrast to pollen, it provides a local picture of the vegetation and reveals a high diversity in herbs and forbs, including endemic taxa. Diatom taxa identified by DNA experience a distinct turnover during the time period analysed, and, together with the aquatic plants, can elucidate lake ecosystem history. Interestingly, sequence data of plants was more consistent between PCR replicates than that of diatoms. Consistency in the plant data between replicates was high to an age of about 2500 yrs BP, while for diatoms, degradation as deduced from rates of success and reproducibility was not as clearly linked to depth. Thus, despite signals of DNA degradation, the results clearly demonstrate that authentic and informative DNA data can be retrieved over millennial timescales from Afro-alpine sites.

O-1023

## Evaluating the potential of environmental DNA metabarcoding in analyses of ancient DNA from contrasting lakes in tropical Asia

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### Abstract

DNA metabarcoding is used to infer the species composition of an environmental sample by extracting, amplifying, sequencing, and analysing target genomic regions, or short sequences of environmental DNA (eDNA) that can be used to distinguish between taxonomically different organisms. The set of techniques comprising DNA metabarcoding allows for the study of all barcode genes recovered from an environmental sample (hence the prefix “meta”). Relying on high-throughput sequencing of bulk samples, and access to an appropriate DNA nucleotide library for identification, DNA metabarcoding potentially can be applied even to degraded target material. The set of techniques therefore has great potential for the study of ancient DNA (aDNA), particularly where the focus is on the reconstruction of past biotic assemblages and/or the environments they represent. This paper evaluates the potential of DNA metabarcoding to dated sediment sequences from three contrasting freshwater lakes in Singapore and the Philippines. The oldest of the sediment sequences covers the last ca 1000 years, while the oldest sediment samples in the youngest date to about 120 years ago. In particular the paper tests the ability of DNA metabarcoding to reproduce results from conventional palaeolimnological analyses of the remains of chironomids and diatoms. The application of DNA metabarcoding to aDNA still faces many challenges, owing mainly to the small quantities of DNA involved, its often highly fragmented and degraded nature, the diversity of possible sources and the high likelihood of contamination. Currently, barcode-based identifications are heavily dependent on sequence availability in public databases, such as **NCBI Genbank** and the **Barcode of Life Data System**, where information from tropical Asian species is relatively sparse. The paper demonstrates the important role played by a major barcoding effort targeting extant tropical Asian taxa in identifying the source of aDNA in lake sediments. Although there have been relatively few palaeolimnology-based studies in tropical Asia, the sediment-based remains of chironomids and diatoms have been extensively used in other parts of the world as proxies of past variations in lake water quality, particularly temperature, nutrient and oxygen availability and pH. Preliminary results are highly promising. These results and their implications for tropical palaeolimnology – and for applications of palaeolimnological results, such as in the setting of restoration targets, the evaluation of possible regime shifts and the determination of local histories of invasive taxa – are discussed.

O-1024

## Vegetation history of the lake Gers (Northern French Alps) told by two different narrators: pollen and DNA

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### Abstract

For the Alps, the pollen analysis of lake and peat bog deposits has for a long time been used to reconstruct the vegetation and land use history. In the last five years, more local records of vegetation cover were obtained in the Northern French Alps, using the emerging DNA metabarcoding approach. Focusing also on mammal DNA, this approach allows the reconstruction of the pastoral history. The combination of these two proxies provided a better understanding of the long-term interactions between the vegetation cover and human activities in the Alps. Similar approach is now developed for all the Alps in the framework of the ECOGEN project, also presented in this session.

This paper will present a reconstruction of the landscape changes from a sediment core retrieved in lake Gers (1540 m a.s.l., Northern French Alps). The palaeoecological record, based on the analyses of environmental DNA and pollen, spans the last 4600 years (5.8 m long core). Our ambition is not to compare the pollen and DNA data, but to combine them to develop a more detailed and realistic vegetation reconstruction.

Pollen and DNA analyses highlight similar "core taxa" (e.g.: *Picea*, *Alnus*, *Acer*...), which are still currently present in the catchment area. Moreover, both pollen and DNA data reflect a similar dynamic of the main vegetation groups. Both proxies agree to indicate a quite stable and mainly forested vegetation from 4600 to 1000 cal. years BP, and a major shift in vegetation occurring at 1000 cal. years BP. However, for this shift, pollen and DNA bring different views on the community composition (due to spatial, taxonomic and taphonomic differences). Pollen shows a significant decrease in tree cover and a change in plant community composition. This deforestation signal is also observed via the DNA, but is less pronounced. The DNA highlights a significant increase in the taxonomic diversity of herbaceous plants. This major change at 1000 cal. years BP was triggered by the development of pastoral activities (cow, goat and sheep) reconstructed from mammal DNA and coprophilous fungi analyses.

O-1025

## Overcoming enzymatic inhibitors in sedimentary ancient DNA (sedaDNA) extracts to maximize recovery for targeted enrichment and PCR metabarcoding

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### Abstract

Two major limitations in palaeoenvironmental metagenomics are DNA loss during extraction and the carryover of prolific enzymatic inhibitors. PCR metabarcoding can overcome some degree of inhibition through repeated silica-based purifications along with the addition of various substances (BSA, increased polymerase concentrations, etc.) during thermocycling. But this technique can be vulnerable to differential amplification rates and a subsequent bias in taxonomic profiles if there was substantial DNA loss with overly thorough inhibitor removal treatments during extraction. Alternatively, sedaDNA extracted with techniques designed to maximize ancient DNA recovery are prone to the carryover of enzymatic inhibitors (contingent on variations in the sedimentary matrix), which can result in failed PCR amplification or failed adapter ligation during library preparation, impeding shotgun sequencing or targeted enrichment strategies.

Our goal with this series of experiments was to evaluate various inhibitor removal treatments for their ability to reduce the carryover of enzymatic inhibitors in sedaDNA extracts while maximizing endogenous palaeoenvironmental DNA that can successfully undergo library adapter ligation. Four previously studied (via metabarcoding) Yukon sediment cores (two permafrost, two lake sediments) were tested using homogenized sediment inputs in triplicate. Our optimized extraction protocol was then directly compared with the DNeasy Powersoil DNA Extraction kit (one of the most commonly used extraction strategies in sedaDNA research along with the DNeasy PowerMax Soil Kit) following manufacturer specifications. Both extraction methods for each of the cores were then further processed for shotgun sequencing, targeted enrichment (enriching for animal whole mtDNA and plant cpDNA barcoding loci), and PCR metabarcoding. High-throughput sequence data derived from each combination of these techniques are compared here, as well as that of metabarcoding sequence data previously derived from these core samples. Preliminary quantitative PCRs indicate an up to 7-fold increase in total DNA recovery among the four core samples (average 3.6-fold) with our alternative extraction protocol, and up to a 5.6-fold increase in 'endogenous' library adapted *trnL* chloroplast DNA (with an average 3-fold increase).

O-1026

## Cross roads at the Western edge of Europe: Ancient DNA gives evidence of prehistoric African gene flow into Iberian Peninsula

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### Abstract

A Southwest-Northeast gradient of African diversity crosses modern European populations, with a maximum in Spain [1, 2]. It is unclear whether this gradient is the consequence of gene flow from Africa into Iberia in the Islamic period (as suggested by some analyses of nuclear DNA in modern populations [2, 3]), or of a much older contact, 10000-8000 years before present (as suggested by studies of uniparental markers, [4, 5, 6]). Here we typed whole ancient genomes from 4 Middle Neolithic and Bronze Age (~4000 yBP) individuals from Spain and Portugal, and found one of our samples from Southern Spain to belong to an undisputable Sub-Saharan mitochondrial lineage (L2a1). To test whether this finding reflects an isolated episode, or a sizable process of prehistoric gene flow from Africa, we analyzed a large genomic dataset of prehistoric samples. Our analysis at nuclear DNA detected small, but not insignificant, levels of Sub-Saharan African affinity in ancient genomes dating back to the Copper Age; and this similarity was stronger in the samples coming from the Mediterranean, than from the Atlantic, watersheds of Iberia. No similar pattern is present, as far as we could test, in other regions of Europe. In agreement with archaeological data, we interpret our results as evidence of an early migration process from Sub-Saharan Africa directly into the Iberian Peninsula. To our knowledge, this study is the first to report direct evidence of African gene flow into prehistoric Europe, following a Western route, likely across the Strait of Gibraltar.

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O-1027

## ECOGEN: a project to examine ecosystem changes and species persistence over time using lake sediment DNA

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### Abstract

We can predict potential future ecosystem impacts by examining the effects of analogous past changes. Within the past 12,000 years, there have been periods of both dramatic and relatively minor climate changes that are comparable to the range of predicted future scenarios. Additionally, human land-use impacts have been varied and widespread across Europe during this interval. Palaeoecological records, such as lake sediments, can inform how these drivers of change impacted past ecosystems. Traditionally, pollen has been used to infer ecological changes in sediment records, but its low taxonomic resolution precludes a detailed understanding of turnover and succession events. In contrast, ancient DNA recovered directly from lake sediments (*sedaDNA*) often yields species-specific information thereby mitigating this issue.

The ECOGEN project is using lake *sedaDNA* to examine the principle drivers of past ecosystem changes (climate and human land-use impacts), principally targeting vascular plants and key herbivores. The project focuses on two major regions: Northern Norway and the European Alps. Both regions have been affected by climatic changes, but the former is far less impacted by past human land-use changes than the latter. The large scale of the project (two regions and up to 40 lake sediment records) also allows for extensive testing of wet-lab and bioinformatic methodologies related to *sedaDNA* analysis.

In this talk, we will outline our major project findings so far, including full vascular plant records from many of our analysed sediment records from Northern Norway. These show distinct regional signals of succession and turnover. Ecological succession in the earliest Holocene tends to be rapid, with diverse plant communities appearing very soon after the Pleistocene-Holocene transition, which indicates swift responses to this short period of severe climatic change. Several records located near archaeological sites also show evidence of human land-use changes, as demonstrated by the appearance of disturbance indicators.

These initial findings demonstrate the efficacy of our approach, and they lay the foundation for large-scale regional comparisons to disentangle past drivers of ecosystem change that would improve our predictions of the near future.

O-1028

## Effect of habitat loss on Tibetan alpine plant diversity since the Lateglacial and in future

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### Abstract

Future warming is proposed to result in loss of alpine plant diversity, which has important implications for vast alpine areas on the Tibetan Plateau. However, long time-series that confirm such a relationship are lacking from this region. Lakes represent useful archives to record long-term ecological change; yet, classical vegetation proxies such as pollen or macrofossil are not suitable indicators for plant diversity change. Here, we present an ancient plant DNA record of the past ~18,000 years, derived from sediments of Lake Naleng in the Hengduan Mountains – a biodiversity hotspot on the southwestern Tibetan Plateau in China. Furthermore, we simulated species richness using information from a modern vegetation database and temperature-related habitat changes. We found that overall plant diversity (i.e. richness) is highest when the lake catchment area is mainly covered by alpine meadows (at the end of the last glacial cycle and during the late Holocene) while diversity is low in warm phases with expanded forests (such as during the early and mid-Holocene, and presumably in the future), or during cold phases characterized by scarce vegetation and upland glaciation (such as shortly after the Last Glacial Maximum). While absolute diversity of each alpine plant family is highest during periods when it is most abundant, the relative diversity is highest when alpine meadows have a maximum extent and therefore offer a large variety of habitats. By analogy to our observed and simulated vegetation composition of former warming phases, alpine diversity will strongly decrease due to alpine habitats loss in a warmer future. Even if human impact will inhibit the invasion of forests and restrict the artificial stabilization of alpine meadows, grazing in alpine meadows will likely not cause a naturally high alpine plant diversity as suggested by analogy to the observed plant diversity change in the course of late Holocene human impact. To our knowledge our record represents the first proof of diversity-area-relationship concept from the past.

O-1029

## Development of the Holocene East Asian Monsoon – Evidence from Singapore and links to the Australasian Monsoon

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### Abstract

Nee Soon (1°24'N, 103°48'E) is a freshwater swamp forest that covers an area of 0.87 km<sup>2</sup> on north-eastern Singapore and is the only remaining swamp forest area on this highly urbanised island. The site occupies the lower portion of several shallow valley systems that eventually drain into the Seletar River and situated less than 10 m above present day sea level. Initial palynological analysis of sediment from this site revealed a record that extended into the last glacial period and parts of the Holocene (Taylor et al., 2001). The presence of montane pollen suggesting substantially cooler conditions, which extended into the early Holocene. During the mid-Holocene there is evidence of rising sea-levels, which is followed by falling sea-levels in the late Holocene. Fires, determined from charcoal analysis, were observed across the entire sequence. More recently 14 sediment cores were collected across the site to provide a more comprehensive picture of the sedimentology of the last remaining peat swamp forest in Singapore and to build on the initial analysis undertaken by Taylor et al. (2001). Subsequently, palynological analysis and radiometric dating has been undertaken on key facies of these sediment cores to provide further insight into the late Quaternary environments of the Nee Soon site, as well as improving the age model/stratigraphy of the sediment. Key findings support Taylor et al. (2001) study that the last glacial was cooler, with the site dominated by open taxa and greater representation of montane taxa. There is an increase in lowland forest taxa and decline in burning around 14,000 years ago that supports the development of the East Asian monsoon at this time and appears to strengthen in the early Holocene to become the dominant precipitation feature for this site onwards. These findings suggest that the precipitation increase occurred at a similar time to the Australasian monsoon development in north-western Australia (Field et al., 2017) but earlier than in the Wet Tropics of northeast Australia (Moss et al., 2017). In addition, variability in precipitation appears to be much less than in northern Australia and may be related to the equatorial location at the site that limits the influence of the El Niño Southern Oscillation phenomenon and other potential drivers of climatic variability.

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O-1030

## Holocene Climate across the ITCZ, Hainan Maar Lake records vs. NE Queensland

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### Abstract

The Asian/Australian monsoon is a coupled climate system through the cross-equatorial flow over the tropical Pacific-Indian Ocean and the migration of the Inter-tropical Convergence Zone (ITCZ). We present differences and correlations between a key sites from Hainan Island (China) and the Atherton tablelands, NE Queensland (Australia). Both sites have good chronological control and have been analysed using high resolution micro-XRF. We aim to explain the significance of the 9.2 ka, the 8.2 ka, the 2.8 ka and the Little Ice Age climate events in both regional and global context and its significance on the Asian/Australian monsoon system.

The following geochemical proxies including the ratios of Rb/Sr, Rb/K, Zr/Rb and Si/Ti were analysed using an X-ray fluorescence (XRF) core scanner.

**O-1031**

## **Tracking abrupt climatic changes of the Holocene using organic sediments from NE Australia**

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### **Abstract**

Sediment cores recovered from Bromfield maar provide a continuous, high resolution record of climate variability through the Holocene for northeastern Australia. X-ray fluorescence (XRF-Itrax) is used in the generation of a long-term record of relative precipitation, supported by a suite of established proxies including humification, macrocharcoal and pollen. Together, these proxy data allow precise identification of wet and dry shifts in a sedimentary sequence comprised of laminated organic-rich muds, gyttja and peat.

In this presentation we describe and provide new interpretations on changes in the Early Holocene as recorded at Bromfield maar, with particular emphasis on laminated organic-rich muds at 4.80m (9.2 ka) and 4.42m (8.3 ka). Additional changes are detected in the Late Holocene peat sequence at 1.37m (2.9 ka) and 1.28m (1.5 ka).

Abrupt climate change events as identified in this study are significant as they allow the correlation of sedimentary records from sites throughout the wet tropics of Australia. The detection of these abrupt climate events also signals possible correlation with records from terrestrial sites across the Southern Hemisphere and potentially, the Northern Hemisphere. Such correlations may prove useful in demonstrating teleconnections, linking climates at a global scale.

O-1033

## Quantitative Estimates of the Last Deglaciation and Holocene Climate from Pollen Data in Northwest Yunnan, Southwest China

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### Abstract

A modern pollen dataset used in this study consists of 75 surface samples from ponds, lakes, and reservoirs in Northwest Yunnan, Southwest China. Climatic data for each site, including monthly, seasonal and dry/rainy seasonal, as well as mean annual temperature and precipitation, were derived from observational data (1961-2010) of 20 meteorological stations in this region using linear interpolation method. Canonical correspondence analysis (CCA) was used to reveal the climatic parameters that best reflect the main patterns of variation in this modern pollen dataset, and to detect anomalous observations. Results of CCA indicate that mean annual precipitation (MAP), precipitation in dry season (November-April) ( $P_{ds}$ ), and January temperature ( $T_{jan}$ ) are three climatic parameters controlling the variation of this modern pollen dataset in Northwest Yunnan. Pollen-climate transfer functions for MAP,  $P_{ds}$ ,  $T_{jan}$  were developed using the weighted-averaging partial least squares (WA-PLS) regression models. According to the performance of WA-PLS regression models, 3-component WA-PLS models were selected respectively for these three climatic parameters with low RMSEP (the root mean square error of prediction), low maximum bias, and high coefficient of determination ( $r^2$ ) between observed and predicted values (RMSEP=48.7, 17.9 mm, and 1.0 °C; Maximum Bias=79.8, 37.1 mm, and 1.6 °C;  $r^2$ =0.6, 0.6, and 0.74 for MAP,  $P_{ds}$  and  $T_{jan}$ , respectively).

Transfer functions for MAP,  $P_{ds}$  and  $T_{jan}$  were then applied to a fossil pollen record from Lugu Lake in Northwest Yunnan to reconstruct paleoclimate in the catchment of this lake. Quantitative estimates of paleoclimate show that MAP and  $P_{ds}$  fluctuated around 1000 and 110 mm (their present values), but  $T_{jan}$  is 0.8-4.3 °C lower than the present (5 °C) during 15000-12800 a BP (cal. a BP). From 12800 to 11500 a BP, MAP and  $P_{ds}$  were ca. 50 and 25 mm higher than the present, and  $T_{jan}$  increased to be the present level. Three climatic parameters at 11500-9100 a BP reached their maxima throughout the last deglaciation and Holocene. MAP,  $P_{ds}$ , and  $T_{jan}$  were 136-350, 35-139 mm, and 0.4-1.2 °C higher than today, respectively. From 9100 to 5500 a BP, both MAP and  $P_{ds}$  decreased, but they still were higher than the present, whereas  $T_{jan}$  declined to be the level slightly lower than the present. Three climatic parameters gradually decreased to be lower than the present from 5500 to 2500 a BP. After 2500 a BP, the catchment of Lugu Lake experienced a persistent period of low precipitation and temperature. On the average, MAP,  $P_{ds}$ , and  $T_{jan}$  were 94, 4 mm, and 1.9 °C lower than the present, respectively. Our quantitative estimates of MAP reveal a temporal pattern of precipitation variability associated with the strength of the Southwest Asian Monsoon during the last deglaciation and Holocene.

**O-1034**

## **A Late Pleistocene and Holocene vegetation and environmental record from Shuangchi Maar, Hainan Province, South China**

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### **Abstract**

Shuangchi is a maar in the volcanic province of tropical northern Hainan Island, South China. A radiocarbon dated record of pollen, charcoal, organic carbon and some fossil algae provides a discontinuous record from its sediments cover the last 20,000 years. The fossil record is broken in places by abrupt pulses of inorganic material washed into the basin from the crater walls, presumably during periods of high magnitude storms. These samples also return anomalous radiocarbon ages. Last glacial maximum was marked by forest but with a high component of grassland, suggesting a drier and cooler climate than today. Forest recovery was rapid from about 9500 years ago and a peak in tropical rainforest taxa persisted until about 5000 years ago and this appears to represent peak warming in the region. From about 5000 years ago until present there is evidence of human impact, and fire was a tool used to clear forest. The human impact signal varies across Hainan which suggests that the level of human resource use was localised at least for several millennia. Human impact signals appear to be widespread from about 2000 years ago.

O-1035

## Asian-Australasian monsoon response to mid-Holocene orbital forcing and greenhouse-gas induced global warming.

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### Abstract

Asian and Australasian monsoons are investigated in Coupled Model Intercomparison Project phase 5 simulations for mid-Holocene and future climate scenario rcp8.5. These two climates show interesting characteristics for monsoon dynamics: while the boreal summer inter-hemispheric contrast strengthens in both climates, the austral summer contrast only strengthens in mid-holocene and weakens in the future. Therefore, Asian monsoon is stronger than present day in both climates, while the Australasian monsoon is weaker in the past and stronger and wider in the future. Mechanisms determining monsoon responses in these two climates are investigated by decomposing the moisture budget in thermodynamic and dynamic components. Under future global warming, the intensification of the Asian monsoon results from a dominant thermodynamic effect (increased moisture) over the weakening of the circulation. In contrast, in the past the strengthening of the circulation (dynamic component) determines most of rainfall response. The Australasian monsoon is stronger in the future because of the thermodynamic component and it is weaker in the past because of the weakening in the tropical atmospheric circulation. Changes in net energy input over land versus ocean explain the different Asian and Australasian monsoon response. Our results highlight that temperature indices are poor indicators of the monsoonal response which is particularly sensitive to the radiative forcing. Therefore, the monsoon response is better constrained by the integrated energy balance, which accounts for changes at the surface as well as at the top of the atmosphere. The circulation is intensified where the anomalous net energy input is positive and weakened where it is negative.

O-1036

## Tephra connections between records of past climate and early modern human evolution in Africa

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### Abstract

The role played by changing climates and environments in the behaviours and dispersal of modern humans since their first appearance in Africa 300-200 thousand years before present (ka BP) is much debated. Recent theories are shaped by marine and terrestrial records of abrupt and extreme climate variability and on-going landscape changes, alongside archaeological evidence for increasing adaptability through time. Archaeological sequences and tropical climate records, on such long timescales, are often difficult to date directly and to correlate precisely, meaning that testing for relationships between modern human behaviours and their changing environments is extremely challenging.

A 280 metre sediment core from the Chew Bahir palaeolake in the southern Ethiopia Rift provides a continuous terrestrial archive reaching back ~600 ka BP, from which past climate and local environmental conditions have been reconstructed spanning the entire interval of modern human evolution. Layers of volcanic ash (tephra) within the Chew Bahir record provide key age-estimates within the site's age-model and also allow precise and direct correlations to some of the most important early modern human archaeological sites in Ethiopia, including the Kibish Formation. Using these tephra isochrons, the Chew Bahir palaeoclimate record provides critical insight into both the contemporary regional climate and local environmental conditions within which our ancestors were living in eastern Africa.

O-1037

## The impact and significance of tephra deposition on a Holocene forest and lake environment in the North Cascades, Washington, USA.

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### Abstract

Volcanic activity can be a driver of short-term climate change and can impact on aquatic and terrestrial ecosystems at various temporal and spatial scales. However, the environmental impacts of tephra deposition are poorly understood. The palaeoenvironmental records from lakes and bogs, are essential tools used to investigate the nature and duration of the environmental response to tephra deposition, as continuous monitoring in active volcanic terrains is rare and few have the decadal durations required to measure environmental changes. Nonetheless, while several multi-proxy studies have indicated significant impacts, others have been ambiguous, reaching no clear consensus due to the difficulty to distinguish from background variability. High-resolution diatom and pollen stratigraphies from mid-Holocene sediments taken from fringe and central locations in Moss Lake, a small lake in the foothills of the Cascade Range, Washington, have been analysed to investigate the impacts (and duration) of tephra deposition on the aquatic and terrestrial ecosystem. Up to 50 mm of tephra was deposited from the climactic eruption of Mount Mazama 7958-7795 cal yr BP. The significance of tephra impacts independent of underlying long-term trends was tested using partial redundancy analysis. Tephra deposition caused a significant local impact on the terrestrial ecosystem, reflected in the fringe core by changes to open habitat vegetation (Cyperaceae and Poaceae) and reductions in aquatic macrophytes (*Myriophyllum spicatum*, *Potamogeton* and *Equisetum*). There was no significant impact of the Mazama tephra detected on the pollen record of the central core. Changes in this core are potentially climate driven. Overall, significant tephra fall was demonstrated through high resolution pollen analyses indicating a local effect on the terrestrial environment, but there was no significant impact on the regional forest independent of underlying environmental changes. The diatom response from both cores indicates a significant change in habitat type following blanket tephra deposition, with a decline in tychoplanktonic *Fragilaria brevistriata* and *Staurosira venter* and epiphytic diatom taxa indicating a reduction in aquatic macrophyte abundance, in agreement with the pollen record. Additionally, the central core shows an increase in tychoplanktonic *Aulacoseira* taxa, interpreted as a response to increased silica availability following tephra deposition. However, partial redundancy analysis provides only limited evidence of direct effects from the tephra deposition, and only from the central core, but significant effects from underlying environmental changes associated with climatic and lake development processes. The analyses highlight the importance of duplicate analyses (fringe and central cores), multi-proxy approaches and vigorous statistical analyses for the robust evaluation of ecosystem change following tephra deposition.

O-1038

## Tephrostratigraphic studies on Lopevi volcano, Vanuatu

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### Abstract

The previously inhabited island of Lopevi, in Vanuatu, has shown regular volcanic activity since Cook's first sighting in 1774 AD. Nine episodes of volcanic eruptions are recorded between 1863 and prior to 1960 AD. Six pre-1960 AD. eruptive episodes, separated by buried soils, are preserved as tephras in a continuous stratigraphic sequence at the westernmost bay of the island, providing a fundamental record with which to elucidate a previously unknown order of lava flows and diamictos elsewhere on the island. This account provides further stratigraphic correlations and discoveries along the southern coast, from a 2005 expedition to Lopevi by the authors.

West of the previous village of Holen, lava flows and diamictos have been emplaced by eruptions in 1939, and subsequent to 1960 AD., extending the coastline and burying older deposits. However east of Holen, to the extinct peak of Mot Mot, at the south-eastern corner of Lopevi, there is a 3 km-long coastal exposure showing at least 4 major diamictos (and further less significant ones), interbedded with at least 3 pre-1960 AD. lava flows in valleys incised within the sequence.

Attempts at radiocarbon dating fossil crab shell and fibrous charcoal have proved fruitless. To aid with surface dating of recent deposits we established a curve of breast-height circumference of *Casuarina equisetifolia* trees, which grow on many of the dated surfaces. This proved useful as a relative dating technique for dating surfaces of unknown age over the last century.

The oldest diamictos appear closest to the south-east corner of the island between the December 2001 lava flow and the extinct Mot Mot, where they appear to be younging westwards. Further westwards, a sequence of four variably thick diamictos are interpreted to be the products of pyroclastic block-and-ash flows due to the presence of charcoal and cauliflower breadcrusted volcanic bombs. This sequence will be described in detail.

Immediately east of Holen is a 4 m-thick diamicton, which eastwards overlies a 1 m+ scoria containing anthropogenic materials. These included the blade of a presumed bone-handled knife, a piece of shattered green glass interpreted as a fragment of a bottle, a 4 cm-long gastropod, which was presumably a local food source, and oven-stone manuports. From 1943 AD. aerial photography this diamicton must precede the 1939 eruption because of the extensive vegetative cover at that time. The surface soil shows 1.2 m of overlying scoria, which we interpret as having been deposited in 1939 AD. We interpret this diamicton to have been emplaced during the 1922 AD. eruption when 500 persons were evacuated from the island. The next underlying unit, a lava flow, was probably emplaced during the 1908 AD. eruption when lava is reported to have descended to the sea.

O-1039

## **Tephrochronology in south-Cappadocia (Turkey): first evidence of regular eruptions from LGM to Roman period, and impacts/non-impacts on human settlements**

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### **Abstract**

In the frame of Turkish-French research cooperation in geo-archaeology, palaeo-environment and palaeoclimate, 19 cores and 6 sections in lake/marsh/river sediments have been studied in connection with archaeological researches in south-central Anatolia. The cores and sections have been studied at four locations: (1) The Melendiz river terraces (Aksaray); (2) The Çiftlik Plain (Niğde); (3) the Bor Plain (Niğde); (4) the Ereğli Plain (Konya.). These geosystems belong to the southern part of the Volcanic Cappadocian Province (Melendiz river system and Çiftlik plain) and to the endorheic depressions lying north of the Taurus highlands (Bor and Ereğli plains). In the sequences presented, tephra layers of various thickness, grain size and lithic composition have been identified, characterized and dated. The results unveil very recent volcanic activity, and risk in the region.

### **State of the art**

In the Hasandağ, researches have evidenced volcanic emissions at 35, 29, 15, 9, 3 to 0 kyrs ago (within at least 1 ka uncertainty: Pastre et al. 1997; Kuzucuoğlu et al. 1998; Schmitt et al., 2014) whereas an eruption (?) sketched on the wall of a Neolithic house is dated 8.4 kyrs ago (Mellaart, 1968; Hodder et al. 2006). In the Erciyes dağ, a rhyolitic activity is dated 9.5 kyrs ago (Hamann et al. 2010; Sarıkaya et al. 2018). Explosive activity is recorded in the Acıgöl caldera between 31 and 18 kyrs, while Late Glacial to Early Holocene tephras have been trapped in Acıgöl maar lake (Kuzucuoğlu et al. 1998; Roberts et al. 2001; Mouralis et al. 2003; Schmitt et al. 2011). No pyroclastite has been dated in the Karadağ (Ereğli-Konya).

### **New data**

Sequences presented deliver numerous and very recent Cappadocian eruptions, and their impacts on populations as some of them have been collected in archaeological context. Eruptions (from different volcanoes?) occurred rather regularly within 3 to 1 kyrs intervals between at least 19.6 and 7.4 kyrs cal BP. Identified both in a core and in an archaeological site, a pumice fall is dated ca 2 kyrs ago. Such results are of tremendous importance as they show that:

- not only this remarkably regular magmatic activity in the region has been widely ignored,
- but populations lived together with eruptions from LGM to Mid-Holocene.



It is now clear that eruption risk must be considered seriously in the region, with monitoring installed over at least two volcanoes, the Hasan Dağ and the Erciyes Dağ.

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O-1040

## Post depositional processes: the environmental impact of plinian eruptions in Iceland

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### Abstract

Large plinian volcanic eruptions have created key isochrones for classic tephrochronology and covered much of Iceland in thick tephra deposits. The long-term impact of these tephra falls on the environment, and the rate of recovery, is poorly understood. Tephra depth can be an important determinant of post-disturbance ecological processes and recovery, which can control the extent of discontinuations in the tephra record and classic tephra sequences. Deposits may be effected by a number of post-depositional processes which control thickness and distribution including slope processes, crust formation, and fluvial and aeolian erosion and remobilisation. Such processes, and their relationship to different plant communities, are important for understanding environmental response to the disturbance. In terms of environmental impact, rather than being a simple measurement, tephra depth could be considered a function of local vegetation (species, plant height, and growth stage), local topography, and season.

By utilising classic tephrochronology alongside palaeoenvironmental methods, the environmental impact of major plinian eruptions can be reconstructed. Within Iceland no such eruptions have occurred since people arrived in the late 9th century AD, so it is important that we explore their environmental impact in order to better understand the potential impact of future large plinian eruptions.

A number of sites are being investigated across Iceland, focusing on the Hekla 4 (c.4200 years B.P) and Hekla 3 (c.3100 years B.P) eruptions. These deposits have been recently remapped and so are significantly better understood than previously. Areas proximal to Hekla were buried under metres of tephra, and it may have taken thousands of years for a stable post-disturbance environment to form. At the other extreme, these layers are thin enough to have only temporarily impact the environment, if at all, and so the extent and length of the disturbance is likely to have varied with tephra depth amongst other controlling factors such as vegetation. By reconstructing the environment prior to, and after the eruption, we can investigate the extent of the impact and how long the environment took to 'recover' to pre-eruption conditions. We can also compare the disturbance between sites at different distances from the Hekla volcano, and at different altitudes, as well as investigating how different environments may have been effected. In doing so, a high-resolution temporal and spatial record of the impact of plinian eruptions in Iceland can be created.

**O-1041**

## **The Early Holocene Saksunarvatn tephra: investigating the environmental effects of volcanic eruptions through annually laminated lake sediments**

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### **Abstract**

Due to its widespread coverage, the Saksunarvatn ash (ca. 10.2-10.3 ka cal. BP, Grímsvötn volcanic system) is regarded as an important stratigraphic marker to correlate multiple sedimentary archives between Greenland and northern continental Europe. While recent investigations revealed that the Saksunarvatn ash can't be considered the result of a single eruption, the relatively short interval between eruptive events, the spatial coverage and the total estimated amount of ejected material still raise questions concerning the duration and magnitude of any potential environmental repercussion.

Here, we make use of annually laminated sedimentary archives from northern Germany to investigate the potential influence of the Saksunarvatn event(s) on terrestrial and aquatic ecosystems. A single Saksunarvatn ash layer was identified in the lacustrine sequences of two distinct study-sites: Poggensee (Schleswig-Holstein) and Woseriner See (Mecklenburg-Vorpommern). Twenty sediment samples, each one spanning 2-5 years, were collected from the varved sequences of both sites, covering an interval of ca. 30-40 years before and after the deposition of the tephra layer.

Palynological and geochemical analysis conducted on these samples reveal a seemingly (multi)decadal episode of ecosystem disturbance occurring around the time of the ash deposition. The magnitude of this event, its proper delimitation in both archives and its relation with the multiple Grímsvötn eruptions will be evaluated within this presentation.

O-1042

## Assessing the impact of Tierra Blanca Joven eruption of Ilopango, El Salvador

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### Abstract

The Tierra Blanca Joven (TBJ) eruption from Ilopango volcano, El Salvador is known to have been one of the largest eruptions in the Common Era. The date of the eruption is poorly constrained, ranging from approximately 255 CE to 536 CE, as many radiocarbon measurements plot on plateaus in the radiocarbon calibration curve. This uncertainty in the date means that the far-reaching impacts of the eruption are not known. However, there has been speculation that it may have caused the dense dry fog that was observed across Europe in 536 CE (Dull et al., 2010), and sulphur spikes in the polar ice cores have been attributed to the eruption (e.g., Zielinski, 1995). Here we present new results from a multi-faceted study into the eruption, which includes: glass chemistry data from all units within the deposits that help correlate deposits over more than 180,000 km<sup>2</sup>; precise wiggle-matched radiocarbon dates from a charred Mahogany tree stump that was found within the TBJ pyroclastic flow; the eruption parameters and the volume of magma erupted, which have been constrained using state-of-the-art dispersal models; and volatile compositions of the deposits that provide estimates of the amount of S and Cl released. These constraints allow us to provide a better assessment of the impacts of the eruption.

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**O-1043**

## **Constraining charcoal source area to better inform paleofire interpretations**

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### **Abstract**

Charcoal-based fire reconstructions inform perspectives on the response of fire regimes to changing climate, ecology, and management. In light of projected changes in global fire activity in response to future climate change, paleofire perspectives are increasingly important. Much previous work has sought to understand the processes affecting charcoal in sediments to develop more robust interpretations of fire records. Constraining charcoal dispersal and source area is essential to the reliable interpretation of charcoal records. Current estimates of source area and dispersal span a wide range, so our understanding of source area remains ambiguous, limiting our interpretations of charcoal records. We synthesize new work aiming to delineate charcoal source area and the spatial scale at which charcoal-based reconstructions record fire history. Firstly, we compile charcoal source area estimates from the published literature and show that these estimates span a wide range (from 10s of meters to 10s of kilometers) and demonstrate methodological biases (e.g. atmospheric and lake sediment traps, models, sediment cores). Using new quantitative geospatial techniques, we compare down-core charcoal accumulation with historical fire data to identify the spatial scales at which charcoal particles of different sizes reliably record fire history in two case studies: the montane forests of the Sierra Nevada, California, and the tundra ecoregions of Alaska, U.S.A. We find that our charcoal source area estimates in the Sierra Nevada (25, 35, and 150 km for charcoal particles >250, >150, and 63-150  $\mu\text{m}$ , respectively) fall within the range of published estimates but that source area estimates in Alaska are much larger (0 to 150 km for charcoal particles >120  $\mu\text{m}$ ). The results of our Alaska case study suggest that an underlying paleofire assumption, that charcoal dispersal is dependent on particle size, does not always hold true. Finally, we present a kinematics-based dispersal model that incorporates variable particle size, density, and shape. We show that the model can explain the source area estimates and variability we see in our spatial analyses. In sum, our work offers new perspective in understanding charcoal source area and improves the interpretation of charcoal-based fire records. Our work also highlights the need to incorporate spatial analyses into the interpretation of paleofire records.

O-1044

## Calibration and validation of transfer functions for burned area and fire severity in the boreal forest

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### Abstract

Charcoal particles preserved in lake sediments are commonly used for reconstructing fire return intervals (FRI) for assessing the fire regime. Yet, when analyzing fire-vegetation relationships, FRI is not always the most appropriate metric. Indeed, longer FRI are not always associated to late successional species while short FRI sometimes do not imply a dominance of early successional species. These discrepancies are only partly explained by taphonomical processes that affect the proxies, notably the production, the transportation and the deposition in the archive. More likely, other fire characteristics such as burned area and fire severity are important in explaining charcoal records and fire-vegetation relationships. Here our aim was to calibrate these fire characteristics against charcoal median surface recorded in traps located within 7 lakes of the western Québec boreal forest during 6 consecutive years. Fire severity was assessed by dNBR (differentiated Normalized Burn Ratio) calculated with LANDSAT images. We assessed charcoal dispersion by extracting fire characteristics at 3, 15, 30km from the lakes and charcoal deposition by analyzing fire characteristics the year of the fire and up to 5 lagged years. A Random Forest based methodology was used to distinguish fire variables that significantly contribute to explain charcoal measurements taken independently. Among those variables only the most relevant were kept for developing transfer functions that will enable to reconstruct fire characteristics. We found that charcoal median surface was related to fire severity and burned area occurring within 30km from the lake the year of the fire (lag 0). We subsequently created two transfer functions: one for reconstructing burned area ( $r^2=0.7576$ ,  $P$ -value  $<0.001$ ) and the other for fire severity ( $r^2=0.7584$ ,  $P$ -value  $<0.001$ ). These two transfer functions show that regional burned area and fire severity explain current year air-borne charcoal deposition. We will then further discuss the reliability of these transfer functions by testing them on sub-actual (last ~100 years) sedimentary charcoal data extracted from 11 lakes in the same vegetation context.

O-1045

## Glacial to interglacial fire history of northeastern Siberia during the last 270 kyrs

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### Abstract

Fire regime shifts under future climate change are difficult to predict, especially in the high-northern latitudes. There, modern fire regimes vary strongly between tundra, summergreen (larch-dominated) and evergreen (pine and spruce-dominated) boreal forests. Whether climate or vegetation are the main drivers of biome-specific fire regimes and the role of internal feedbacks with permafrost are highly debated. Yet, knowledge on past fire regimes and associated feedbacks in the high latitudes is scarce, especially on longer time scales beyond human interference.

Here, we study the long-term fire regime history of Chukotka, northeastern Siberia, using sediment core PG1351 from Lake El'gygytyn that covers the last 270,000 years. We focus on two glacial-interglacial transitions of similar summer insolation, but different global ice volume, and different vegetation composition. Multiple fire proxy records from the same samples allow to characterize the fire regimes of a warmer than modern (MIS 5e) and a cooler than modern interglacial (MIS 7e). We analyzed sedimentary charcoal from pollen slides that reflects various combustion efficiencies from regional sources, whereas the presence of the spores of *Gelasinospora* (a fungi indicative for fires) depends on the regional availability of fire-disturbed soils. In addition and for the first time, we provide long-term sedimentary records of the molecular fire markers levoglucosan, mannosan and galactosan from ultra-high performance liquid chromatography-high resolution mass spectrometry that indicate regional low-temperature biomass burning of varying burning conditions.

We find higher concentration and influx of all fire proxies during interglacials suggesting greater fire activity compared to the preceding glacials. Yet, proxy ranges, proxy record variability and ratios between the fire proxies of the two interglacials were significantly different, on both, millennial and centennial time scales. A comparison of fire proxies with available climate reconstructions from the same core and pollen-based vegetation reconstructions from the same samples suggests a strong dependence of fire regimes on regional biome configuration, but also on temperature and permafrost thaw. Hence, understanding long-term internal climate-vegetation-permafrost feedbacks is crucial for fire regime prediction in the future.

O-1046

## Using ATR-FTIR to quantify pyrolysis intensity as a proxy for fire severity in eastern Australia

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### Abstract

There is significant uncertainty regarding past, present and potential future fire regimes in eastern Australia, and many of these questions require a longer baseline than is available from instrumental or historic records. Addressing such questions is also clearly often hindered by the ambiguity of charcoal as a proxy for fire. This ambiguity can result from the variability of charcoal formation, taphonomy can be uncertain and the delivery of charcoal into deposition environments can be dependent on the nature of the fire (severity, extent, distance to deposition site) and post-fire events. The inter-connected components of a fire regime can also influence charcoal accumulation and hence confuse the interpretation of any given record.

Here we apply attenuated total reflectance (ATR) Fourier-transform infrared (FTIR) spectroscopy to oven-produced charcoal formed at different temperatures (between 350 and 900°C) and to charcoal sampled in the field from fires of known severity. We show that we can discriminate IR spectra from these different 'pyro-intensities' using partial least squares regression.

We then apply these techniques to macroscopic charcoal (>250 micron) isolated from well-dated sedimentary sequences to consider 'pyro-intensity' over three temporal scales at sites in eastern Australia: (1) the last full glacial cycle at Thirlmere Lakes; (2) over the Holocene at sites in the Sydney Basin; and (3) over the last 500 years in Kosciuszko National Park.

The methods outlined represent a novel use of charcoal for considering changes to fire intensity and allow several contentious issues to be addressed about fire in eastern Australia. In this talk we focus on issues associated with the response of fire to climate change and variability, the human use of fire and the question *have fire regimes of the recent past increased in severity?*

O-1047

## Fire and fuel in Holocene northern Australian tropical savannas

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### Abstract

Fire has a long history of interaction with Australian ecosystems but poses a growing risk as future climate change is predicted to lengthen fire seasons and increase extreme fire weather. Tropical savannas cover almost one quarter (1.9 million km<sup>2</sup>) of the Australian land mass, and fire occurs here almost annually. A greater understanding of past fire regimes, and their environmental context, is essential for management and planning in an increasingly fire-prone landscape. Despite the central importance of fire in savanna ecosystems, the region remains understudied in Australian palaeofire research. In light of this knowledge gap, this study combines established and emerging optical and chemical methods for charcoal analysis in the context of northern Australian tropical savannas.

This study presents three new Holocene palaeofire records from tropical savanna wetland sites in far northern Australia, each with diverse land-use histories. Three methods were applied to achieve a more comprehensive understanding of fire and fuels over time in tropical savannas.

1. Charcoal abundance is presented for four size classes covering a local signal (>250  $\mu\text{m}$  and 250-125  $\mu\text{m}$ ) and surrounding regional signal (125-63  $\mu\text{m}$  and <63  $\mu\text{m}$ ).
2. Particle morphology and aspect ratio are proposed indicators of fuel type (e.g. grass, leaf, wood). However, this technique derives primarily from temperate environments, notably from experimental burns and sites in the Northern Hemisphere. Our study tests methods developed in temperate, Northern Hemisphere settings on charcoal from the Australian tropical savanna. Fuel type data are discussed using a morphotype classification system, and a length-width ratio of  $\geq 3.6$  is used to identify macroscopic grass particles.
3. We demonstrate the application of chemical quantification of pyrogenic carbon (PyC) as well as isotopic identification of fuel type. PyC abundance determined using hydrogen pyrolysis and  $\delta^{13}\text{C}$  composition (contribution of C<sub>3</sub> versus C<sub>4</sub> plants) are presented for the three sites and combined with the data generated using optical methods. All records are supported by <sup>210</sup>Pb and <sup>14</sup>C chronologies and XRF core scanner data on elemental composition.

Preliminary results show negligible variations in fuel composition through time at each site, with broad correspondence between fuel type determined by morphology and isotope composition. Variations are apparent between different charcoal size classes (macroscopic and microscopic) in both abundance and fuel composition at all sites, reflecting differences in local and regional fire signals and highlighting the importance of size differentiation during analysis.

This study is a step towards filling the palaeofire knowledge gap represented by northern Australia and is an important assessment of the application of existing palaeofire techniques to this unique context.

O-1048

## A new method to reconstruct past fire temperatures from charcoal chemistry

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### Abstract

Fire activity plays an important role in natural ecosystem function and as a tool for the human modification of ecosystems. For example ecological studies have shown that exposure to low temperature fire can be required to promote seed germination, while high temperature fires can remove all but the most specialist species. Furthermore, due to the intrinsic dangers of fire to people, management of fire today is a critical part of humans relationship with many ecosystems. In the past fire must also have played a critical role in ecosystem function and the ecosystem-human relationship. However, due to methodological constraints, palaeoecological studies do not typically reconstruct key aspects of past fire activity, such as temperature, focusing instead on the metrication of the past abundance of charcoal. Consequently, studies of palaeo-fire are likely missing information on how fires modified ecosystems in the past.

Here we present a new palaeoecological approach to reconstruct past fire temperatures. We achieve this through the exploration of the relationship between the chemical composition of charcoal and the temperature at which it was combusted. We use Fourier Transformed Infrared Spectroscopy (FTIR) to infer the chemical composition of a reference charcoal data set and compare these data with charcoal fragments picked from a sedimentary sequence dating from ca. 1400-450 years ago. The FTIR spectra of the datasets were statistically analysed to identify and match charcoals with similar chemical composition.

The inferred chemistry (FTIR spectra) of the reference and fossil charcoal were directly comparable, allowing likely fire temperatures to be assigned to the fossil fragments. Our results suggest that the use of FTIR analysis of charcoal can differentiate low (<400°C) and high (>500°C) temperature fires. The new method for reconstructing past fire temperatures presented here will, we hope, allow understanding from modern fire ecology to be tested against longer term palaeoecological data sets.

O-1049

## Evidence of anthropogenic modification of the landscape through biomass burning from an Amazon lake sediment core

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### Abstract

Anthropogenic modification of the Amazonian landscape has been one of the most debated issues in recent decades. A published lake sediment record of pollen, macrocharcoal (>125µm) and land use metrics from Lake Carana in the Amazon Tapajos Reserve shows the extent of human modification of the landscape throughout the past 4,500 years (Maezumi et al., 2018, Nature Plants). This record shows human land use for the cultivation of multiple annual crops and enrichment of edible plants that intensified with increased human populations. Of particular interest is the ecological impact of the use of fire in the pre-Columbian period. Here, we build upon these findings using a recently developed method for the determination of refractory black carbon (rBC) from lake sediments using a new incandescence-based method (Chellman et al., 2018, Limnology and Oceanography: Methods). Sub-micron rBC particles are approximately three orders of magnitude smaller than macrocharcoal fragments and transported through eolian rather than fluvial processes, BC records have thus been interpreted as reflecting regional to global scale carbon emissions from past fires.

The Lake Carana sediments were sampled at 0.5 cm intervals, dried, milled, and analyzed for rBC concentration and particle mass distribution. The rBC flux record demonstrates excellent agreement with the existing macrocharcoal record from Lake Carana. These records show a significant increase in biomass burning 1,250 years before present, associated with an increase in pre-Columbian activity, and a decrease in biomass burning associated with the arrival of Europeans and fire suppression during the rubber boom in the region. The rBC flux record also demonstrates agreement with BC records from South America and Antarctica, suggesting a regional change in biomass burning at these same time intervals. We also show an increase in the rBC particle mass distribution from ~2,500 to ~750 years before present associated with increased human modification of the landscape through biomass burning practices during the pre-Columbian period. rBC particle mass distribution reaches a low associated with fire suppression during the rubber boom and increases in the last two decades. The Lake Carana rBC and macrocharcoal measurements were compared with a neighbouring speleothem record which supports the interpretation that humans were the dominant driver of biomass burning in the eastern Amazon, rather than climate. This is in contrast to previous publications which have proposed climate to be the primary driver of biomass burning in the Southern Hemisphere during the past 2,500 years.

O-1050

## Ice-flow patterns and precise timing of ice sheet retreat across a dissected fjord landscape in western Norway

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### Abstract

We reconstruct patterns of ice flow and retreat of the south-western Scandinavian Ice Sheet across a landscape of dramatic topographic variations, where fjords hundreds of metres deep are oriented parallel, obliquely and at right angles to the dominant paleo-ice-flow direction. We combine field observations of glacial striae ( $n = 2900$ ) with LiDAR/GIS-mapping of 60 ice-marginal delta locations and altitudes to resolve the pattern and timing of retreat. Each ice-marginal delta is dated with decadal precision by reference to a regional shore-line diagram constructed from two relative sea-level curves dated with over 100 radiocarbon dates from isolation basins. This approach allows us to date the pattern of ice margin retreat and timing of deglaciation with unprecedented precision.

Rapid retreat commenced immediately at the Younger Dryas/Holocene boundary at 11,600 cal. years BP. Retreat rates were fast in the deepest fjords ( $160 \text{ m a}^{-1}$ ), slower in shallower fjords ( $60\text{--}80 \text{ m a}^{-1}$ ) and even slower on land. The fastest retreat rates,  $240 \text{ m a}^{-1}$  and  $340 \text{ m a}^{-1}$ , were experienced in the largest fjords, Hardangerfjorden and Sognefjorden, bordering the study area to the south and north, respectively. Cross-cutting glacial striae along wide fjords indicate the development of calving bays during retreat, which can be mapped up-fjord with decadal resolution. Observations of glacial striae directions confirms the isolation of ice caps/remnants on islands and peninsulas as retreat progressed. The combination of the complex pattern of deep fjords with fast ice-margin retreat, further increased the speed of deglaciation by isolating such ice remnants from the source areas of the main ice sheet. Ice-margin retreat paused, or slowed down, between 11,300–11,100 BP, probably due to cooling and/or increased precipitation during the Preboreal Oscillation. The final section of the ice margin that reached sea level is dated to 10,900 BP, and may be contemporaneous with the well-mapped Eidfjord-Osa moraines near the head of Hardangerfjorden.

During the Last Glacial Maximum, ice flow was towards the west across the entire study area, including across and independent of several-hundred meter deep fjords. During deglaciation the ice flow adjusted to the topography and the dominant flow direction switched towards the south-west

O-1051

## Retreat pattern and chronology of the Scandinavian Ice Sheet using high-resolution landform mapping and varved sediments

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### Abstract

The commonly-found annual silt-clay alternations in eastern and southern Sweden have, since the late 1800's, been used to map the retreat of the Scandinavian Ice Sheet by recording the site-to-site onset of proglacial lake sedimentation. The ensuing Swedish Varve Chronology is an unparalleled tool for linking the deglacial history of Sweden with associated palaeo-environmental change at an annual timescale. However, the construction of the chronology, especially for the earlier deglacial picture, has been fraught with problems arising from misidentifications, miscorrelations, and missing varves. The southeastern-most corner of Sweden (eastern Blekinge and southern Småland) is particularly problematic, with few varved records successfully connected to reconstruct local ice retreat, nor connected to existing robust regional chronologies. However, this region also encapsulates the abrupt warming of the Lateglacial Interstadial (~14.7 ka BP) and associated rapid and highly-dynamic ice margin retreat across the marine-terrestrial transition.

Here we revisit varved clay sequences in the Blekinge-Småland area, in conjunction with high-resolution digital terrain analysis of the pattern of ice margin retreat, in order to reconstruct the timing, style, and magnitude of ice sheet response to late-glacial warming. Digitisation and reanalysis of existing unpublished varve thickness records, typically ~30-120 varve years long, alongside acquisition and analysis of new varve sequences both on land and at sea, has enabled us to connect local varve sequences as well as to extend an existing robust chronology eastwards. Detailed mapping of glacial landforms from new terrestrial and bathymetric terrain data informs and supports the varve correlations, and reveals a complex pattern of ice flow and retreat in this area. The distribution and size of the eskers and meltwater channels draining the area indicates an area of high meltwater flux to the ice margin, with ice likely funneled into the Kalmar Strait (between the Swedish mainland and the island of Öland) as grounding line retreat responded to the local bathymetry. We present an ice retreat framework spanning the Blekinge-Småland region and interpret how both the pattern and magnitude of ice margin retreat responded to late-glacial warming.

O-1052

## Overridden ice-walled lake plains in Northern Sweden and their implications for the history and dynamics of the Scandinavian ice sheet

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### Abstract

Northern Fennoscandia is a key area for reconstructing the timing and extent of the Scandinavian ice sheet during the early and middle Weichselian. In this area, sediments and landforms have survived the Last Glacial Maximum and provide records of interstadial environments, glacial dynamics and ice-sheet extent in time and space. With few exceptions, most of these records are, however, fragmented and poorly constrained in time, which lead to large uncertainties and diverging interpretations of the glacial history.

A distinct feature is the so called Veiki moraine landscape which forms a lobate belt in northern Sweden (Fig. 1A, B). The Veiki moraine plateaux are currently interpreted as ice-walled lake plains that have been overridden by at least one ice sheet, and their distribution has been suggested to represent a former margin of the Scandinavian ice sheet. Their time of formation is proposed to be either Early or Middle Weichselian (Marine Isotope Stage 5c or 3).

We have used digital elevation models, derived from LiDAR data, for geomorphological mapping and studied the sediment architecture of the plateaux with ground-penetrating radar profiling (Fig. 1C, D). Sediments and small-scale structures have been documented in natural exposures and in excavated trenches as well as by coring. Luminescence and radiocarbon dating is used to determine the age of the deposits.

There is a range in plateau morphology from high, relatively flat-topped hills to low rim ridges surrounding a depression. The variation in height has a spatial trend, which may reflect original sediment abundance. Many plateaux have double rim ridges and these seem to largely consist of stratified sediments, either sorted or diamict, which were deposited by flowing water or by mass movements. Diamict sediments also seem to dominate the bulk of higher plateaux, while sandy-silty or organic sediments are found in the basins of lower landforms. The first dating results suggest an age of ca 50 ka for the basin infill sediments; more ages are pending.

Here we will present our interpretations of depositional processes and environments of Veiki moraines as well as the implications of the results for the glacial history of Fennoscandia.

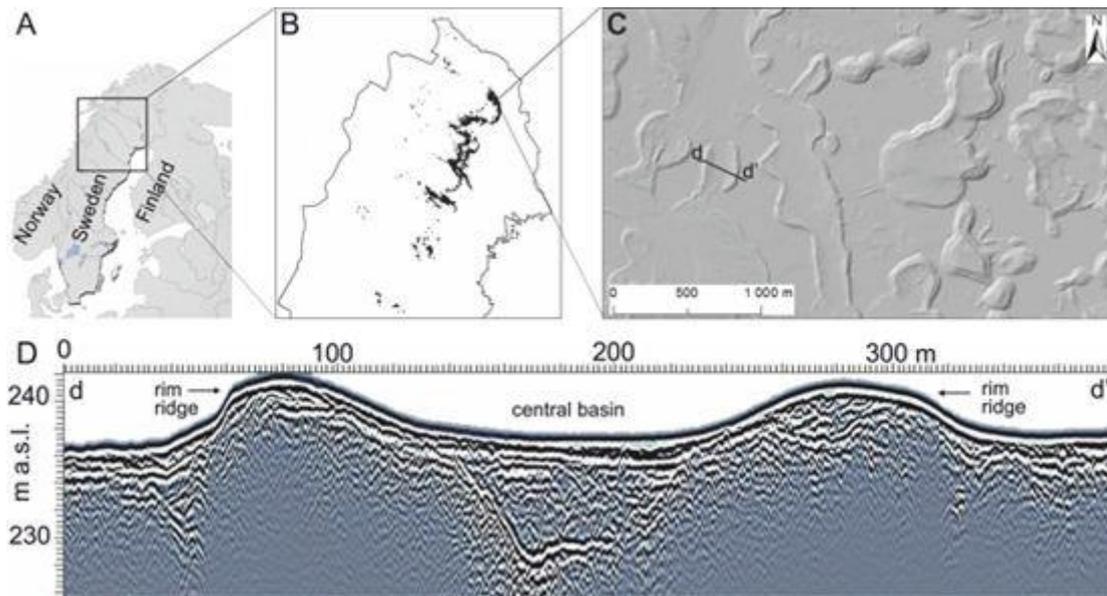


Figure 1. Location of Veiki moraine in northern Sweden (A, B), a hillshade of the Kortejärvi area with several Veiki moraine plateaux (C) and a 100 MHz ground-penetrating radar profile across one of the plateaux (see line d-d' in C for location).

O-1053

## Retreat of the southern front of the last Scandinavian Ice Sheet: dates and rates

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### Abstract

The last Scandinavian Ice Sheet (SIS) in northern Europe was one of the major Northern Hemisphere ice-sheets of the last glacial cycle. The southern fringe of the last SIS located to the south of the Baltic Basin reached its last maximum extent during the Late Weichselian, around 24–19 ka, and retreated gradually with episodes of regional and local ice readvances. The timing of the last SIS retreat reflects the Late Weichselian climate fluctuations, as well as the internal dynamics of the ice-sheet controlled largely by activation and deactivation of ice streams. Here, we present new results of erratic boulders dating with in-situ cosmogenic nuclides from the southern sector of the last SIS. This new data set compiled with already published but recalculated <sup>10</sup>Be surface exposure ages, as well as OSL/<sup>14</sup>C ages available in the literature, enabled to explore the timing of the last SIS maximum expansion and retreat with respect to the climate fluctuations during the Late Weichselian.

The new 55 <sup>10</sup>Be ages and one <sup>36</sup>Cl age come all from erratic located in-situ on glacial landforms in NW Poland, and were compiled with 20 already published <sup>10</sup>Be ages recalculated according to the most recent <sup>10</sup>Be production rate. The full surface exposure age dataset is interpreted as representing the initiation of the ice sheet retreat at the termination of specific glacial phases during the Late Weichselian. The error-weighted mean ages of the ice margin retreat for the Brandenburg, Frankfurt and Pomeranian Phases are calculated at  $20.7 \pm 0.8$  ka,  $17.3 \pm 0.5$  ka and  $16.4 \pm 0.3$  ka respectively. Based on these results and their correlation with independent age constraints (<sup>14</sup>C ages of organic deposits and OSL ages of sand deposits intercalated in tills deposited by the last SIS), the age of the maximum ice sheet limits during the Brandenburg, Frankfurt and Pomeranian Phases may be estimated at ~25–21 ka, ~22–18 ka and ~16.5 ka respectively.

The available geochronological data (cosmogenic nuclides, <sup>14</sup>C and OSL ages) together with the morphostratigraphical and lithostratigraphical contexts of the dating sites, were used as inputs in a Bayesian approach to model the chronology of the last deglaciation along the southern front of the SIS. This approach allows to construct a consistent chronology of the last SIS retreat and to model the rate of the ice front recession in northern Poland.

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O-1054

## Paired cosmogenic-nuclide data from two extreme locations with respect to the Last Glacial Maximum extent of the Scandinavian Ice Sheet

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### Abstract

Andøya and Rendalssølen are situated at two extreme locations with respect to the Last Glacial Maximum extent of the Scandinavian Ice Sheet; at the margin and beneath the ice divide, respectively. Both areas have bedrock surfaces providing <sup>10</sup>Be surface exposure ages older than the timing of the last deglaciation. Samples from such surfaces have been reprocessed for AMS analysis of Al and Be and erosion rates based on Markov Chain Monte Carlo modelling of <sup>26</sup>Al and <sup>10</sup>Be will be presented.

Andøya (69°N, 16°E) is the northernmost island of the Vesterålen archipelago in northern Norway. It is located between the 500-m-deep Andfjorden and the shelf. The short (8-15 km) distance to the shelf-break has two major implications with regard to ice-sheet boundary conditions: a proximity to northward flow of ocean currents, as well as to the margin of large continental ice sheets. Andøya is characterised by N-S trending mountain massifs with steep slopes hosting cirques and tarns, separated and surrounded by a gently undulating, mire-covered strandflat. Summits reach above 500 m a.s.l., and plateaus, arêtes and rock pinnacles are common. Exposed bedrock is relatively rare and mainly found in steep slopes and cirque headwalls. The bedrock mainly consists of granite, gneiss and gabbro.

Rendalssølen (61°N, 11°E, 1755 m a.s.l.) is an isolated mountain massif protruding the Femunden mountain plateau (600-1000 m a.s.l.) in southeastern Norway. The region has experienced limited glacial erosion, as indicated by few deep glacial valleys and widespread regolith cover, and this is usually explained as a result of cold-based glaciers and proximity to the ice divide. Openwork blockfields dominate the surface above 1100 m a.s.l. Exposed bedrock is found in steep slopes and cirque headwalls on the western side of the massif, and locally on the summits. The bedrock consists of arkosic sandstones, conglomerates and mudstones.

O-1055

## Exploring the controls on the early and stepped deglaciation of the western margin of the last British-Irish Ice Sheet

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### Abstract

During the Last Glacial Maximum (LGM) western Scotland and northwest Ireland supported coalescing ice centres that were drained respectively by ice streaming across the continental shelf of the Malin Sea between Ireland and Scotland, and westwards from Donegal Bay in Ireland. Geophysical data from the continental shelf, mapped terrestrial glacial landforms and a range of new and legacy radiocarbon and cosmogenic nuclide exposure ages from offshore and onshore locations provide a detailed history of ice sheet retreat in this large sector of the British-Irish Ice Sheet (BIIS). Our new data reveal that the ice margin was located at the shelf edge around 27 ka BP, with ice retreat having started by 26 ka BP, prior to the global LGM. Extensive grounding zone wedges across the Malin Sea shelf and arcuate recessional moraines on the Donegal Bay shelf indicate that net retreat of the ice margin was punctuated by readvances or stillstands, with evidence of a major stillstand on the mid-shelf at ~23–22 ka. Subsequent decoupling of Scottish and Irish-based ice occurred at ~20.6–19.4 ka BP and was accompanied by the cessation of ice streaming across the Malin Shelf. During this time, the ice margin in NW Ireland lay along the northern coastline and crossed the mouth of Donegal Bay, where the prominent ‘Donegal Bay Moraine’ records a major stillstand or possible readvance of the ice sheet during deglaciation between 20 and 18 ka BP. The contemporaneous ice margin off western Scotland lay offshore in the Sea of the Hebrides, and thereafter underwent slow oscillatory retreat, becoming grounded amongst the Inner Hebrides. Quite rapidly after this time and by 17–16 ka BP ice had retreated entirely on land in both western Scotland and NW Ireland, and by ~15.0 ka only residual land-based icefields occupied mountain source areas. Our chronologically-constrained reconstruction suggests that the initial retreat of the marine-terminating western margin of the BIIS was initially driven by local ice loading that increased water depths, promoting ice losses by calving, rather than forcing by rises in ocean and atmospheric temperature. Subsequent timing of episodic retreat is possibly linked to a combination of substrate and topographic characteristics and local sea-level changes rather than by external forcing. The final stages of deglaciation, however, appear to have been driven by changes in global temperature.

O-1056

## Reconstructing the Last Irish Ice Sheet in the Irish Midlands: Mapping Hummocky Topography using LiDAR and Ground-Penetrating Radar (GPR)

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### Abstract

Ice-marginal and sub-marginal landforms that formed during the recession of former ice sheets are widely used to reconstruct ice retreat dynamics, including shifting thermal conditions and marginal oscillations. This information is used to predict the future behaviour of modern ice sheets during recession. The last Irish Ice Sheet is of interest in this context, due to its southerly position and proximity to the North Atlantic. Prominent moraines along the coast and on the continental shelf clearly indicate ice margin positions during retreat. However, there are few well-developed moraines inland. Instead, hummocky topography, interpreted as evidence of ice stagnation, has been used as evidence for former ice-marginal positions. However, hummocky topography may form in a variety of ways and in a number of positions in relation to the ice margin.

In the central Irish Midlands hummocky topography has been previously used to indicate the position of the Drumlin Readvance Moraine (DRM), originally proposed to have formed during a readvance associated with the formation of extensive drumlin fields in the northern half of the island. However, the position and nature of this inland ice margin, and the evidence for ice readvance, remains under debate. Here we use a combination of LiDAR, mapping from high-resolution air photos, ground-penetrating radar (GPR) surveys, and sedimentological analyses to examine hummocky topography in 3D in the central Irish Midlands, in order to establish (i) how the topography formed and (ii) inform ice sheet dynamics during deglaciation.

Results show that extensive areas previously mapped as hummocky topography actually consist of multiple short, ice-marginal, diamicton ridges with streamlined crests, that have been superimposed on the remnants of mega-scale glacial lineations. We interpret these features as evidence for accelerated ice flow and ice readvance. A second type of hummocky topography, consisting of geometric arrangements of mounds, with evidence of normal faulting along the margins of individual mounds indicates supraglacial deposition of sediments within crevasses during ice melting. We conclude that at least one significant readvance of the Irish Ice Sheet associated with accelerated ice flow occurred in the central Irish Midlands, but that this post-dated drumlin formation.

**O-1057**

## **Geoconservation of Quaternary sites and landforms in the Republic of Ireland**

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### **Abstract**

The Quaternary is one of 16 themes addressing geological heritage in the Republic of Ireland in the Irish Geological Heritage Programme of Geological Survey Ireland (GSI). An original scheme to identify and designate statutory geological and geomorphological Natural Heritage Areas has been superseded for pragmatic and resource reasons. Now, the only effective geoconservation is through the listing of geoheritage sites as County Geological Sites. These are fully defined and documented in county-based audits led by the GSI but funded mainly by the Heritage Council and commissioned by the Heritage Officer in each county. On completion, the County Geological Sites (CGS) are adopted into County Development Plans, acquiring an effective protection against many, but not all developments requiring planning permission. Only raising landowner awareness through the audit process can protect sites from damage through activities such as field clearance, drainage or earthworks. Subsequent outreach activities such as pictorial exhibitions or non-technical books are also employed to promote geoconservation of such sites.

Around three quarters of all Republic of Ireland counties have now been audited and a more complete picture of many hundreds of important Irish Quaternary sites is developing. Quaternary CGS include erosional landforms such as corries and glaciated mountain terrains and depositional forms such as eskers, fans, drumlins, rogen moraine, erratics, kettle holes, pingos along with stratigraphical sites. Many sites have multiple interests, also representing karstic or coastal or lacustrine geology.

The presentation will include an overview of the progress with auditing Quaternary sites, show some highlights and lesser known examples, but also discuss the criteria for selection of sites. Of potential importance to other territories or agencies embarking on Quaternary geoconservation initiatives will be some discussion of the approaches taken to the definition of boundaries and the question of scale of sites. Also examined in the presentation is the issue of listing active quarries and pits within Quaternary sand and gravel deposits.

O-1058

## Conserving Scotland's Quaternary marine geoheritage: the role of Marine Protected Areas

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### Abstract

In comparison with the terrestrial environment, the conservation of marine geoheritage has been largely neglected. However, the application of new underwater survey techniques, using sonar, seismic and multibeam swath bathymetry methods, combined with coring of seabed sediments has revealed a great wealth of information about Scottish Quaternary nearshore and offshore landforms and deposits. The last Scottish Ice Sheet (SIS) and its predecessors were largely marine-based. Their geomorphological and dateable sedimentary records are particularly important for understanding the history and dynamics of marine-based ice sheets and their responses to climate change, ocean circulation and other forcing factors such as sea-level change. The landforms and deposits of the west coast fjords also demonstrate the later stages of deglaciation of the SIS and the subsequent re-expansion of glaciers in the North and West Highlands during the Loch Lomond (Younger Dryas) Stade. In addition to glacial landforms and deposits, the offshore and nearshore zones include submarine mass movements, submerged coastal landforms and dynamic bedforms. Using a methodology comparable to that of Geological Conservation Review, 35 key areas have been identified in Scottish territorial and offshore waters to represent the range of geological and geomorphological features of high scientific importance on the seabed. As well as for their scientific value, there is also growing recognition of the importance of seabed landforms and sediments in providing a platform supporting a diversity of marine habitats and fisheries, while the sediments form significant marine sinks for organic carbon from terrestrial sources. The Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009 have enabled the establishment of 33 Nature Conservation Marine Protected Areas (MPAs) within Scottish territorial and offshore waters. Although these are designated primarily for biodiversity, they incorporate many geoheritage features which provided a strong supporting case. In addition, other existing protected area designations that form part of the MPA network include key geoheritage areas. Practical and policy issues present challenges that demand a flexible approach to marine geoconservation involving integration with biodiversity management in existing protected areas, and elsewhere for stand-alone measures to be based on evidence of the sensitivity and vulnerability of the interests present.

O-1059

## Geoconservation comparisons, UK and Portugal: Rivers Thames and Tejo (Tagus)

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### Abstract

The authors have been undertaking comparison of the scientific records of the two important European rivers, Thames and Tejo, which share lower reaches with important evidence of hominin occupation during the Quaternary. Key differences are that the Thames also has an exemplary palaeontological record (largely lacking in the Tejo) and the Tejo has been more influenced by sea-level fluctuations, on account of the narrow offshore continental shelf. There are advanced geoconservation measures in the UK and Portugal, although differences exist in the approach used in the Thames and Tejo. Thames Quaternary interests are well covered by a network of statutory site designations, with a network of 'Sites of Special Scientific Interest' (SSSI) and, the jewel in the crown, the Swanscombe National Nature Reserve (NNR), where pieces of a single hominin skull were found in 1935, 1936 and 1955. Outreach measures are somewhat limited, however, and have long been problematic, as has casework in relation to development projects, this area being a prime area for infrastructure improvement (to the east of London, close to the river crossing of the orbital motorway). Outreach is to the fore in the Lower Tejo. Two contrasting examples are the 'Núcleo Museológico do Centro Português de Geo-História e Pré-História', a local museum established in an old school at Golegã, a small town in the middle Portuguese sector of the Tejo valley, with a particular relevance to children, and explanatory boards at a low-terrace archaeo-geological site at Foz do Enxarrique, near the border with Spain. In both valleys there is a significant overlap between Earth science and archaeology, with the Palaeolithic record from the Thames representing something of a template for the rest of southern Britain. The museum at Golegã covers both geological and archaeological interests, the former including fossils (dinosaurs and their footprints are prominent) from the Mesozoic strata that form the basement of the Tejo synclinal basin. The site at Foz do Enxarrique was excavated recently to investigate Mousterian and Upper Palaeolithic levels, with vertebrate fossils preserved in some of these low-level Pleistocene sediments.

O-1060

## Kula Unesco Global Geopark and its importance in terms of human history and Earth sciences

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### Abstract

Kula Geopark is located within the administrative territories of the Kula and Salihli districts of Manisa Province in the central part of the Gediz graben in the Aegean Region of Turkey. The Kula Geopark is situated in a tectonically active region and also constitutes one of the youngest volcanic fields in Turkey. This geopark is not only an important window for the study of tectonic forces in Western Turkey, but an excellent example, of world-wide comparative significance concerning geomorphology and climatic change. Due to its outstanding significance of tectonism, stratigraphy, paleobiology, paleoclimate, petrography, erosional process, and volcanism, it provides an ideal location for the study of both past and current and ongoing geological/ geomorphological processes, regional tectonic evolution and environmental change. The Geopark records the Earth's history spanning over 200 million years, and provides significant evidence from the paleotectonic and neotectonic periods. The Park offers wide-ranging insights into a vast array of Earth surface processes, both active and in the recent geological past. Therefore it presents an outstanding opportunity to engage with a wide variety of stakeholders in the Earth Sciences. The Kula Geopark contains more than 65 geosites, some of which have international importance in terms of Early Pleistocene climate changes, landscape evolution and Early Pleistocene hominin occupation of western Anatolia.

Kula Geopark, which won its global geopark title in 2013 for the first time, has been the subject of extensive scientific research in the last two decades. As a result of these scientific studies, geosites with different levels of importance were identified in the geopark area. In this presentation we introduce some examples.

**O-1061**

## **Holocene history of the Kungur forest-steppe (pre-Urals, Russia): origin and nature conservation**

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### **Abstract**

The Kungur forest-steppe is the most northern outpost of the European forest-steppe zone, the ecotone biome between woodlands and open landscapes stretching from the Carpathians to the Ural Mountains. The Kungur forest-steppe is located in the SE Perm region (Russia) within the zone of the pre-Uralian belt of hemiboreal spruce and fir-spruce forests with intermixed broadleaf trees. Due to the co-existence of boreal, temperate and steppe species, this island is characterized by high plant diversity and represents an important biodiversity hot-spot in the boreal zone. Intensive agriculture, pasture, and lumbering are leading to the loss of these unique steppe ecosystems. For sustainable protection management, a background in vegetation history is a necessary requirement. Several driving factors for the origin of the Kungur forest-steppe were proposed by botanists and geographers: geology, the climate of the past, or humans. However, no palaeoecological studies were implemented in order to understand its history. The project aims to understand the phenomenon of the Kungur forest-steppe in terms of its formation and dynamic within the hemiboreal zone of the pre-Urals. For this, peats and lacustrine sediments from Kungur forest-steppe are being studied in comparison to those from the typical hemiboreal forests. Studies on pollen and non-pollen palynomorphs (NPP) provide a basis for the reconstruction of vegetation and environmental history of both regions. While pollen is used for reconstructions of the vegetation history, NPP indicate other important processes for the landscape dynamic such as pasture, erosion intensity or eutrophication. Since almost no pollen studies were carried out in the entire Perm region, in this work I will present the first results of the project with a special emphasis on nature conservation issues.

O-1062

## **Beyond the bog: the importance and value of small-scale stratigraphic deposits in the landscape as archives for applied palaeoecology.**

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### **Abstract**

A growing desire for both high-nature value farming and rewilding as conservation strategies has highlighted a pressing need to understand long-term dynamic change in natural and semi-natural vegetation systems. Palaeoecology can, and does, contribute much to our understanding of ecological dynamics in these systems. Modern palaeoecology is increasingly focussed on linking with ecosystem models at regional and global scales, and scaling up collated datasets from lake and bog archives. However much information of application to nature conservation requires scaling down. There are still surprising gaps in our knowledge-base: areas where paleoecology is either missing, or at too coarse a temporal or spatial resolution to provide useful data for modern application. In order to develop understandings of local-scale ecological dynamics and their drivers new local-scale palaeoecological histories, from mosaics of small sites, in landscapes of interest are required. Scaling down and collecting new data can also assist in filling in the considerable spatial gaps in the current set of regional-scale palaeoecological models.

Whereas large areas of peat, or lake systems, are increasingly recognised, as carbon stores and for biodiversity value, with ecosystem service valuation driving protection, preservation and conservation of the geoheritage archive within them; in contrast, local-scale palaeoecological archives are seldom considered and are potentially being lost. Much ecologically relevant palaeoecology relies on samples from small peat hollows, ponds etc. within cultural and woodland landscapes. These deposits are often disturbed or drained with little thought for the historical and palaeoenvironmental records that they contain.

This paper will present and explore examples of local-scale palaeoecological research especially in the context of social-ecological systems in traditional agricultural and wooded landscapes. Examples from personal research in Ribblesdale, north Yorkshire, Scotland and the English Lake district will be presented, as well as some review of other studies. Via these examples, the paper aims to highlight the value of a range of non-standard palaeoecological sites within the landscape, and to urge consideration of a wider range of sites as contributing to a valuable palaeoecological geoheritage.

O-1064

## Late Pleistocene glacier chronologies and fault slip rates in the Teton Range, USA, revealed by $^{10}\text{Be}$ dating of fault-displaced moraines

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### Abstract

The Teton Range of the western USA is bound by the eastward-dipping Teton normal fault which extends ~70 km along the base of the mountains. An intertwined history of late Pleistocene glaciation and tectonism is evidenced by exquisitely preserved moraine sequences that are offset by prominent scarps along the trace of the Teton fault. Modeling studies suggest that fault slip rates are dynamically linked to glacial episodes in the greater Yellowstone-Teton region, such that faster slip is predicted to be stimulated by intervals of ice unloading during deglaciation. We aim to evaluate this prediction by developing chronologies of Yellowstone-Teton glacier fluctuations and constraining time-integrated offset rates along the Teton fault.

At its late Pleistocene maximum, the greater Yellowstone glacial system consisted of an ice cap on the Yellowstone Plateau that coalesced with glaciers from adjacent high mountains, including the Teton Range. Although the Tetons harbored only a small fraction of the greater Yellowstone ice mass, valley glaciers in this range left behind some of the region's best-preserved moraine sequences and ice-scoured bedrock, thus enabling reconstruction of detailed high-resolution glacier chronologies. Our investigations are focused on obtaining  $^{10}\text{Be}$  exposure ages of glacial landforms in drainages along the eastern Teton Range front. Specific dating targets include moraine ridge crests and deglaciated surfaces that are measurably displaced by the Teton fault, which affords an opportunity to determine time-averaged slip rates.

Initial  $^{10}\text{Be}$  results show that high lateral moraines in selected Teton drainages date to ~23–21 ka, whereas adjacent distal end moraines date to ~17–15 ka. These ages indicate construction of the high lateral moraines during an earlier phase of the last (Pinedale) glaciation, and suggest the younger end moraines record a subsequent advance and eventual retreat of more deeply scouring valley glaciers that extended further downvalley. Rapid and widespread deglaciation of the greater Yellowstone region occurred at ~15 ka, as defined by  $^{10}\text{Be}$  ages of recessional moraines and scoured bedrock in the Teton Range,  $^{10}\text{Be}$  ages of end moraines around the periphery of the Yellowstone ice cap, and basal-most radiocarbon ages in postglacial lake sediments in the Tetons. Measured vertical relief of fault scarps that cut across the older high lateral moraines and younger deglaciated surfaces, respectively, indicate faster offset rates as high as ~2.1 mm/yr from 22–15 ka followed by slower postglacial rates of ~0.8 mm/yr since 15 ka. These geomorphic constraints on late Pleistocene and Holocene tectonic activity are complemented by published and newly emerging paleoseismic evidence of Holocene slip rates from trench exposures across the Teton fault. Coordinated efforts involving additional  $^{10}\text{Be}$  exposure dating, fault trenching and lake sediment analyses are underway and will elucidate a more comprehensive glaciotectonic history of the Teton Range.

O-1065

## Constraining complex history of fluvial deposits using a $^{10}\text{Be}$ complex depth profile, OSL dating and modelling

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### Abstract

The Campine Plateau (CP, NE Belgium) is a low-altitude plateau (100-30 m a.s.l.) covered with fluvial sediments and gently dipping towards the north. The area west and east of the plateau is known to be in an erosive regime since the last 0.6 to 1 Ma, the dominant geomorphic process being differential erosion between the surrounding region and the relatively erosion resistant material of the CP. Nonetheless, the post-depositional history of the different lithological units of the CP remain poorly understood, and quantitative data on topographic evolution of these sediments are scarce. The objective of this research is to constrain depositional and post-depositional history, of a fluvial sediment sheet made of fine to coarse gravels (called “Zutendaal gravels”) of the CP over the last 1 Ma. To constrain scenarios explanative for the formation and evolution of the Zutendaal gravels, in-situ cosmogenic radionuclide (CRN) dating is applied using a  $^{10}\text{Be}$  depth-profile in the Zutendaal gravels, containing 14 samples covering 7 meters of depth at regular interval. The  $^{10}\text{Be}$  concentration of the sediments was measured at the AMS facility of ETH-Zurich.

Subsequently, a modelling approach simulating scenarios of alternating burial/erosion/stable episodes given as parameters, was developed. The model output is the concentration in  $^{10}\text{Be}$  over a 10 m depth column at centimeter resolution resulting from the parametrized sequence of episodes. The model encompasses 3 production pathways (spallation, fast muons and negative muons) and dynamically adjusts  $^{10}\text{Be}$  concentrations as a function of time-variable denudation and burial, inheritance and total exposure duration.

Realistic model scenarios are firstly constrained with geological evidence, i.e. intra-formational hiatuses encompassing a series of fining-upward sequences in the 7 topmost meters. We also applied independent dating of the upper sandy unit using optically stimulated luminescence (OSL). This allowed model scenarios to be further constrained by both providing minimum absolute age for this youngest sequence and a minimum burial duration for the unit located below.

Model output is then compared with observed data. Diagnostic scenarios for the observed  $^{10}\text{Be}$  concentrations and its variability in the Zutendaal gravels were determined from optimization of the Nash-Sutcliffe efficiency index, over a limited range of unconstrained parameter values.

O-1066

## Integrating soil characteristics and cosmogenic nuclide dating in the study of active faults: examples from the southwestern Basin and Range

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### Abstract

Widespread application of cosmogenic isotope dating of alluvial fan surfaces and deposits reveals intriguing temporal patterns in fault slip over timescales ranging from  $10^4$ –  $10^5$ yr. Such behavior may emerge from static and dynamic stress changes during earthquake cycles, geometric and mechanical interactions among fault networks, and/or variations in climatically modulated surface loading. At present, epistemic uncertainties associated with post-depositional modification of alluvial surfaces can severely limit the utility of cosmogenic nuclide (TCN) ages to address the timescales of these processes. Moreover, the difficulty and expense of obtaining ages often limits their application to a single site along a given structure. Soil profile development indices (PDI) can be acquired for a fraction of time and cost of absolute ages, and calibrated soil chronosequences can provide a reliable chronologic framework across a region of similar climate.

We illustrate this approach with an example drawn from recent work along active faults in eastern California. We developed a soil chronosequence that relies on well-preserved and dated surfaces from Panamint Valley and the western Mojave Desert spanning a range in age from  $\sim 10^3$ -  $10^5$ ka. These surfaces have been dated using a combination of  $^{14}\text{C}$  (wood and tufa), optically-stimulated luminescence (OSL), and  $^{10}\text{Be}$  depth profiles. Morphologic descriptions of soil development were conducted at all sites and combined using a PDI index. We rely on these observations to establish local soil stratigraphy and to evaluate post-depositional modification of surfaces (erosion or deposition) critical for the interpretation of TCN results. Along the Garlock fault, sinistral displacement of a  $\sim 30$  ka fan generated a shutter ridge that blocked drainage along the southern flank of the Slate Range; soils developed within an alluvial fan unit truncated by the shutter ridge are  $\sim 2$ -4 ka, suggesting an exceptionally rapid pulse of slip in the late Holocene that is 2-3 times the long-term average rate (Rittase et al., 2014). In southern Panamint Valley, right-lateral displacement of a debris-flow levee provides a precise estimate of dextral-oblique fault slip along the Panamint Valley fault zone. However, exposure ages of unweathered boulders on debris-flow levees range from 20 – 40 ka. The degree of soil development and local cross-cutting relationships with dated Late Pleistocene lacustrine shorelines indicate that this flow is only  $\sim 9$ -12 ka. The cosmogenic nuclide concentrations in these boulders are interpreted to reflect significant inheritance accumulated in the steep, high-relief catchment. In both examples, the degree of soil development provides critical information that informs and refines the dating of the surface. Our results demonstrate how radiometric dating of geomorphic surfaces can be combined with soil stratigraphic studies to refine our understanding of active fault systems.

O-1067

## Integration of soil-profile development improves age interpretation of TCN depth profiles: An example from Late Pleistocene lake shorelines, southwestern US

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### Abstract

Interpretations of cosmogenic isotope accumulation in the shallow subsurface are well-known to be sensitive to post-depositional surface modification by erosion and deposition. The influence of these processes is typically the single largest source of uncertainty in age determinations from depth profiles of isotope concentration. Here we show how soil stratigraphy can assess the relative stability of depositional surfaces locally, and can provide relative age-control. We focus on a Late Pleistocene lacustrine shoreline in Panamint Valley, California. The age of this feature has been problematic; previous efforts to date it with a range of techniques generally yield ages that fall between 50 – 100 ka. Such ages are inconsistent with well-dated lacustrine highstands in adjacent valleys, where shorelines are dated to ~180 ka (Death Valley) and ~160 ka (Searles Valley). To assess this discrepancy, we combine TCN (<sup>10</sup>Be and <sup>36</sup>Cl) dating techniques with soil stratigraphy on both shoreline remnants (gravel beach ridges) and adjacent alluvial fans.

Four soil profiles on preserved remnant surfaces of a gravel beach ridge (~615 m amsl). The soils all consist of a well-developed Av-ABvk-Btkyz-BCKy-CB-Ck vertical horizon sequence with soil depths of ~125-135 cm. Both the vesicular Av-ABvk horizon (6-8 cm thick, prismatic structure) and Btkyz horizon sequences (~65-85 cm thick, 7.5YR-5YR hues, prismatic to blocky structure) are well-developed. All remnant surfaces are level, at the same elevation, have smooth surfaces (no rills, gullies), and are covered with well-developed desert pavement. The lateral distribution of identical soil profiles and surface properties indicate that these soils formed beneath the original depositional surface and have experienced minimal net erosion.

TCN depth profiles yield disparate dates resulting from assumed erosion rates. Best-fit model ages from a <sup>10</sup>Be depth-profile are ~71-106 ka (-10-30 cm total erosion). By comparison, <sup>36</sup>Cl depth-profile ages are ~164 ka if model-predicted erosion rates (~100 cm total erosion) are used, and ~84-111 ka if -10-30 cm total erosion is considered. Removal of a potential outlier sample from the model analysis yields best-fit ages of 74-96 and 143 ka (-10-30, and 100 cm erosion, respectively). Expected ages of the beach ridge soils are ~70-80 ka when a well-constrained regional soil chronosequence (14 dated soils ~0.6 to ~176 ka) is considered. Consistent soil stratigraphy and regular surface morphology indicate minimal erosion and do not support model results that imply >30 cm erosion. The presence of the well-developed Av horizon and Btkyz horizon sequence form a systematic vertical soil-horizon sequence supporting this argument. If net-zero erosion is assumed, as indicated by the soil-stratigraphy, the resulting shoreline age is ~88 ka from both TCN chronometers and is reasonably consistent with the independent chronosequence data. These results show that inclusion of soil stratigraphy can greatly enhance age interpretations of TCN depth profile ages.

O-1068

## Glacial chrono-stratigraphy constrained by rock avalanches along the Mendoza river valley, Argentine Central Andes (32° S).

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### Abstract

Huge rock avalanches clustered in the northern extreme of the Cordón del Plata range (32°S) stratigraphically related to Pleistocene glacial drifts and valley fill deposits were chrono-stratigraphically studied. Cosmogenic dating (TCN) on surficial blocks of the rock avalanche deposits and optically stimulated luminescence dating (OSL) of paleo-lakes dammed by these rock avalanches were performed. These dates (17 TCN and 4 OSL) determine Middle-Late Pleistocene ages contrasting with the previously glacial chronology of Mendoza river valley that was established based on relative dating techniques, paleontological context, and tephrochronology. Hence, the previously dated ash layers were geochemically analyzed by ICP spectrometry to clarify if indeed those tephra relate to a single event.

TCN dating technique opens the possibility of dating landslide directly constituting the most useful tool for Quaternary studies for the Arid Central Andes where tephrochronology is limited to relative ages, and thermoluminescence techniques (TL/OSL) are limited to fine sediments. Late-Middle Pleistocene age obtained by TCN for rock avalanches clustered in the Cordón del Plata range is significantly confident and consistent with stratigraphic studies. Besides, new findings throw light on the regional neotectonic as the studied rock avalanches, presumably triggered by  $M > 6$  earthquakes, are gathered along the active Carrera Fault System. As well, obtained cosmogenic dates adjust the ages for the first horse (*Hippidion devillei*) remains found in the province of Mendoza, initially assigned to the Middle Pleistocene by stratigraphic relationships.

Clearly, our findings help to redefine the geomorphological evolution of the Mendoza river valley. Especially indicate that the glacial stratigraphy earlier proposed must be reconsidered. In addition, our data suggest that the Carrera Fault system bounding the valleys of the Cordillera del Plata has been more recently active than earlier proposed.

O-1069

## Chlorine degassing of Early Holocene lava domes, central Turkey, estimated by cosmogenic $^{36}\text{Cl}$ and radiocarbon dating

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### Abstract

We provide a novel approach to estimate the Cl degassing on young lavas and deliver new evidence of geochronology of the volcanism and activity of the Cappadocia Volcanic Province in the central Anatolia during the early Holocene. We applied a combined approach using the cosmogenic  $^{36}\text{Cl}$  and radiocarbon dating methods to unravel the Cl degassing partition coefficients and eruption chronologies of three volcanic domes on the slopes of the Mount Erciyes (ancient name *Argaeusor Argaios*), the largest stratovolcano in central Turkey. The famous ancient geographer, Strabo (63 B.C.-23 A.D.) described swampy plains around Mt. Argaios, where local fires break out in pits. Here, we collected 27 cosmogenic samples to date three monogenetic parasitic lava domes on the flanks of the volcano. Our ages indicate an early Holocene eruption activity of lava flows and yielded average age range between 6-10 ka. We also applied radiocarbon dating using two charcoal samples from burned tree branches in a pyroclastic flow related to the lava domes. Charcoals provided an average age of  $9.7 \pm 0.1$  ka cal. B.P. (calibrated with Calib 7.1). We argue that since the radiocarbon age does not agree with the cosmogenic ages, the nucleogenic  $^{36}\text{Cl}$  were probably affected by the Cl degassing of the magma. Our study suggests that the radiocarbon age indeed lies between the 0% Cl degassing ( $6.8 \pm 0.5$  ka, under nucleogenic  $^{36}\text{Cl}$  equilibrium) and the 100% degassing conditions ( $9.9 \pm 0.6$  ka, under nucleogenic  $^{36}\text{Cl}$  disequilibrium), which implies a partial Cl degassing (93%) during the eruption. Earlier estimates of Cl degassing from melt inclusions, matrix glass, and volcanic vents are range from 17% to 67%. Our value is somewhat higher than earlier estimates and the difference may result from the miscalculated nucleogenic and/or low-energy neutron production of  $^{36}\text{Cl}$ , uncertainties arising from the corrections due to hydrogen-rich cover (i.e., snow) of lava surfaces or due to unconsidered geological complications.

O-1070

## Erosion of low-relief basement by the Fennoscandian ice sheet based on bedrock $^{10}\text{Be}$ and $^{26}\text{Al}$

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### Abstract

Glacial erosion can be intensive and it has created some of the most dramatic landscapes on Earth. Estimated glacial erosion rates range over multiple orders of magnitude, with very low erosion evidenced by preservation of landforms under non-erosive ice and high erosion illustrated by deeply carved fjords and by sediment output from present-day glaciers. Most glacial erosion estimates are derived from high-relief mountainous landscapes and their glaciers. Ice sheets that covered North America and northern Eurasia during the Quaternary covered low-relief topography and it is the erosional imprint of these ice sheets on low-relief landscapes that is the focus of our study.

To investigate glacial erosion of low-relief topography under large ice sheets we have measured  $^{10}\text{Be}$  and  $^{26}\text{Al}$  in 32 bedrock samples from the east coast of Sweden. These samples are derived from a low-relief (0-70 m a.s.l.) crystalline basement region around Forsmark with well-constrained timing and rates of deglaciation and isostatic rebound. Simple exposure ages range from 2 to 71 ka. Taking the shielding by water due to isostatic rebound into account, all samples but one have  $^{10}\text{Be}$  and  $^{26}\text{Al}$  concentrations higher than commensurate for deglaciation, with most samples being 3.5-10 ka too old. This cosmogenic inheritance due to prior exposure enables us to explore model space for past glacial erosion. Tracking the cosmogenic nuclide production rate over time and depth, we simulate the buildup of  $^{10}\text{Be}$  and  $^{26}\text{Al}$  under a range of scenarios with varying ice cover durations, subaerial erosion rates, and modes of glacial erosion (constant erosion rate or constant erosion depth for each ice cover period). Under these assumptions and if excluding one sample, the simulations yield Quaternary glacial erosion lower than 0.4 m/ka or 3.3 m per ice cover period. For most of the samples for which we yield a solution for both  $^{10}\text{Be}$  and  $^{26}\text{Al}$ , glacial erosion was restricted to 0.04-0.09 m/ka or 0.4-1.1 m per ice cover period. For the last glaciation (last 100 ka), this translates into a total erosion of only 1.6-3.5 m. A comparison with previously published  $^{10}\text{Be}$  and  $^{26}\text{Al}$  data from bedrock samples in low-relief regions of Fennoscandia lends support to limited glacial erosion, with a large number of samples displaying cosmogenic inheritance. Our data and analysis show that the glacial erosion rate of the low-relief landscape under the last Fennoscandian ice sheet may be significantly lower than common glacial erosion rates in alpine regions.

O-1071

## Deciphering ~45.000 years of Arctic Ocean lithostratigraphic variability through multivariate statistical analysis

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### Abstract

Our understanding of past climate conditions in the Arctic Ocean has been hampered by poor age control caused in part by low sedimentation rates (< 1cm/kyr), hiatuses during glacial intervals as well as the scarcity and poor preservation of calcareous nanno- and microfossils in the sediments. Although recent advances using variations in single element (e.g. Mn) content or physical sediment properties (e.g. bulk density, grain size, colour) of the recovered sediments have aided Arctic core-to-core correlations, unique depositional events and post-depositional changes can complicate stratigraphic interpretations based on individual or even multiple, physical or chemical parameters. Furthermore, clear correlations between cores using physical and chemical parameters are not always possible to establish. To tackle this issue, we developed an algorithm that combines clustering and multivariate ordination to test the interrelation of multiple input parameters (e.g. an array of individual XRF elemental contents), and subsequently identifies statistically significant stratigraphic units on centimetre to decimetre scales. Our preliminary results show that a distinct sedimentological pattern during the past 45,000 years characterizes cores from the region of the Morris Jesup Rise and the Greenland side of the Lomonosov Ridge. Stratigraphic patterns of the Siberian Side of the Lomonosov Ridge yield distinct differences, thus allowing for novel insights into sedimentary processes shaping the different regions within the Arctic Ocean. We also argue that our approach can compensate for some of the weakness of single element or proxy applications, and hence aid the construction of a robust stratigraphic framework for a wide geographical range of Arctic Ocean sediments.

O-1072

## Towards 250,000 years of paleoenvironmental and paleoclimate evolution recorded in Onepoto Maar Lake, New Zealand.

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### Abstract

Long, continuous maar lake sediment sequences spanning at least 100 ka are well documented and researched in the Northern Hemisphere mid-latitudes and have enabled climate reconstructions as far back as the Mid-Pleistocene. In contrast, records of similar quality and length are rare in the Southern Hemisphere and tend to be discontinuous. However, Auckland's maar lakes provide long, continuous, high-quality, laminated sediment records that are very suitable to study Southwest Pacific paleoclimate for the last two glacial cycles at resolutions down to a sub-decadal to even annual-scale.

Onepoto paleolake, located within the Auckland Volcanic Field, New Zealand, contains a lacustrine sediment record spanning from ca. 9 ka BP back to its formation (ca. 250 ka). The sediments have been subject to various research projects focusing on the preserved tephra layers or on paleoenvironmental research questions. Yet, until recently no complete sediment record had been retrieved. Therefore, we here present a complete composite lake sediment record at sub-decadal resolution unique in the Southern Hemisphere and established from a recent drilling campaign undertaken in 2018 and well-preserved, core material from extracted 2011. Furthermore, based on continuous, high-resolution micro-XRF data sets, we provide new insights into the sedimentary and environmental evolution of the lake, as well as climatic-forcing recorded in the sediments. These novel results, together with related work currently underway for nearby Orakei Maar, will substantially reduce the existing gap in two glacial cycle paleoclimate data from the Southern Hemisphere mid-latitudes.

New Zealand is ideal for the application of tephrochronology due to the many active volcanic centers in the Taupo Volcanic Zone and the Auckland region. However, in contrast to the well-dated post-46 ka record, the tephra older than 46 ka suffer from poor age control, the dating of which depends on discontinuous sequences. Nevertheless, using sedimentation rates extrapolated from the ca 46 ka Rotoehu tephra to the base of the laminated Onepoto Maar paleolake sequence we expect to be able to produce ages robust enough to relate observed environmental events in the sequence to broader climatic trends and environmental events in the study area and eventually to larger interregional, and perhaps even global trends. Additionally,  $^{40}\text{Ar}/^{39}\text{Ar}$  dating on basalt lava from the crater base as well as U-Th measurements will provide further evidence to narrow down absolute ages in the lower part of the paleolake sequence.

**O-1073**

## **Using XRF to differentiate between sediments of glacial and periglacial origin in the Vale of York, UK**

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### **Abstract**

Glaciolacustrine deposits are important archives of palaeoenvironmental change and suitable for high-resolution analyses by XRF core scanners. In particular, captured elemental data are useful for estimating grain size and determining sediment provenance. As yet, there are limited investigations into sediment provenance that differentiate between glacially-derived inputs resulting from seasonal melting of adjacent ice lobes and periglacially-derived inputs from weathering of the surrounding extra-glacial terrain. To test this approach we compare elemental data—acquired using an Avaatech XRF core scanner—from known glacial and periglacial deposits in eastern England with high-resolution elemental data from the basin-fill sediments in the Vale of York. These sediments comprise alternating units of reddish brown to dark greyish brown laminated to faintly stratified silty clay and dark greyish brown silt interbedded with yellowish brown silty sand. They were deposited during the Devensian (Weichselian) glaciation, when ice lobes of the British–Irish Ice Sheet impounded regional drainage, forming glacial Lake Humber. The adjacent uplands are mantled by discontinuous deposits of gravelly clay, and matrix-rich diamicton interdigitated with sands and gravels. These are interpreted as colluvial deposits, sourced largely by periglacial weathering of the underlying frost-susceptible and predominantly calcareous bedrock. Using principal component analysis, we identify sedimentary texture and carbonate content as the two dominant parameters (principal components) explaining elemental variance in our data. While this can differentiate between the glacial and periglacial end members it is less robust for other aspects of the basin-fill elemental data, where additional sedimentary parameters such as colour reflectance are needed.

O-1074

## The link between precipitation and sedimentation processes in a subtropical mountain lake, north-eastern Taiwan during late Holocene

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### Abstract

Monsoon rainfall in eastern Asia is an essential sub-system of the global monsoonal belt and affects nearly one-quarter of the world's population. Yet our understanding of its variability on different geological time scales is limited. An ideal location to study East Asian monsoonal variability is Taiwan, an island located in western subtropical Pacific, and situated in the purview of the East Asian monsoonal system. Additionally, the island is also exposed to strong typhoon activity during summer/autumn. This provides the unique opportunity to study monsoon and typhoon changes in the western subtropical Pacific during the geological past. However, Holocene paleoclimate records retrieved from various lakes in Taiwan have shown discrepancies in their recorded climate variability. This is aided by the lack of modern sedimentological observations which limit our understanding of the mechanisms controlling lake sedimentation and thus introduces uncertainty in comparisons between lake records. In order to tackle this issue, sediment traps were collected monthly since July 2017 at Cueifong Lake (24°30' N, 121°36' E, 1840 m above sea level) in northeastern Taiwan. The collected data encompasses variations in sediment influx during winter and summer monsoon seasons, as well as sediment related to typhoon events. These results enable us to specify the main factors controlling sediment deposited in the Cueifong Lake and link these to seasonal precipitation variability. Subsequently, our modern findings have been applied to the lake sediment, allowing core records to be used for paleoclimatic reconstructions of a ~1.8 m long sediment core retrieved from the deepest part of the lake covering the last ~3 kyr, based on <sup>210</sup>Pb and <sup>14</sup>C dating. A multi-proxy approach analysis was applied for the sediment core consisting of X-ray fluorescence (XRF) core scanning, grain-size analysis, geochemical analysis (TOC, TN), and stable carbon isotope (d<sup>13</sup>C) analysis.

Our modern findings indicate that decreases in sediment grainsize occur during high lake level periods, which correspond with winter monsoon season. In the core record, three periods of sediment fining (high Rb/Sr, reduced mean grain-size) can be observed during 1040-1150 yr BP, 1680-1810 yr BP, and 2400-2550 yr BP. These intervals are also accompanied by decreased TOC and thus point towards high lake level periods. Additionally, we find another period of sediment fining between 1900-2010 CE, accompanied by a sharp increase in the inc/coh ratio. This most likely correlates to a logging event around the lake during 1912-1982 CE. Our results not only clearly demonstrate the unique ability of the alpine lakes in Taiwan to act as a truthful recorder of East Asian monsoon variability, but also highlight the need to better link modern observations and paleo-records.

O-1075

## High resolution scanning of South Pacific lake sediment: relative benefits offered by state-of-the-art micro-XRF and SEM systems

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### Abstract

A methodological evaluation for the efficient investigation of laminated core material collected from the South Pacific islands is presented that is expected to be of broad interest to the core scanning community. Efficient identification of laminae, their number, chemistry and mineralogy provide crucial information in inferring sediment accumulation rates and environmental and climate change. The material investigated was collected as part of NERC grant NE/N006674/1 - **The legacy of cyclone Pam: a unique opportunity to build a long term record of cyclone activity in the western tropical Pacific** (PIs David Sear, Pete Langdon and Ian Croudace). The project is part of a multi-party study involving the PIs, 3 PhD students and collaborating specialists. Analytical data obtained from measurements of a 10 cm section of resin impregnated lake sediment from Lake Te Roto (Atiu Island, Cook Islands) will be discussed. Investigation of the sediment block was made using Itrax, Bruker M4+ micro-XRF and Leo SEM systems. The benefits of using the different approaches are evaluated with the purpose of establishing a preferred approach that would be applied to detailed investigation of all or selected core material collected from two field campaigns. The analytical timeline including an efficiency budget (sample preparation, analysis) as well as the robustness and comparability of analytical outputs (textural, density and elemental variations) will be presented.

Figure: SEM montage of BSE-Ca and S for impregnated Lake Atiu laminated sediment (10 cm). Darker layers have higher mean atomic number. Very bright areas represent Ca and S (hence gypsum) which are inferred to correlate with drying episodes.

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O-1076

## Don't count on it – Robust use and interpretation of geochemical records obtained by XRF core scanning

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### Abstract

The use of XRF core scanning data in terms of geochemical element records has become a routine analysis. Most commonly used are element intensity records produced by XRF scanners, despite the known weaknesses these records. The great benefit of XRF cores scanning is that analyses are performed directly at the core surface, which provides continuous element records at sub-millimeter sampling resolution. However, element intensity records are not only affected variations in the chemical composition but also by variations of the sample geometry, attenuation, and matrix effect down core. Aside of matrix effects, these variations are effectively eliminated by normalization of element intensities in terms of element ratios or proportions of a constant number of elements. Unfortunately, matrix effects are non-linear and not effectively compensated by normalization. By estimation of relative matrix effects, log-ratio calibration is the only model providing a solution for non-linear matrix effects.

The log-ratio calibration model demonstrated that log-ratios of XRF intensities are linearly related to log-ratios of geochemical concentrations, and are consistent with statistical analysis of compositional data, unlike net counts or element intensities. Consequently, log-ratios of element intensities provide the most reliable records for statistical analysis of XRF core scanning data in terms of chemical composition. These advantages are combined in the Xelerate software package and facilitate statistical analysis, calibration and visualization of XRF element records and core photographs. This software provides detailed and robust statistical analyses of sediment composition and reduces the influence of elements with a low precision by including analytical uncertainties as derived from replicate scans or quantitative calibration. Here we present several examples that demonstrate the benefit of this method for climatic and environmental interpretations of XRF cores scanning results.

O-1077

## An empirical method to predict sediment grain size from XRF core scanner measurements

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### Abstract

Grain size is one of the most fundamental properties of sediments. It is frequently used in paleoclimate, paleoceanographic and paleoenvironmental research as a proxy for river discharge, current and wind strength, and to identify mass flow deposits. Measuring grain-size is, however, time-consuming and destructive. Given the strong influence of grain size on sediment inorganic geochemistry, single element variations measured by X-ray fluorescence (XRF) core scanning are increasingly used to estimate grain-size variations at high resolution in sediment cores. This approach is however limited to a narrow grain-size range since individual elements only monotonically relate to grain size over a narrow size range. Here, we present a simple, code-free, multi-element technique based on Partial Least Square regression to predict sediment mean grain size from inorganic geochemical data over the range of sizes commonly encountered in sedimentary basins. The method was first tested using river sediment samples separated in eleven grain-size fractions and it was later successfully applied to two sediment cores from the Chilean fjords, with mean grain sizes ranging from 16–31 and 7–180  $\mu\text{m}$ . Our technique only requires measuring grain size on a limited number (around ten) of selected training samples, and it allows to predict mean grain size at XRF core scanner resolution. Provided sediment provenance, weathering, and diagenesis are relatively stable through time, this technique is applicable to any lake or marine sediment core, and we anticipate that it will result in a significant increase in the resolution of sediment proxy records of climate and environmental change.

O-1078

## How tides and rivers shape flood-protecting levees and crevasses

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### Abstract

Natural levees and crevasse splays are highly-elevated geomorphological overbank features in dynamic delta and tidal environments. They are important for past and future human occupation and protection against floods. Their dimensions vary owing to differences in sediment supply, flood regime and floodplain properties. Despite their importance for safety around estuaries, their formative controls have so far been mainly analysed for fluvial environments only. We focus on the levees and crevasses of the Old Rhine estuary in the Netherlands to better understand how tidal and fluvial processes form these overbanks deposits. The main Rhine branch debouched into this estuary between 6500 and 1000 cal yr BP. The 50 km long channel belt runs through a vast peatland and formed the natural corridor for the limes in the Roman period. We use existing geological data and new field data to reconstruct levee evolution, which we correlate to reconstructed changing boundary conditions over the late Holocene (fluvial discharge, tides, sediment supply). Numerical and experimental modelling in Delft3D and the Metronome facility respectively were used to test the mechanisms behind levee evolution inferred from the Holocene geological record.

The variation in overbanks in space and time along the Old Rhine shows the influence of tides and tidal backwaters. Orientation, abundance and size of crevasse splays indicates increasing tidal influence towards the estuary mouth. Field data furthermore reveals two distinct phases of overbank deposition from the fluvial to the coastal realm. In the middle of the channel belts' lifespan around 3500-3000 BP, the thickest and siltiest levees formed together with 10 km long narrow crevasses penetrating into the peatland. As the estuary mouth became smaller the tidal influence reduced after ca. 3000 BP these crevasse splays became less active. The importance of tides is confirmed by our model results showing that they trigger relatively large and abundant levee-crevasse complexes. The effects of increased fine sediment supply are observed from ca. 2800 BP onwards. This human-induced effect was caused by land-use changes (i.e. deforestation) in the upstream Rhine catchment. As a result, peat formation stopped and relatively clayey, very wide and thin overbank deposits were formed. Our experimental and numerical modelling demonstrates that, besides these external forcings, floodplain setting (e.g. vegetation density) and autogenic feedbacks between accommodation space (max. water level) and levee growth, are important drivers in levee dimensions and phasing. This study shows how tidal levees are distinctly different from their fluvial counterparts and provides important clues on how vulnerable landscapes can change when human induced changes in sediment load and river discharge occur.

O-1079

## Prehistoric coastal changes of the Mekong delta: Implications for recent erosion

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### Abstract

The coastline of the Mekong delta is thought to have suffered the decline in the fluvial sediment supply after the enhanced human disturbance, especially the construction of hydropower dams in the upper reach, since the late 20th century. However, coastal erosion observed after 1970's is not fully accounted for by the recent disturbance, and thus may also reflect the longer-term trends in sediment discharge. To compare with the historical observation, we report prehistoric changes of a 320 km stretch of the South China Sea coastline of the Mekong delta over the last 2500 years based on fossilized shoreline records and their OSL and radiocarbon dating. The South China Sea coast of the Mekong delta is divided into two parts: the northeastern part characterized by inter-distributary sandy compartments, and southwestern muddy coast. The coastline is affected by the southwestward longshore drift. The northeastern sandy compartments show minor shifts of depocenter, but their total accretion rate is consistent ranging from 0.7 to 1.2 km<sup>2</sup>/year before 400 year BP, followed by a modest increase to 2 km<sup>2</sup>/year in the last 400 years. The accretion rate of the southwestern muddy coast was 2 km<sup>2</sup>/year before 1400 year BP and increased by several times after 1400 year BP. The Camau Peninsula, which outlines a remarkably prominent delta shoreline towards the sea, was formed entirely in the last 600 years. Accelerated accretion of the southwestern shoreline after 600 year BP is thus inferred, owing to an overwhelming mud supply, while the modest accretion of the northeastern compartments after 400 year BP is caused by sand supply. These separate trends may be linked to the contrast between the northeastern and southwestern shorelines observed over the last 20 years. The overwhelming mud supply is possibly linked to the migration of the large population into the Yunnan in China, the uppermost reach of the Mekong River, in the 14th century and extensive shifting cultivation. The majority of the current erosion is happening in the southwestern coastline, which started even before the hydropower dam construction. This severe erosion thus may reflect longer-term fluctuations in mud supply that was overwhelming over the last 600 years but sharply decreased sometime before 1970's, which are not relevant with the hydropower dam construction.

O-1080

## Rapid shifts in storm climate 3,500-2,200 years ago, detected from the ancient coastal formations – Estonia, NE Baltic Sea.

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### Abstract

Beach ridge systems and foredune plains are widespread worldwide and are common features on many types of coasts. Postglacially uplifting seacoasts of Estonia are rich in rhythmic coastal landforms such as ridge-depression sequences and spits. These rhythmic patterns may extend kilometres inland from the current shoreline. It should be noted that the Baltic Sea coast is a tideless environment with water level fluctuations forced by strong storms. The ridge systems in this region are offering a unique opportunity to examine the events over at least the last 6,500 years when the Baltic Sea mean water table has been consistently dropping and a steady shoreline advancement has been punctuated by rare extreme events. We have found that the signs of past storms are clearly reflected in the internal structure and size of the ancient ridges. The current study is focusing on high ridge systems containing extensive seaward-dipping layers formed 3,500–3,000 years ago and the following small, nearly unnoticeable ridges, formed 3,000-2,200 years ago.

In this study, ground-penetrating radar survey, complemented with drilling results and GIS analyses based on LiDAR topography were carried out in the coastal ridge systems. Four study areas with different exposure to the storms and different rates of land uplift were selected. The records of aeolian sand influx into the nearby peat bogs and past climatic records of northern Europe were compared with recent (last 100 years) shore processes. The findings of this study are supported by previously published luminescence dating results.

We have found that higher ridges with extensive seaward-dipping layers, large foredune systems and major spits were formed 3,500-3,000 years ago. Also, an increased sand influx was reported into the bogs in this period. The period was characterised by increased storminess – similar to today's situation. A rapid drop in the heights and nearly no seaward dipping layers characterise the ridges formed during the next 800 years. Sand influx into the bogs also dropped significantly. This suggests a rapid regime shift towards much calmer conditions. It should be noted that the contemporary increase in storminess is related to the shifts in cyclone trajectories. Similar shifts have probably taken place 3,500 years ago. However, it is likely that around 3,000 years ago the shift did not restore the previous state but created a new one. We may assume that during continuous shift of cyclone trajectories northwards, a certain threshold was exceeded and the cyclones were probably redirected along the high Scandinavian mountains to the north leaving our region in more continental climatic conditions. A number of palaeoclimatic records also support this theory. Similar shift cannot be ruled out today.

**O-1081**

## **Recent coastal barrier evolution in the Bras d'Or Lake, Nova Scotia, Canada**

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### **Abstract**

Barrier beaches enclosing small ponds and lagoons (locally known as 'barachois') form a significant part of the Bras d'Or Lake shoreline in Cape Breton, Nova Scotia, Canada. The Bras d'Or Lake itself, is a large, inland sea, with many of its coarse gravel barriers developed into harbours, roads and recreational areas. Well preserved, submerged ( $\leq 25$  m below msl) early-mid Holocene coastal landforms identified from multibeam acoustic imagery in the Bras d'Or Lake, including spits, tombolos and barrier beaches (Shaw et al. 2006), may represent an indication of things to come, especially given the predicted relative sea-level rise for this region over the next 100 years: the highest in Canada (James et al., 2014). An understanding of the age of the barachois, the paleoenvironmental records archived in their underlying sediments, and the morphodynamics of their barriers (i.e. how quickly they evolve from growth or stable phases to landward-migrating or submerging phases), represents important baseline data with which modern and future coastal dynamics may be compared, and with which vulnerability to future sea-level rise and coastal erosion can be estimated. Interpretations of recently acquired acoustic data collected inside the barachois (shallow seismic, sidescan sonar), as well as sediment core data (XRF, radiocarbon dates, lithology, and organic matter), will be presented.

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O-1082

## Applying faunal indices for palaeoenvironmental reconstructions with benthic foraminifera: a case from a Holocene succession of the Po Delta, Italy

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### Abstract

In the last decades, the depositional history of the Po River coastal plain has been studied using different environmental proxies. In this work we first ever attempt to interpret the palaeoenvironmental evolution of a shallow marine succession from this area (core 205-S9, collected about 10 km south of the modern Po Delta) using several diversity indices, bivariate analysis and Murray's Ternary Plot. We also tried to find out the potentials and limits of these tools in reconstructing palaeoenvironments.

The analysed shallow marine succession was formed in response to the last phases of sea-level rise (ca. 8 kyr BP) and the Holocene regression resulted from the high-stand coastal progradation. In this part of the core, Murray ternary plot and Bivariate plot of Fisher's alpha index and Shannon-Wiener index show two distinct clusters highlighting high percentage of calcareous porcelaneous forms in the lower part and high percentage of calcareous hyaline taxa in the middle and upper portions. Fischer's  $\alpha$  index and species richness values provide evidence for three intervals: the lower is highly diversified while in the middle the value gets decreases and in the upper the value increases but not as high as lower part. Evenness (E) and Dominance (D) indices show that the lower part is characterised by a homogeneous, highly diversified and evenly distributed fauna. In contrast, the middle part shows a strong dominance of few species with low faunal diversity with some variations in the upper part. The ratio of epifaunal and infaunal species defined oxygenated bottom water condition with low organic matter in the lower part, and high organic matter with relatively low oxygen concentration in the upper part.

All these indices clearly discriminate between a lower and a middle-upper portion of the sediment succession. The integration with the distribution of selected species allows to attribute the lower interval to a shallow marine environment with low fluvial influence (transgressive barrier and offshore transition), whereas middle and upper parts record an increase of fluvial influence (prodelta). Therefore, the applied indices can be considered as good proxies for recognition of deltaic conditions and identification of changes in riverine influence within shallow marine deposits. Furthermore, most indices highlight variations in foraminiferal distribution within the prodelta. Combining foraminiferal distribution and indices values, these variations can be attributed to unsteady freshwater influx.

O-1083

## Holocene paleoecology of black mangrove (*Avicennia germinans*) along the northern Gulf of Mexico coast, U.S.A.

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### Abstract

The modern distribution of black mangrove shows a disjunct distribution along the northern Gulf of Mexico Coast of the U.S. It has dense populations in southern and central Florida, the Mississippi River delta, and western Texas, but notable gaps exist in the Florida Panhandle, Alabama, Mississippi, western Louisiana, and east-central Texas. It is unknown whether the disjunction is a result of recent long-distance dispersal in response to climatic warming, or range contraction from a former widespread distribution attributable to climatic cooling during the Little Ice Age. We reconstructed the Late Holocene history of *Avicennia* along the northern Gulf Coast by means of palynological and stratigraphic techniques and investigated their modern distribution and environmental controls by means of remote sensing and geomorphological mapping using drones. Multiple sediment cores were taken from a suite of coastal locations from Cedar Keys and Apalachicola Bay in Florida, Port Fourchon and Rockefeller Wildlife Refuge in Louisiana, and the Bolivar Peninsula and Port Aransas in Texas. Pollen data from Port Fourchon, Louisiana, where dense populations of black mangrove occur today, show that *Avicennia* pollen was absent throughout much of the Late Holocene and only started to appear in the uppermost sediments less than 100 years ago. Pollen data from the Rockefeller Wildlife Refuge in western Louisiana, where black mangroves are absent today, suggest that *Avicennia* never colonized this coastal area even during the Medieval Warm Period. Our drone surveys and ground observations of modern coastal vegetation communities in southern Louisiana and eastern Texas show that *Avicennia* populations suffered significant mortality as a result of the freezing events in the winter of 2017/2018, but the overall long-term trend was marked by population expansion and colonization in response to warmer winters over the past few decades. The paleoecological data so far seem to support the hypothesis that the modern disjunct distribution of *Avicennia* along the northern Gulf Coast was a function of long-distance dispersal in response to climate warming during the past century, and black mangrove had not expanded beyond its present distribution limit during the Late Holocene. Spatial modeling and transfer function studies will be conducted to relate modern and fossil pollen data to contemporary environmental parameters to shed light on the environmental factors limiting the distribution of black mangroves along the northern Gulf Coast.

O-1084

## It's in your glass: A history of sea level, storminess and human activity from the Laphroaig peat bog

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### Abstract

Severe winter windstorms in northwestern Europe have become an increasingly common occurrence over the last few decades. This increase in storminess is thought to be a result of global warming and, as such, is expected to intensify in the future. The IPCC has however, “low confidence” in these future projections, particularly on regional scales. This is in part due to a lack of continuous data detailing natural changes in storminess, which limits our ability to predict future scenarios. Peat-based storm records can be exploited to fill this gap. To date these records have been from coastal areas located downwind from significant sand sources. The basic premise is that stronger winds during stormier conditions transport larger grains to these peat bogs. The island of Islay on the southwest coast of Scotland provides an excellent location for studying storminess as it meets three key criteria: (i) it is one of the first landmasses to be hit by storms crossing the Atlantic Ocean; (ii) the wet maritime climate favours peat development, and the island therefore is rich in deposits; and (iii) the island has extensive sand dune and tidal flat systems providing an abundance of sand.

For this study a ~4 m long peat sequence was recovered from the Laphroaig peat bog (of whisky fame). This is an ombrotrophic (atmospherically fed) peat deposit located ~600 m downwind from a coastal dune system on Laggan Bay. Conventional peat paleostorm proxies such as ash content and grain size were used to acquire detail about changes in relative wind strengths over time. This was complimented by mineralogical analyses and multi-element XRF data treated using Principal Component Analysis. If we only consider changes in ash contents and Principal Component 1, which is interpreted to represent the input of large grained detrital minerals and therefore storms, no storm signals are found between ~7000 to 3000 cal yr BP. However, the grain size data from this period show several increases in the proportion of larger grain sizes (>150 µm), suggesting stronger winds. Elemental biplots show that the source of the detrital minerals reaching the peat bog transitioned ~3000 cal yr BP. These features can be linked to falling sea levels, consequent changes in sand source (size and location) and the build up of the dune system on Laggan Bay. At Laphroaig we find general agreement with available regional peat based storm records including key events such as the 2.8 event and the Little Ice Age. Broadly speaking, observed periods of storminess co-occur with periods of ice rafting in the North Atlantic, although multiple drivers of varying temporal importance are likely and need to be further investigated. This highlights the need for further such peat paleostorm records.

**O-1085**

## **Conditions for Dansgaard-Oeschger like oscillations and abrupt climate changes**

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### **Abstract**

During the last termination of ice age cycle (deglaciation), Heinrich event 1 as well as B/A, Antarctic Cold Reversal (ACR) and Younger Dryas occurred as millennial scale climate changes. On the other hand, millennial scale climate changes such as D-O cycles recorded in ice core and deep sea cores in both hemisphere seem to occur more frequently during the mid-glacial state than during the early or late glacial state. Here we ran several sensitivity experiments and deglaciation simulations using a coupled atmosphere and ocean GCM (MIROC4m AOGCM) developed in Japan and analyzed the stability of AMOC and climate. Many model experiments were run for longer than 10000 years under many different conditions of constant Greenhouse Gas levels, obliquity with/without glacial ice sheet and with and without freshwater flux into North Atlantic region. The results show large self-sustained oscillation of AMOC and high latitude temperature change similar to B/A and D-O cycles, comparable with ice core data and deep-sea data for some cases. We show that the D-O like oscillation and B/A-Y/D type change occur with Glacial ice sheets under limited range of CO<sub>2</sub>, obliquity, and freshwater forcing. Implication on the mechanism and the conditions of the millennial scale climate changes for the past time period is discussed.

O-1086

## An Atlantic-Pacific seesaw in overturning circulation and biogeochemistry

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### Abstract

Ocean circulation at high latitudes exerts a strong control on heat transport, biological productivity, and ocean-atmosphere CO<sub>2</sub> exchange. Today, the North Atlantic and North Pacific have contrasting circulation regimes, with vigorous deep-water formation in the North Atlantic, but only limited local ventilation in the North Pacific. This drives distinct patterns of nutrient supply and heat transport in each basin, and represents a first order asymmetry in global biogeochemistry and climate. Here, using a variety of high-resolution sediment core records, we demonstrate that this Atlantic-Pacific circulation asymmetry was repeatedly reversed during rapid climate change events of the last ice age, with invigorated overturning in the North Pacific during intervals of reduced overturning in the North Atlantic. This drove abrupt changes in nutrient and CO<sub>2</sub> supply to the high latitude surface ocean, with reduced overturning associated with high biogenic flux. Using an earth system model, and by analogy to the modern circulation and nutrient regimes of the North Atlantic and Pacific, we show that a “stratified” basin allows nutrients to accumulate, whereas a vigorous local overturning circulation flushes nutrients from high latitudes. Our results thus challenge the paradigm that regional stratification necessarily drives reduced nutrient supply. They also support the idea of a dynamic link between Atlantic and Pacific overturning and suggest an active role for the North Pacific in glacial climate and CO<sub>2</sub> change.

O-1087

## A $^{10}\text{Be}$ -dated record of ice sheet response to Termination 1 in the North Atlantic as a proxy for atmospheric temperature

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### Abstract

The recent refinement of cosmogenic nuclide dating has revolutionised glacial chronologies and, in turn, our understanding of the manifestation and terrestrial impact of abrupt climate change. With the objective of providing a robust geologic baseline for conceptual and numerical models, we present a new record of cryospheric change, as a proxy for atmospheric temperature, in the northern British Isles. This chronology, constrained with cosmogenic beryllium-10 and calculated using the new Scottish  $^{10}\text{Be}$  production rate (Putnam *et al.*, 2018), captures the intricate pattern of deglaciation and periodic readvance of the British ice sheet following the Last Glacial Maximum (Termination 1). Exploiting the highly sensitive, yet intrinsically straightforward, relationship between temperature and glacier mass balance, this and similar emerging glacial records are painting a fascinating picture of 'stadial' climate that contrasts with the traditional view of these severe climatic perturbations. Taken together with existing palaeoclimate data for Termination 1, the glacial record from northern Scotland implies a central role for seasonality in North Atlantic stadial-interstadial climate and, crucially, helps place regional events into a global context.

[Putnam, A., et al., 2018. An in situ  \$^{10}\text{Be}\$  production-rate calibration from a  \$^{14}\text{C}\$ -dated late-glacial moraine belt in Rannoch Moor, central Scottish Highlands. \*Quaternary Geochronology\* 50, 109-125. DOI: \[10.1016/j.quageo.2018.11.006\]\(https://doi.org/10.1016/j.quageo.2018.11.006\)](#)

O-1088

## A deglacial ice core record of synoptic activity in West Antarctica: links to the southern westerlies, upwelling and CO<sub>2</sub>

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### Abstract

The last deglaciation (20-10 ka BP) represents a rich, and sometimes abrupt, interplay between different components of the Earth System set in motion by gradual orbital variations. The large-scale atmospheric circulation is an important component of these coupled changes, for example via the strength and meridional position of the southern hemisphere (SH) westerly winds. Proxy evidence on past atmospheric circulation changes is typically indirect, for example via tropical hydrology, isotopic composition of meteoric waters, ocean frontal positions, El Niño strength, windblown dust, or ocean upwelling.

Here we present a newly developed ice core gas-phase proxy that directly samples an important component of the large-scale atmospheric circulation: synoptic-scale pressure variability. Krypton-86 excess ( $^{86}\text{Kr}_{\text{xs}} = \delta^{86/82}\text{Kr} - \delta^{40/36}\text{Ar}$ ) reflects the degree of gravitational disequilibrium in the firn layer. Surface pressure variations from passing weather systems drive macroscopic air movement in the firn, causing gravitational disequilibrium and a shift in  $^{86}\text{Kr}_{\text{xs}}$  towards negative values. Note that ice cores do not record individual weather systems, but rather the time-average intensity of barometric variability.

We present a 'core-top' calibration of  $^{86}\text{Kr}_{\text{xs}}$  using late-Holocene ice core samples from nine locations around Antarctica and Greenland that shows a strong correlation between multi-sample-average  $^{86}\text{Kr}_{\text{xs}}$  and site synoptic variability from ERA-interim reanalysis, providing the first validation of this new proxy. We address several caveats in the interpretation.

Next, we present a new  $^{86}\text{Kr}_{\text{xs}}$  record from the WAIS Divide ice core in West Antarctica through the last deglaciation. We find a negative excursion in  $^{86}\text{Kr}_{\text{xs}}$  during the deglaciation, with peak values during Heinrich Stadial 1 and the Younger Dryas – abrupt cold phases in the North Atlantic associated with warming in Antarctica and the global ocean interior, and rising atmospheric CO<sub>2</sub>. We interpret the  $^{86}\text{Kr}_{\text{xs}}$  record as an increase in barometric variability in West Antarctica during the last deglaciation. We suggest this may be linked to poleward displacement of the SH westerly winds during this time, which brings storm tracks closer to Antarctica, allowing cyclonic systems to penetrate more deeply into the continent.



The  $^{86}\text{Kr}_{\text{xs}}$  record moreover closely resembles Southern Ocean Opal flux records that have been interpreted as markers of wind-driven upwelling, suggesting both may have a common driver, with the SH westerly winds being a candidate. The coincidence of enhanced SO upwelling with periods of atmospheric  $\text{CO}_2$  increases is commonly cited as evidence of wind-driven ventilation of respired carbon from the abyssal ocean controlling the deglacial  $\text{CO}_2$  rise. Our gas-phase storminess proxy allows direct comparison to ice core  $\text{CO}_2$  records with zero age uncertainty. More broadly, our work provides a new forensic tool for investigating past changes to large-scale atmospheric circulation, to which synoptic activity is closely tied.

O-1089

## The impact of abrupt sea ice loss on Greenland water isotopes during the Last Glacial Period

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### Abstract

Greenland ice cores provide excellent evidence of past abrupt climate changes. However, there is no universally accepted theory of how and why these Dansgaard Oeschger (DO) events occur. Several mechanisms have been proposed to explain DO events, including sea ice, ice shelf build-up, ice sheets, atmospheric circulation, and meltwater changes. DO event temperature reconstructions depend on the stable water isotope  $\delta^{18}\text{O}$  and nitrogen isotope measurements from Greenland ice cores: interpretation of these measurements holds the key to understanding the nature of DO events. Here, we demonstrate the primary importance of sea ice as a control on Greenland ice core  $\delta^{18}\text{O}$ : 95% of the variability in  $\delta^{18}\text{O}$  in southern Greenland is explained by DO event sea ice changes. Our suite of DO events, simulated using a general circulation model, accurately captures the amplitude of  $\delta^{18}\text{O}$  enrichment during the abrupt DO event onsets. Simulated geographical variability is broadly consistent with available ice core evidence. We find an hitherto unknown sensitivity of the  $\delta^{18}\text{O}$  paleothermometer to the magnitude of DO event temperature increase: the change in  $\delta^{18}\text{O}$  per K temperature increase reduces with DO event amplitude. We show that this effect is controlled by precipitation seasonality.

O-1090

## Impact of the Channel Outburst Flood at 455 kyrs before present on North Atlantic climate

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### Abstract

Geophysical evidence from the seafloor of the English Channel provides strong evidence for the occurrence of an outburst flood caused by the spillover of a proglacial lake in the southern part of the North Sea that breached the chalk ridge, thereby forming the Strait of Dover (Gupta et al. 2017). Marine sediment cores from the Bay of Biscay indicate that the initial breach occurred at 455 ka (Toucanne et al. 2009) during the Elsterian–Anglian glaciation which is correlated to Marine Isotope Stage (MIS) 12. Here we studied MIS 12 at Site U1385 (Shackleton site) on the Iberian Margin and identified a distinct peak in ice rafted detritus (IRD) at 455 ka, which is accompanied by an increase in the abundance of the polar foraminifer *Neogloboquadrina pachyderma* (sinistral). At the same level in the core, the 455-ka event is marked by a decrease in benthic  $\delta^{13}\text{C}$  indicating a reduction in the influence of North Atlantic Deep Water and an increase in remineralized carbon in the deep North Atlantic. The EPICA-Dome C ice core indicates the 455-ka event coincides with a drop in atmospheric methane (a northern hemisphere signal; Loulergue et al., 2008) and an increase in Antarctic temperature (Jouzel et al., 2007), which is a typical signature of a bipolar seesaw response to freshwater forcing and reduced overturning circulation in the North Atlantic. These results suggest the Channel Outburst Flood had a significant impact on climate at 455 ka, which will be tested by model simulations forced by a point source of meltwater emanating from the English Channel.

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O-1091

**Strong Atlantic overturning circulation under high-latitude freshwater input during marine isotope stage 11: Insight from modelling and nitrogen isotope.**

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**Abstract**

The marine isotope stage 11 (MIS 11) is often used as a potential analogue for the Holocene because of its similarities regarding orbital and greenhouse gas forcing (e.g., Droxler et al., 2003). However, recent studies portrayed the surface subpolar North Atlantic to be fresher by about 6 salinity units compared to today (Kandiano et al., 2017). This added to the growing body of evidence that the subpolar North Atlantic was characterized by much fresher and cooler surface waters during MIS 11 peak interglacial conditions (MIS 11 *sensu stricto(ss)*) compared to the Holocene (Kandiano et al., 2016; Thibodeau et al., 2017). Interestingly, MIS 11ss is often characterized by a strong AMOC (e.g., Vázquez Riveiros et al., 2013; Dickson et al., 2009), which seems at odds with the notion of major fresh and cold water input at high latitudes (e.g., Rahmstorf et al., 2005). Here, I show that the fresh and cold surface layer in the Nordic Seas created a strong salinity gradient in the polar North Atlantic at the beginning of the interglacial concurrent with strong variation in the surface nutrient utilization. I further demonstrate, with the help of a simple box model, that the weakening of this gradient in the peak interglacial allowed for the onset of deep water formation in the Nordic Seas, which contributed to a global intensification of the AMOC. Finally, I highlight that this thermohaline-driven sharp intensification of the AMOC is concomitant with the observed general enrichment in North Atlantic benthic  $\delta^{13}\text{C}$  (Lisiecki, 2010) and could help explain the abnormally long duration of MIS 11 (Dickson et al., 2009), underlining the importance of the North Atlantic freshwater budget in regulating AMOC.

O-1092

## Social resilience to climate instability in mainland Southeast Asia: the influence of socio-political factors

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### Abstract

For communities across the Southeast Asian mainland during the last millennium, episodes of societal florescence, decline and mobility are often linked to climate fluctuations (Lieberman and Buckley, 2012). For example, the Khmer kingdom, which dominated the mainland between the 9<sup>th</sup> and 15<sup>th</sup> century C.E., experienced an alternating series of severe dry and wet episodes during the 14<sup>th</sup> and 15<sup>th</sup> centuries C.E. that broadly coincided with a dramatic reconfiguration of Khmer society and its borders. At this time, Khmer political power waned, territory contracted, and urban populations across the kingdom migrated away from urban complexes toward smaller centres on the kingdom's periphery, presenting an apparent case of mobility and rupture in the face of heightened climate variability (Buckley et al., 2010, Hua et al., 2017).

However, two aspects of this narrative are worthy of further investigation. First, placed in the context of long-term climate records and socio-ecological dynamics the climate variability of the 14<sup>th</sup> and 15<sup>th</sup> centuries should not have been catastrophic for mainland communities. Second, recent palaeoenvironmental research indicates that land use attenuation within Angkor (Penny et al., in review) and at two (at least) secondary centres elsewhere in the kingdom (Penny et al., 2014, Hall et al., 2019) was complex and protracted and had begun a century or more before the climate crises of the preceding centuries, while other centres maintained populations throughout these centuries of climate instability (Hall et al., 2018). Therefore, what characteristics of these communities and Khmer society overall accounted for this variability in mobility and rupture at this time? This paper discusses the influence of socio-political factors, particularly increasing power centralisation in the kingdom, on the vulnerability of urban-agrarian populations through this important transition period in Southeast Asia, and discusses the implications for Cambodian communities facing increased climate variability in the contemporary landscape.

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O-1093

## What is behind crop change? Agricultural decision-making and water availability during the Neolithic in the NW Mediterranean region

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### Abstract

Archaeobotanical research has been so far widely implemented for the study of agricultural practices in the past. The NW Mediterranean region is a particularly interesting area during the Neolithic period because it witnessed the contact between at least two different farming traditions corresponding to the two waves of advance of Neolithic groups from SW Asia: the central-european LBK tradition and the Mediterranean one. Crop changes over the early Neolithic and subsequent periods in this area might be due to several factors, both of cultural and climatic nature. In the framework of the SNSF-funded AgriChange project (2018-2021, PP00P1\_170515), we want to use several on-site proxies to approach climatic fluctuations in the past in connection to crop change. For this presentation we want to focus on stable isotope analyses (mainly C, but also N) obtained from charred grains in order to see if crop changes observed in the archaeobotanical record coincide with changes in any of these values, and thus help us to start putting forward better-funded hypotheses regarding agricultural decision-making during the Neolithic period. There is abundant existing research on the use of stable isotopes as proxies for crop spring-water availability (C) and manuring (N). For this presentation we chose one site with an excellent and well-dated stratigraphy: the Cave of Can Sadurní (Barcelona, Spain). It contains deposits dated between 5400 cal BC to 3900 cal BC and abundant plant macroremains. Previous archaeobotanical research showed a first phase with a high importance of glume wheats in the late 6<sup>th</sup> millennium cal BC, followed by a period with more naked barley and naked wheat during most of the 5<sup>th</sup> millennium cal BC and a subsequent increase of glume wheats towards the end of this phase. According to soil micromorphology analyses, glume wheats coincide with drier phases, while naked wheat and naked barley expand in wetter periods. This is therefore an ideal case study to attempt an approach using stable isotope values and contribute to the main question of this session regarding the potential role of environmental factors in economic change.

O-1094

## Developed viticulture and winemaking in the mountains of Transcaucasia - an indicator of the Holocene climate warming

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### Abstract

The discovery of new markers for the presence of wine in archaeological vessels according to palynological data, which, in addition to grape pollen, is starch and epidermis of grapes, as well as the remnants of fruitfly *Drosophylla*, helped to clarify the history of wine in Transcaucasia. The first and the earliest traces of viticulture and winemaking were found in the cultural layers and in the vessels of the early agricultural Neolithic settlements in the territory of Georgia. According to the result of radiocarbon dating, these archaeological sites existed 5900-5500 BC. This is the earliest discovery of wine residues in the world. A long palynological study of material from Neolithic settlements, as well as from lake and sea sediments of the Transcaucasia showed that 8,000 years ago the climate became much warmer than at the very beginning of the Holocene. According to palynological and archeobotanical data, the next stage of intensive development of viticulture and wine-making was associated with the Holocene optimum and dates from the turn of IV and III millennia BC. At this time, a new Kuro-Araxes culture appears on the territory of the Transcaucasus, which was a very long culture. The warm climate at this time contributed to the spread of the population in the highlands. Traces of viticulture according to palynological data were found on the settlements and barrows of the high mountains of Transcaucasia up to 2000 m.a.s.l. The important point is the fact that the wine at this time takes a cult purpose as the vessels with wine are placed in the grave of the dead for the afterlife. Wine rhytons are also found on the altar of the temple of the settlement of Aradeti-Orgora, the layers of which date back to 14C as the 31 - 28th centuries BC. Traces of intensive viticulture in the high mountains are noted in the material of the mounds of the period of the Bedeni culture, dated to 14C by 25-22 centuries BC. This period in the South Caucasus is also characterized by a significant warming of the climate. In the first millennium BC, and especially with the warming climate of 6-4 centuries BC, wine-making on the territory of Georgia acquires a special role in human economic activity. For storing wine, a new kind of huge Kvevri ceramic tableware appears. There, they were completely buried in the ground, which contributed to the best preservation of wine. Such a long history of the development of viticulture in the South Caucasus, and especially on the territory of Georgia, has led to a large number of grape varieties (525 varieties).

**O-1095**

## **Neolithic plant economy in the SW Baltic area – a long-term perspective**

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<sup>1</sup>CAU Kiel, Kiel, Germany. <sup>2</sup>Archäologisches Landesamt Schleswig-Holstein, Schleswig, Germany

### **Abstract**

Continuous collective effort in retrieving and analysing archaeobotanical material from the Neolithic sites in SW Baltic region has resulted in a large collection of the remains and the data on plant production and use during the Neolithic. Combined with the high-resolution absolute chronology, the qualitative and quantitative archaeobotanical data now offer a comprehensive picture of the introduction and establishment of crop production and plant economy. Further, the results allow tracking of trends and changes in the choice of cultivated crops and gathered plants through time. The arable weed record gives insight into the conditions in which crops grew and helps identify specific agricultural strategies. Changes in the plant assemblages and the subsistence strategies are discussed in the light of environmental and cultural developments.

O-1096

## Prehistoric Land Use and Settlement Dynamics in Mining Districts of the Eastern Alps

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### Abstract

Prehistoric peopling of the Eastern Alps occurred in several waves according to palynological data. The first occurred in the 4<sup>th</sup> millennium BC and seems to be correlated to hydrological changes in the southern Alpine foreland. In the 3<sup>rd</sup> and 2<sup>nd</sup> millennium BC follow further settlement phases. Thereby the possibility of the procurement of raw materials appears to be relevant. The research centre “HiMAT - The History of Mining Activities in the Tyrol and adjacent areas: Impact on Environment and Human Societies” at Innsbruck University deals with these issues in a multidisciplinary approach. A crucial problem in the evaluation of the pollen record is the segregation of agricultural and mining activities. Here we present a multi-proxy approach by pollen, geochemistry and historical data to separate these two components. A calibration data set of pollen and geochemical analyses in a mediaeval and Early Modern mining district reveals the vegetation development in connection with mining, which we validate by historical data on the demography of miners and silver production volumes in the mining district. Thereby a spread of the pioneer trees *Pinus* and *Larix* is detected which might be connected either with selective clearances for the gain of pastureland or with a natural reforestation on scree. A correlation of the pollen values of these pioneer taxa as well as those of Poaceae, settlement and cultural indicators with historical data of silver production volumes as a proxy for former mining activities reveals that a secondary succession on the waste dumps is more likely than the expansion of pastureland. Furthermore, this multi-proxy approach with modifications in geochemical analysis of heavy metals is applied for other prominent mining districts in the Eastern Alps. Moreover, we correlate the vegetation and land use changes in the districts’ surroundings with climate proxies. Settlement/farming activities appear overall climate driven, albeit changes in mining activities seem to be governed by economic regularities too.

O-1097

## Three intermittent phases of human clearance and forest recovery in the last 5500 years at Lake Lucone in N-Italy.

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### Abstract

The Lucone Basin (Italian Alpine foothills) originated as an intermorainic depression in the Last Glacial Maximum. After a phase of high-stand, proglacial lake, it hosted a closed, shallow lake (about 800 m diameter) until artificial drainage in the late Middle Ages. The limnic sedimentation consisted of alternating authigenic carbonates and organic mud, recording several phases of human impact. These started with late Neolithic (Copper Age) clearance by burning the oak-beech deciduous forest surrounding the basin. During the end of the third and the first half of the second millennium BC the littoral lake was inhabited by at least three pile-dwelling villages. Two of them were archaeologically excavated. After the complete abandonment of the lake dwelling, two subsequent phases of human impact are recorded by palaeobotanical evidence of land-use, respectively in the late Iron – Roman Age and the late Middle Age. Overall, the lake record consists of three intermittent phases of human impact, separated by phases of complete recovery of the terrestrial forest ecosystem to the late Neolithic baseline.

We explore this intermittent record of the terrestrial and aquatic ecosystems by changes in pollen, green algae, microcharcoal concentration, macrofossils, dung spores, and correlated P and K nutrients supply in the last 5500 years of the littoral sedimentation. We aim to disentangle the relationships between forest clearance, farming, domestic fire activities and limnic macrophyte and planktonic algae communities, together with the effects on sedimentation. We also aim to analyze the resilience of the seminatural terrestrial ecosystems at a centennial scale after the farming and dwelling activities abandonment.

The first impact phase, i.e. at the end of the third millennium BC, is of special importance as the study site was inhabited by farmers during the first phase of the Early Bronze Age. They built a typical, though small, pile-dwelling village. The human impact on littoral lake sedimentation is recorded in a near-site position by the studied archeological deposits. The forcing over the biochemical carbonate / organic ratio along the sequence near to the dwelling is highly correlated with farming and dwelling, with no lag at a decennial time scale resolution. At the time of the dwelling, the marginal lake acted as a sink for waste disposal of livestock, crops and forest residues, partly committed to domestic charring and partly to non-charred plant waste. Sediment recorded an expanded accumulation of bone and plant ash and plant detritus supplying P and K-rich organics, non-airborne pollen, and charred wood. The aquatic communities were impacted by strong alkalinity. We discuss the outlook for a quantitative interpretation of terrestrial ecosystems from palaeobotanical assemblages recorded in a virtually continuous sediment record near-site to a dwelling. The near-site concept requires further focusing in terms of potential for palaeoecological reconstructions.

O-1098

## Late Roman Period and Early Middle Ages. The cause and effect of a changing climate, landscape and society.

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### Abstract

When looking at landscape-human interaction and the resultant environmental changes, the Late Roman Period (AD 300-500) and Early Middle Ages (AD 500-1000), pose an interesting case study. This time period, sometimes called the Dark Ages or migration period, is a period of large cultural change in NW Europe. New data from the Netherlands show that a shift to a colder climate, forest regeneration, geomorphological changes, and a population decline all occurred simultaneously here. The collapse of the Roman Empire is often seen as the main factor controlling the subsequent population decline and the Dark Age reforestation. However, the timing of all these changes suggests that climate developments had an (in)direct influence on landscape developments and cultural trends. Using a multi-disciplinary approach which combines climatological, palynological, geomorphological, and archaeological data the cause and effect of the changes during this time period is investigated. Hereto, we present the first chironomid-inferred temperature reconstruction from this period for the Netherlands, a unique overview of regional vegetation developments and landscape changes, combined with a detailed population density reconstruction.

In the summer-temperature record from lake Uddelermeer, we identified the presence of a Roman Warm Period and the Dark Age Cold Period. In the Uddelermeer pollen record the Dark Age Cold Period is contemporaneous with a reforestation phase. This Dark Age reforestation phase is additionally recognized in numerous palynological records throughout the Netherlands. The intensity of this reforestation trend varies as a result of landscape setting and varying population densities. Additionally, the Dark Ages in the Netherlands are characterized by large-scale landscape changes, especially in the coastal and river area. Here we see increased flooding and the emergence of new tidal inlets and river systems. These changes were most likely the result of human interference as well as environmental/climatic change. In the river area this increase flooding led to the abandonment of marginal areas which were previously used for habitation as well as agriculture resulting in a reduced human impact. Overall this study highlights the importance of understanding the relation between landscape and humans to explain complex changes in geomorphology, vegetation and population densities.

O-1099

## Deciphering dynamic vegetation histories by integrating bulk geochemistry, leaf wax compounds, and ancient DNA in lake sediment from Arctic Canada

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### Abstract

Amplified warming in the Arctic is causing marked shifts in tundra vegetation. Such changes are not only dramatically impacting local ecosystems, but are also contributing to global climate feedbacks through changes in albedo and greenhouse gas concentrations. Past distributions of tundra vegetation, particularly during warm periods in the Quaternary, can help provide a blueprint for how—and how quickly—the Arctic landscape may change. Recent advances in lake sediment analyses are enabling more detailed reconstructions of past plant communities, but each technique is limited by a unique set of biases related to the production, transport, and preservation of the compounds that inform each proxy. Here, we present a comparison and integration of three proxy approaches for understanding landscape changes in a lake catchment: 1) bulk geochemistry, including  $\delta^{13}\text{C}$  and C:N ratio for characterizing organic matter sources, 2) leaf wax biomarkers, including the distribution of fatty acid chain lengths to distinguish between terrestrial and aquatic plant sources, and 3) sedimentary ancient DNA (*sedaDNA*) metabarcoding using universal plant primers. By combining proxies of varying levels of specificity, we gain more comprehensive insight into climate- and succession-driven landscape changes, from the dominant organic matter sources to a lake to the presence/absence of particular plant taxa. Our analysis focuses on two lake sediment records from Baffin Island, Arctic Canada, that span the Holocene and capture dynamic vegetation responses to the insolation-driven warmth of the early Holocene. We will also present preliminary data from a third lake sediment record that extends through the warmer-than-present Last Interglacial, investigating the potential for vegetation reconstructions via lacustrine *sedaDNA* on longer timescales than have previously been explored.

O-1100

## Hidden species richness detected in ancient DNA: algae and worms recorded in Pleistocene and Holocene lake sediments

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### Abstract

Metabarcoding of sedimentary ancient DNA (*sedaDNA*) has proven to be a powerful tool for recovering ecological data from sediments. The main advantage of *sedaDNA* over more traditional methods such as pollen or macrofossils is the potential for a higher taxonomic resolution. A second advantage is the identification of taxa that normally do not preserve well in sediments and that are difficult to detect with traditional methods.

Metabarcoding relies on the use of generic primers for the amplification of larger groups of species (e.g. plants or mammals). But due to the generic nature of the primers, they may amplify more than just the target organisms, resulting in a large set of “bycatch” sequences. These sequences are often ignored since they are not the taxa of interest, or because they cannot be identified.

The amount of reference sequence material is ever increasing, via both large-scale sequencing efforts (for example the Barcode of Life Consortium) or smaller sequencing efforts targeting a handful of species. The larger pool of reference material allows us to identify the mostly ignored bycatch sequences generated by metabarcoding and allow for novel ecological interpretations, which can have strong environmental implications.

Here two studies are presented of unexpected bycatch taxa in *sedaDNA*. First the detection of various worm species in mammalian lake sediment metabarcoding data from the Varanger peninsula, northern Norway (10 700-3300 cal. a BP) and the Polar Urals in Russia (24 000-1300 cal. a BP). Second the detection of freshwater (non-diatom) algae in plant metabarcoding data from lake sediments across northern Norway and Svalbard (27 000 cal. a BP-present), which occasionally dominate the datasets, indicating the presence of algal blooms. Both the reason for the unexpected detection and the potential for both groups of taxa as proxies for environmental conditions such as temperature, moisture and nutrient availability are discussed.

O-1101

## Using ancient DNA to investigate glacial survival of Norway spruce (*Picea abies*) in Scandinavia

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<sup>3</sup>Departamento de Recursos Naturais e Desenvolvimento Sustentável, Instituto Politécnico de Castelo Branco, Escola Superior Agraria, Castelo Branco, Portugal. <sup>4</sup>Forest Research Centre, School of Agriculture, University of Lisbon, Tapada da Ajuda, Lisbon, Portugal

### Abstract

The survival of boreal trees in ice-free cryptic refugia's at high latitudes during the Last Glacial Maximum has been subjected to a long-standing debate. Norway spruce (*Picea abies* L. Karst) is generally believed to have recolonised Scandinavia from the east after the last glaciation. Spruce appears for the first time in the pollen assemblages in central Sweden around 3000 years before present (yr BP). However, a growing body of macrofossil and genetic evidence suggested that spruce could have survived in ice-free areas around the Norwegian shore and contributed to the recolonisation of Scandinavia from the west. Genetic research has shown that modern spruce populations contain two sequence variants for the maternally inherited mitochondrial mh05 fragment across its Eurasian distribution, of which one is unique to Scandinavia. The Scandinavian variant shows the highest frequency in western Scandinavia and its modern distribution suggesting that the variant was already present before the last glacial period. In previous research, the Scandinavian variant was also detected in lake sediment dating back to 10,300 yr BP at Trøndelag in Central Norway (63°N), and chloroplast DNA from spruce and pine was recovered at Andøya in north-western Norway as early as ~22,000 years ago.

We are using sensitive melting curve qPCR assay and high-throughput sequencing to detect the presence of the Scandinavian variant in several sediment cores covering Scandinavia and north-east & southern Russia. So far, the qPCR melting curve assay detected the Scandinavian variant in peat sediment from northern Finland (~52,000 – 42,000 yr BP), in lake sediments in central Sweden and central Norway (~10,000 – 900 yr BP) and in southern Sweden (~12,000 – 11,000 yr BP), which is far earlier than currently believed. Additional lakes are being processed and samples positive for the Scandinavian variant with the qPCR assay will be subjected to high throughput sequencing to confirm sequence identity. The results of this study will increase our understanding of the glacial survival and colonisation of Norway spruce in Scandinavia after the Last Glacial Maximum.

O-1102

## Why is Northern Siberia dominated by larch forests? – Illuminating the history of Siberian larch using target-enriched sedimentary ancient DNA

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<sup>3</sup>University of Potsdam, Institute of Biochemistry and Biology, Potsdam, Germany

### Abstract

Although the climatic conditions in Siberia are similar to those in Northern Europe and North America, the latter regions are dominated by evergreen needle-leaf forest in comparison to the deciduous larch (*Larix* Mill.) forests in Siberia. This is even more peculiar as *Larix* is a poor competitor with evergreen needle trees in mixed stands. The basic mechanisms controlling the distributions of these two biomes are still not well understood and future alterations due to climatic changes are uncertain. Previous work has failed to provide insights into long-term biogeographic patterns of *Larix* species, as established methods (pollen analysis, metabarcoding) cannot distinguish ancient *Larix* below genus level. In this study, we want to sequence whole ancient chloroplast genomes of *Larix* from lake sediment samples originating from southern Taymyr peninsula (72.399° N, 102.289° E). We will do this by enriching sedimentary ancient DNA (*seda*DNA) extracts for *Larix* chloroplast DNA using hybridization-capture prior to high-throughput sequencing. In a second step, we will extend the capture target to informative mitochondrial and nuclear SNPs. Preliminary results from shotgun sequencing of *seda*DNA from a sediment core dated back to 7000 years BP show that, although most of the sequences are of bacterial and archaeal origin, *Larix* chloroplast DNA was recovered. The enriched data set will enable us to trace distribution changes of Siberian *Larix* lineages in Northern Siberia through time.

O-1103

## **Ancient DNA taphonomy and the challenges for palaeoenvironmental reconstruction: an integrated approach for understanding Holocene intertidal deposits at Cardigan Bay**

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### **Abstract**

With the emergence of ancient sedimentary DNA (sedaDNA) as a novel tool for palaeoenvironmental reconstruction, current research into the proxy has demonstrated the potential for enhancing or complementing standard palaeoecological data.

However, as with all new proxies, there is a need to address the issues of taphonomy, as a means to provide robust interpretations of sedaDNA within the context of the sedimentary archives. At current, key issues such as biological source of sedaDNA and the mechanism of deposition (i.e. local-scale, wind-blown, etc) have been addressed and widely discussed within the discipline. However, the impact of inmaterial source-type and post-depositional taphonomic processes remains a key issue, in particular how sediment composition and subsequent binding properties (i.e. organic or minerogenic clays) may affect preservation on sedaDNA within in-situ palaeoenvironmental deposits.

Using samples taken from an area with rich paleoenvironmental records (therefore providing a reference point for understanding taphonomic processes), this project aims to address some of the questions relating to post-depositional taphonomy, in particular how this will impact on the on the bioinformatic processes of data analysis for addressing the key criteria for assessing sedaDNA authentication (damage assessment, controls, replication). In order to address all forms of potential authentication criteria, datasets were generated from the two key methods of sequencing (metabarcoding and shot gun sequencing) and have been analysed for the potential presence of ancient sedimentary DNA, with a particular focus on ancient plant DNA. In parallel, analysis has not only focussed on key aspects of authentication, such as replication and damage, but also within stratigraphic context and how this may potentially differ across strata based on material type. It is clear that the two variables inform each other, and are two central components for a robust interpretation of sedaDNA within a palaeoenvironmental context.

The complexity of the intertidal context for this research has been challenging, and poses the validity on working in such environments with sedaDNA, as a tool for palaeoenvironmental reconstruction. However, it has also demonstrated important aspects of working with this novel proxy and providing robust interpretations, including the application of robust bioinformatic tools for analysis of such large and complex datasets. Most importantly, it has highlighted the importance of addressing key questions such as authenticity, and the ability to contextualise such interpretations within the context of taphonomic processes, as this is not only a fundamental component of palaeoenvironmental research, but remains central to the integrity of aDNA research.

O-1104

## Using *sedaDNA* and lipid biomarkers alongside traditional palaeoenvironmental proxies for understanding wetland and lake side archaeological sites

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### Abstract

Wetland archaeological sites, including settlements on lake shores and artificial islands, often provide a wealth of well-preserved archaeological material, but are generally difficult and expensive to excavate. An alternative, or complimentary approach, can be the retrieval archaeological data from lake-edge sediments, which can contain a continuous record of the archaeological site, the lake and its surrounding catchment. Here we present data from a study of crannogs (artificial island settlement) and an Iron Age lakeshore village where *sedaDNA* and faecal steroids were analysed from proximal sediment cores. The sites are located in SW Scotland and Northern Ireland, UK and range in date from the Iron Age to the early Medieval period. The *sedaDNA* metabarcoding and steroids provides direct and detailed information about the plants and mammals that lived, died, or were kept on the sites in different periods of site use. This information is compared with traditional proxies that allow us to differentiate between (i) changes that happened regionally in the lake catchment (ii) changes that happened in the lake ecosystem and (iii) changes that occurred very locally at the sites (based on pollen and spores, diatoms, invertebrates, sterols and *sedaDNA*). Unusually strong *sedaDNA* and lipid biomarker results from both plants and animals are believed to result from the creation of a biogeochemical halo around the sites which is preserved due to rapid sedimentation, the presence of clays, and a lack of disturbance. The human activities on the artificial islands caused severe eutrophication of these small lakes, which only partially recovered after the abandonment of the sites. Our *sedaDNA* and steroid results complement data from both archaeological excavation and traditional palaeoenvironmental proxies to provide a more detailed and comprehensive image of the environment in which our ancestors were operating, the changes they had on their ecosystems and the inheritance of this today.

O-1105

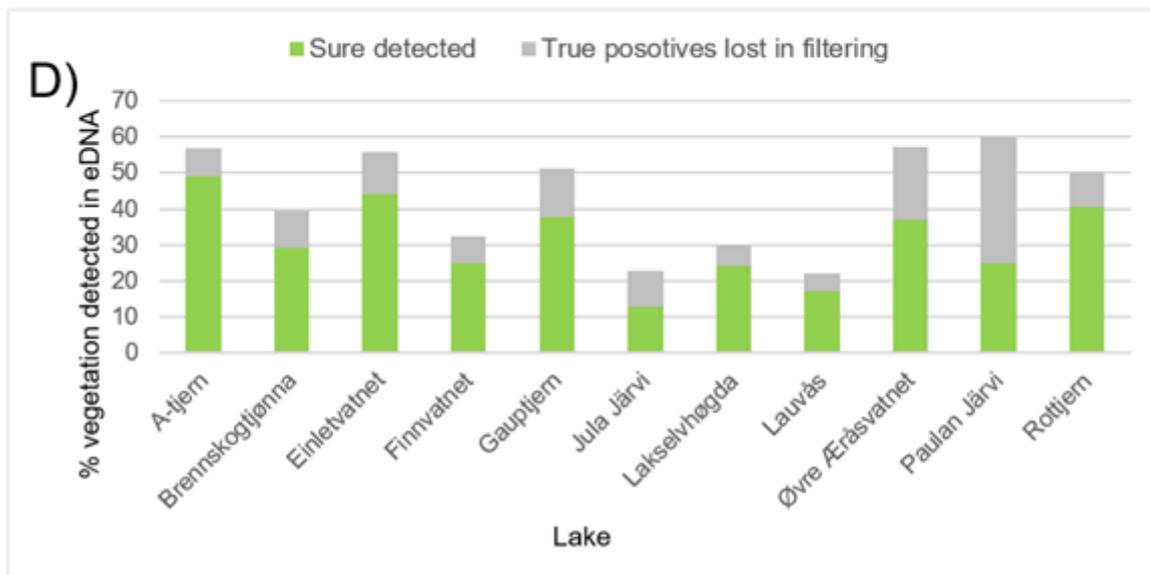
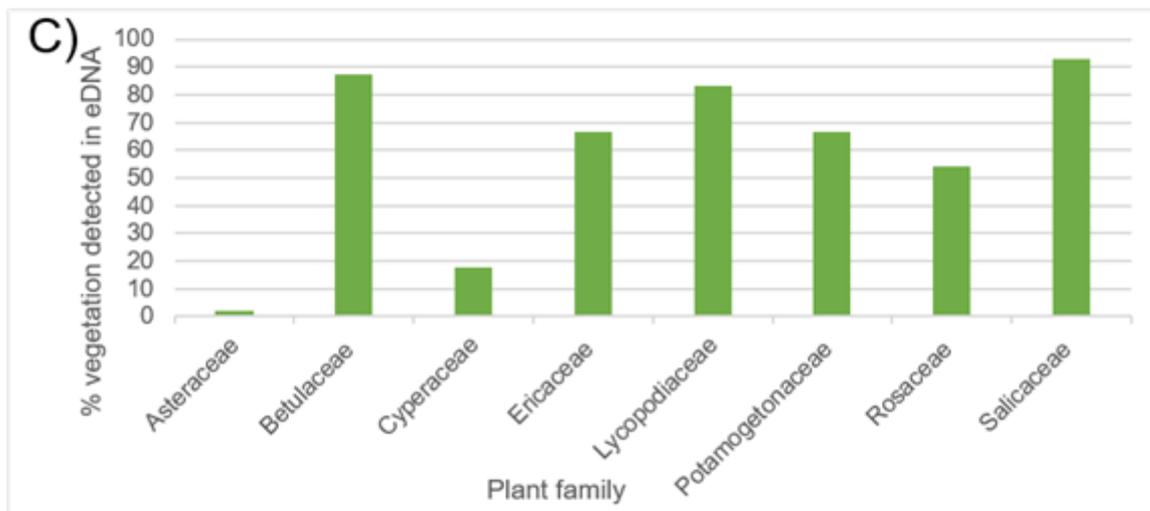
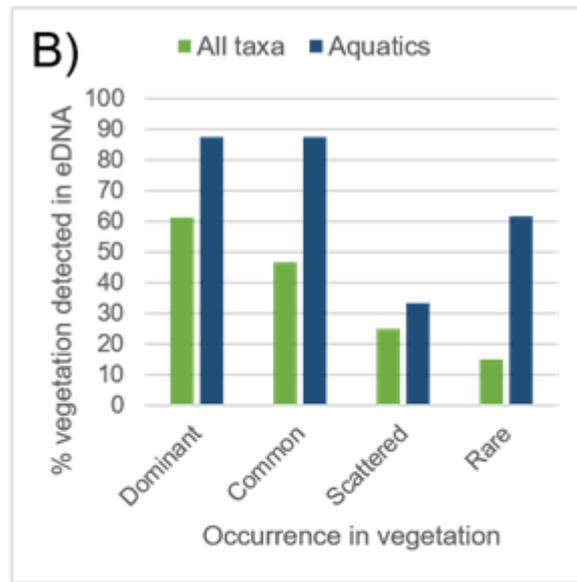
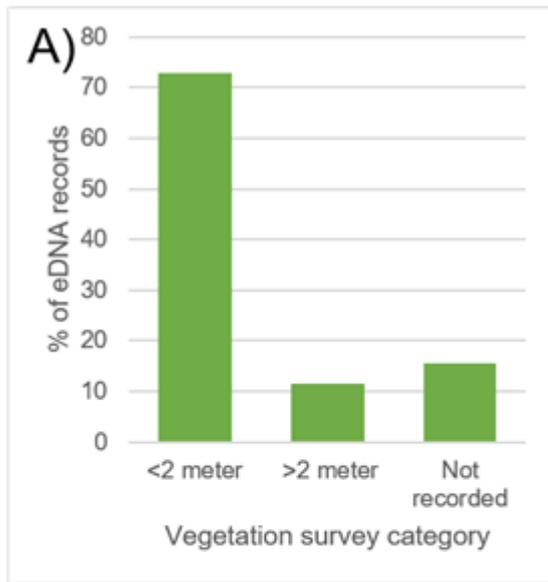
## How ancient sediment DNA can improve our understanding of past vegetation and the impacts of climate change

Inger Greve Alsos<sup>1</sup>, Peter D Heintzman<sup>1</sup>, Tony Gavin Brown<sup>1,2</sup>, Dilli Prasad Rijal<sup>1</sup>, Kelsey Lorberau<sup>1</sup>, Youri Lammers<sup>1</sup>, Sandra Garces Pastor<sup>1</sup>, Nigel Giles Yoccoz<sup>1</sup>, Mary E Edwards<sup>1,2</sup>, Kari Anne Bråthen<sup>1</sup>, Dorothee Ehrich<sup>1</sup>, Tina Jørgensen<sup>1</sup>, Per Johan Sjögren<sup>1</sup>, Ludovic Gielly<sup>3</sup>

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### Abstract

Lake sediment ancient DNA (*sedaDNA*) may detect species overlooked by studies of micro- or macrofossils as it may be recorded even in the absence of identifiable plant fragments. The taxonomic resolution obtained depends on the molecular methods used, the local flora, and the representation of species in the DNA reference library, and may be as high as 80-90% of taxa detected. The detection of taxa may vary among lakes, plant families, distance from lake and quantity in the vegetation (figure), and common species growing close to the lake (or within the lake) are best detected. Compared to macrofossils, *sedaDNA* generally gives a higher number of species and is superior in displaying species persistence. It may show species diversity similar to pollen records, but it is superior in detecting terrestrial and aquatic herbaceous species. Also, as it is deposited locally, results are not confounded by long-distance transported pollen. False positives due to contamination, PCR or sequencing errors, DNA reference library errors, and/or the erroneous identification of short DNA fragments are still issues but may be overcome by stringent laboratory routines, reference databases of high quality and representation, and optimized bioinformatic filtering. Our lab has analysed, or is in the process of analysing, ~40 long (up to 26 000 year old) and 11 short (0-1000 year old) lake sediment cores from the Alps to Svalbard and Scotland to the Polar Urals. General patterns have emerged from these data. Aquatic vascular plants are exceptionally well represented and do often show marked change through time. The taxa recorded in *sedaDNA* often indicate a warmer climate than what has been inferred based on pollen records; this is in concordance with macrofossils. The *sedaDNA* further indicates that limits of the past northern treelines have been underestimated based on pollen studies. Some heathland species, such as *Vaccinium* spp. and *Empetrum*, often show a time lag in arrival compared to other species with similar climate requirements. Thus, despite the fact that they have berries and therefore are well adapted to long-distance dispersal by bird, something is constraining their ability to respond to climate changes. In the near future, the combination of many sites, complete reference libraries, and advanced molecular methods will allow for the tracking of individual species through time and space.





**Figure: Match between records of taxa in the sedimentary eDNA in relation to vegetation surveys (Alsos et al. 2018 PlosOne).**

**O-1106**

## **Late Pleistocene environments and human occupations of the Thar Desert**

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### **Abstract**

The Thar Desert, India, is located at a major biogeographic threshold, marking the eastern edge of the Saharo-Arabian desert belt and the western edge of the monsoonal Oriental zone. This threshold is most clearly marked by the change in precipitation and its seasonality associated with influence of the Indian summer monsoon, with ensuing impacts on the ecology of regions on either side of the Thar Desert. Late Pleistocene climatic change appears to have substantially modulated the environments at this key threshold, with evidence for both enhanced humidity and increased aridity at different times through the past, with impacts for the potential for human occupations. It is increasingly apparent that the Saharo-Arabian desert-belt has played a critical role in mediating the eastward expansions of modern humans from Africa, and thus the Thar Desert marks the first major ecological transition that would have been encountered by these dispersing populations. A program of interdisciplinary fieldwork conducted over the past decade has illuminated patterns of human occupation over the Thar Desert and placed this within a chronological and environmental framework. This presentation will review terrestrial archives of environmental change in the Thar Desert and evidence for human occupations through the Late Pleistocene, and place this within wider debates surrounding modern human dispersals.

**O-1107**

## **East Asia monsoon variations and the vegetation developments in Southeast and Northwest China during the MIS 5 and MIS 1**

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### **Abstract**

East Asia Monsoon (EAM) origins in western Pacific Ocean, and influences a large region from Southeast China to Northeast China, but goes weaker and weaker northwards. However, the strength of the monsoon varied between glacial and interglacial time. This study is based on the comparison between the pollen records from two marine records from northern South China Sea (SCS) and one record from Lop Nor Lake. The goal is to compare the vegetation developments and the influences of East Asia Monsoon in the two end regions of the monsoon influence, Southeast and Northwest China, during two typical interglacial periods, the MIS 5 and MIS 1.

The records from the SCS show that with the rise of temperature, the vegetation in South China experienced a good succession toward more tropical types. The tropical components started to increase at the beginning of each interglacial (MIS 5 and MIS 1), and then reached the maximum, but dropped near the end of the warm period. This phenomenon is more represented by the rise and fall of some montane components. The sea surface temperature indicates that temperature may be more crucial in the succession.

The vegetation in Northwest China is more sensitive to the moisture, and thus was more controlled by the shifting of the end-line of the EAM. MIS 5 and MIS 1 are two periods that the vegetation was better developed and more mesic, especially during the early-mid Holocene. Based on the vegetation history, we tend to believe that East Asia Monsoon had reached at least eastern part of the desert region in Northwest China during some time of these two periods, but then retreated.

**O-1108**

## **Indian Ocean monsoon behavior during the 4.2 kyr event from Madagascan stalagmites**

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### **Abstract**

The climatic and societal impacts of the 4.2 kyr event are centered on the Mediterranean and Middle East. Yet the event is stratigraphically defined by a stalagmite record from Mawmluh Cave in eastern India, which is subject to a different, more tropical, climate regime. The behavior of the tropical rain belt at this time has important consequences for understanding the climate system's response to abrupt Holocene forcing, and to the civilizations surrounding the Indian Ocean at the time. To enhance our understanding of Indian Ocean climate at the 4.2 kyr event we present a high-resolution, precisely dated, stalagmite stable isotope record from Anjohikely Cave in northwest Madagascar.

The new record covers 5.1–1.9 kyr BP at sub-decadal resolution, providing an important southern hemisphere perspective on tropical hydroclimate during the middle to late Holocene generally, and the 4.2 kyr event specifically. We show a two-phase response of the Madagascan monsoon to the 4.2 kyr event: 1) a shorter dry event from 4.2 to 4.0 kyr BP, but one where the magnitude and duration was not unusual; 2) a longer multi-centennial scale drying until 3.5 kyr BP. We also compare our southwestern tropical Indian Ocean with five other high-resolution stalagmite records from around the Indian Ocean basin. Our analysis highlights controls on Indian ocean tropical hydroclimate to both meridional and zonal processes. The results provide new insight into regional coherence and synchronicity of the climate response to the 4.2kyr event.

O-1109

## Reconstruction of Holocene (MIS I) paleomonsoons: lake sediments

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### Abstract

Reconstructions of the Asian paleomonsoonal shifts for the late Quaternary-Holocene period demands a deep understanding of the application of multiproxy data for climate modelling and predicting future monsoon trends. Freshwater bodies such as lakes and ponds are major sinks and depocentres for carbon and detritus and the lake sediments preserve signatures of geochemical and biological variations derived principally from the surrounding rocks and soils owing to precipitation and erosion. In this presentation, multi and interdisciplinary proxy data collected from four lake sediment cores, South India (Pookode, Kukkal, Berijam, and Vellayani) is presented. These lakes receive dominantly the southwest monsoon. Climate proxies, including sediment texture, total organic carbon (TOC), total nitrogen (TN), C/N, pollen and geochemical composition indicate a steady progression to wetter and drier conditions, with two stepwise changes at about 8100, and between 3200 and 1800 yr BP. The change at 8200 solar insolation event - 8100 yr BP appears to correspond to a brief (100–150 years) dry spell recorded elsewhere in India. Most of the lake records show a decline in SWM since the middle Holocene period with intermittent intense wetter conditions since 6240 yr BP to present. This allowed the lake margins to shrink and expand. Some lakes hold the signatures of abrupt and extreme events such as the 4200-extreme aridity, 3800, 2000 and 600 yr BP dry and warm conditions. The change at 3200–1800 yr BP consisted of a rapid weakening of the SWM, and can be correlated with the initiation of the 'Roman Warm Period'. The C/N ratio of the sediments range from 14.02 to 8.31, indicating that the organic matter originated from a mixture of lacustrine algae, vascular and terrestrial plants. Chemical weathering indices (Chemical Index of Alteration (CIA), Chemical Index of Weathering (CIW), and Plagioclase Index of Alteration (PIA)) are consistent with extreme silicate weathering. Pollen data also show a development from savanna vegetation prior to ~8000 yr BP, followed by grassland with palms, the appearance of ferns just prior to 3200 yr BP and the establishment of the tropical humid forest between 3200 and about 1800 yr BP. Decline in the intensity of monsoon led to weakened river dynamics, that played a critical role in the collapse of several river valley civilizations, which relied on monsoon rains to fuel their agricultural surpluses.

O-1110

## Monsoonal variations at the northeastern Tibetan Plateau during the Holocene – the aeolian record

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### Abstract

Despite being one of the most important atmospheric systems on earth, intensity, timing, and extent of the Asian Summer Monsoon (ASM) is still poorly understood. The northeastern Tibetan Plateau (TP) is located at the present day northern limit of the ASM and was identified as one of the key areas to study the evolution of the ASM. Previous studies in the area mainly focused on lake sediments and resulted in considerable divergent interpretations. These differences are partly related to problems with the chronology as they are influenced by the hard water effect.

For this study, aeolian sediments were used to reconstruct the Holocene development of the ASM on the northeastern TP. They can be easily dated by optical stimulated luminescence (OSL), which captures the last exposure to light. In the case of aeolian sediments, these last exposure occurred during the last transport of the particles. Aeolian sediments are widespread on the semi-arid north-eastern TP. However, many sections in the area are discontinuous. Therefore, a large number of sections has to be analyzed. During the last decades, the number of dated sections from the northeastern TP has been increasing rapidly and now nearly 500 ages are available. Two different trends can be observed in the dataset. At first, there is a time-transgressive onset of the ASM on the northeastern TP. An increase in precipitation occurred at the eastern margin as early as the late glacial, while the central part of the northeastern TP experienced an increase in the early Holocene. However, further to the west, a short-term influence of the ASM occurred in the mid-Holocene only. During this time, maximum precipitation occurred in the eastern regions. The late Holocene is characterized by dry climate conditions with high aeolian activity. The weakening of the ASM occurred more or less simultaneously in the area. Nevertheless, the several decadal to millennial scale climate variations are preserved in the aeolian record from the late Holocene. In the last 2000 yrs, aeolian activity increased during reduced northern hemisphere temperatures. This was accompanied by an increasing strength of the northern hemisphere mid-latitude westerlies. Furthermore, phases of enhanced aeolian activity occurred parallel to the so-called Holocene Bond events in the North Atlantic. However, other high resolution records from the North Atlantic indicate no clear match on the multi-decadal to multi-centennial timescale. The study emphasizes that long and short term trends in the ASM can be reconstructed from non-continuous aeolian sediments in a semi-arid environment, provided a sufficient number of ages is available.

O-1111

## East Asian Monsoon History and paleoceanography of the Japan Sea over the last 460,000 Years

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### Abstract

The Japan Sea is directly influenced by the Asian monsoon, a system that transports moisture and heat across southeast Asia during the boreal summer, and is a major driver of the Earth's ocean-atmospheric circulation. Foraminiferal and facies analyses of a 460-kyr record from Integrated Ocean Drilling Program Expedition 346 Site U1427 in the Japan Sea reveal a record of nutrient flux and oxygenation that varied due to sea level and East Asian monsoon intensity (Fig. 1). The East Asian summer monsoon (EASM) was most intense during marine isotope stage (MIS) 5e, MIS 7e, MIS 9e, and MIS 11c when the Tsushima Warm Current flowed into an unrestricted well-mixed normal salinity Japan Sea, whereas East Asian winter monsoon (EAWM) conditions dominated MIS 2, MIS 4, MIS 6, and MIS 8 when sea level minima restricted the Japan Sea resulting in low-salinity and oxygen conditions in the absence of Tsushima flow. Reduced oxygen stratified, low-salinity, and higher productivity oceanic conditions characterize Terminations TV, TIII, TII, and TI when East China Sea coastal waters breached the Tsushima Strait. Chinese loess, cave, and Lake Biwa (Japan) and U1427 proxy records suggest EASM intensification during low to high insolation transitions, whereas the strongest EAWM prevailed during lowest insolation periods or high to low insolation transitions. Ice sheet/CO<sub>2</sub> forcing leads to the strongest EAWM events in glacials and enhanced EASM in interglacials. Mismatches between proxy patterns suggest that latitudinal and land/sea thermal contrasts played a role in East Asian monsoon variability, suggesting that a complex interplay between ice sheet dynamics, insolation, and thermal gradients controls monsoonal intensity.

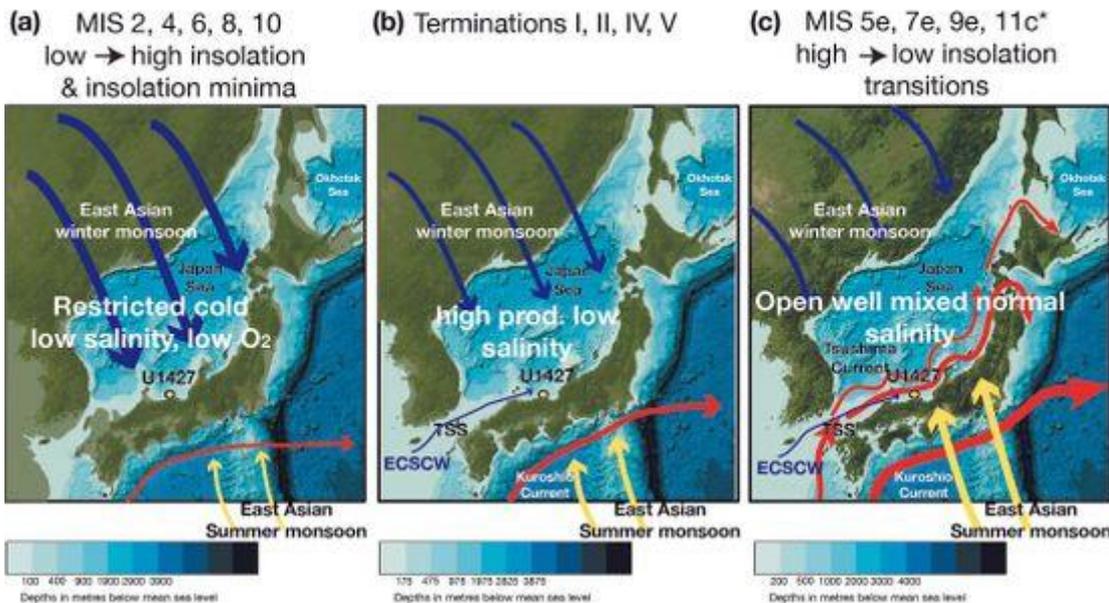


Fig. 1. Variations in

oceanography and the position and intensity of the East Asian monsoon during (a) low to high insolation transitions and insolation minima, (b) terminations, and (c) high to low insolation transitions. \*MIS 11c coincides with an insolation maxima during an eccentricity low. The thicker blue arrows signify enhanced EAWM and thicker yellow arrows a stronger EASM. The thin blue line (ECSCW) is the path of fresh water from the China Sea during terminations and interglacial maxima. The base map is from General Bathymetric Chart of the Oceans ([www.gebco.net](http://www.gebco.net)) where modern bathymetry represents interglacial maxima. This is recalibrated to ~100 m below present for glacial phases and ~25 m below present during the terminations. Prod. = productivity; ECSCW = East China Sea Coastal Water; EAWM = East Asian winter monsoon; MIS = marine isotope stage.

Reference: Gallagher, S.J., Sagawa, T., Henderson, A., et al, **2018**. East Asian monsoon history and paleoceanography of the Japan sea over the last 460,000 years. *Paleoceanography and Paleoclimatology* v. 33, 683-702. doi: 10.1029/2018PA003331

O-1112

## Palaeoclimate anomalies since MIS 4 to MIS 1 inferred from Loess Palaeosol Sequences (LPS), Kashmir Valley, Western Himalaya

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### Abstract

Understanding climate processes demand reconstruction of environmental and climate history (Krauß et al. 2018). Studies reported during the last few decades have deemed loess sediments as one of the important records for the Quaternary palaeoclimate and paleoenvironmental reconstructions. This study is focused on reconstruction of signatures of the late Quaternary palaeoclimate anomaly recorded in loess sediments of the Kashmir Valley. The loess palaeosol sequences (LPS) exposed around Ganderbal, Kashmir Valley, reveals six polycyclic palaeosols formations of varying thickness, a loess (C) horizon and partially pedogenised loess forming Cambisols. The chronology of the loess section is constrained by five OSL dates and four AMS  $^{14}\text{C}$  dates. The loess palaeosol sequence (LPS) represents sedimentation records from 68 ka to 7 ka (MIS 4 to MIS 1). Field observations, sediment textural data, stable isotope ( $\delta^{13}\text{C}$ ), geochemical data, organic elements and supported by AMS  $^{14}\text{C}$  and OSL ages have revealed five major climate events since 68 ka. The palaeosols from 8 m to 6.4 m depth represents ameliorated moderate climatic condition since 68 ka to 44 ka (duration 24 ka) supporting deciduous plants or open conifer forest vegetation. Unaltered loess layer from 6.4 m to 6.0 m depth (C horizon) dated to 44 ka to 43 ka reveal influx of fine sand (36%), with very low TOC content, weak weathering, and enriched values of  $\delta^{13}\text{C}$  (-23 ‰) indicating dry and cold climate conditions with high wind velocity. Sediment deposition corresponding to 43 ka to 35 ka age yields high TOC content and supported by more depleted  $\delta^{13}\text{C}$  values and moderate to strong weathering reflect warmer and wetter conditions leading palaeosols formation. The sediment deposition corresponding to 35 ka to 13 ka, exhibit very weak weathering and accumulation of  $\text{CaCO}_3$ , indicating cold and dry conditions representing the LGM forming calciorthids and cambisols represented by Bt/Bck and Bwk horizons. These horizons supported  $\text{C}_3$  grasses and shrub coppice vegetation. Loess deposition terminated around 15 to 13 ka and subsequently deposited reworked loess and fluvial sediments that aggraded over the glacial melt water deposits of pebbles and gravels. This signifies the retreat of the nearby glaciers that continued to occur until around the late Pleistocene–Holocene transition. The upper two-meter sediment deposition, age dated from 12 ka to 6.9 ka represents a mixture of reworked aeolian and fluvial sediments that are pedogenised and more depleted values of  $\delta^{13}\text{C}$  reflecting an overall warm climate conditions since 12 ka to 6.9 ka.

**Key words:** Loess palaeosol sequence, climate anomaly, OSL dating, stable isotopes.

### Reference

1. Krauß, L, Kappenbergb, A, Zensa, J, Kehlc, M, Schultea, P, Zeedena, C, Eckmeierd, E & Lehmkuhla, F 2018, 'Reconstruction of Late Pleistocene paleoenvironments in southern Germany using two high-resolution loess-paleosol records', *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 509, pp. 58-76.

O-1113

## Tephrochronology as a Tool for Volcanologists

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### Abstract

Tephrochronology is a stratigraphic method that is widely used in palaeoenvironmental and archaeological research; its value in synchronising stratigraphic records comes from the ability to identify individual eruptions using often trace amounts of small glass and crystal fragments (volcanic ash). These distal and ultra distal ash deposits are also valuable for addressing questions related to physical volcanology, although they not often incorporated into volcanological studies. Here we review some ways in which tephrochronological data can be used to enhance volcanological research. First and foremost, characterization of distal and ultradistal tephras can substantially improve understanding of eruptive processes, including eruption magnitude, frequency and fragmentation conditions. For example, a major challenge in determining eruption magnitude (volume or mass erupted) is estimating the mass contribution of far-travelled ash, which may comprise a significant proportion of the overall volume. Additionally, determining eruption frequency requires good stratigraphic and age control. This is often best established using sediment cores from lakes, bogs or marine environments, where the legacies of individual eruptions are not disturbed by either post-placement modification or erosion by subsequent eruptive products. Alternatively magma fragmentation is a signature of explosive eruptions. Fragmentation may be primary or secondary, and may occur early or late in the vesiculation process; each leaves its mark in the physical characteristics (size, shape, bubble textures) of tephra particles. Other applications of tephrochronologic data to volcano studies relate to the chemical analysis of constituent glass and mineral phases, which can be used not only to “fingerprint” the deposit, but also to assess source variability (e.g., tapping of zoned magma reservoirs) and pre-eruption conditions (e.g., Fe-Ti oxide constraints on magma temperature and oxygen fugacity), and even to determine which part of the eruption sequence produced widely dispersed ash deposits. Finally, physical characterisation of distal and ultradistal ash deposits can be used to (1) construct more accurate models of ash transport, models that are key to air traffic safety, (2) determine lag times between ash and aerosol deposition in polar ice cores, which is important for climate models, and (3) constrain elements of post-eruption modification of distal tephra deposits by gravity, water and wind, thereby placing constraints on the nature and extent (both spatial and temporal) of post-eruptive ash hazards. In summary, the distal and ultradistal tephra records used in tephrochronology represent an archive of eruptive activity that has been under-utilized by the volcanology community, in part because of the tephrochronology focus on the chemical, rather than physical, attributes of far-travelled ash particles.

O-1114

## Refining the late Quaternary tephrochronology for southern South America using the Laguna Potrok Aike sedimentary record

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### Abstract

Here, we revisit the Laguna Potrok Aike (51.97053°S, 70.37551°W) sedimentary sequence which was cored as part of the Potrok Aike Maar Lake Sediment Archive Drilling Project (PASADO; ICDP expedition number: 5022), and sits in the back-arc of the Austral Volcanic Zone (AVZ) of the Southern Andes, Argentina. The record is 106.09 m-cd (metres-composite depth) long and extends back to ~80 ka, providing a detailed record of long-term explosive volcanism in the region. The lake sequence additionally represents one of the only synglacial/glacial records from the region, and as such provides an excellent opportunity to analyse the relationship between ice-unloading and volcanic activity in continental arc settings.

We identified 94 tephra layers in the Laguna Potrok Aike sedimentary sequence, and analysed the textural, mineralogical and major elemental (glass) chemical properties of each layer using microscopy, and wavelength dispersive electron microprobe techniques. To enable robust tephra correlations, a reference tephra (glass) compositional database of expected deposits was created by combining newly acquired and existing data of proximal deposits from: Hudson (H<sub>1</sub>, H<sub>2</sub>), Aguilera (A<sub>1</sub>), Reclus (R<sub>1</sub>, R<sub>2-3</sub>), and Lautaro (historical) volcanoes, and Mt Burney (MB<sub>1</sub>, MB<sub>2</sub>, MB<sub>x</sub>, MB<sub>1910</sub>). One new correlation was produced to the widespread H<sub>1</sub> eruption from Hudson volcano, dated to 8.6-9.0 cal ka BP; the MB<sub>1</sub> and R<sub>1</sub> deposits, from Mt Burney and Reclus volcano, are now better geochemically characterised, and have depositional ages of 10.0-10.4 and 14.1-14.5 cal ka BP, respectively.

The depositional mechanism of tephra layers was established: 25 were primary, 1 was unknown, 3 were possibly reworked and 65 were reworked. Reworked layers had the characteristics of primary fallout at a macroscopic level, but displayed characteristic features of reworking at a microscopic level. Such features included: heterogeneous compositions, rounded minerals and minerals with minimal glass-coating, increased abundance of organic material, and a low glass-shard abundance. The identification of a high proportion of reworked material throughout this sedimentary sequence indicates that emplacement via primary fallout should not be assumed, and that special care should be taken when analysing visible and invisible (crypto-) tephra layers to decipher their emplacement mechanisms. Using event-frequency, and chemical composition data of the 25 primary tephra layers in the sequence, we finally investigate the relationship between ice-unloading and volcanism and determine that, while there is a marked decline in eruptive activity between 43.4 and 62.9 cal ka BP, no firm relationship between glacial cycles and volcanic activity can be identified in this record.

O-1115

## Zircon U-Pb dates for Gold Run tephra confirm the antiquity of ancient permafrost and the world's oldest recovered genome

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### Abstract

Gold Run tephra is a prominent Middle Pleistocene chronostratigraphic marker in the Klondike region of northwest Canada, at the eastern edge of unglaciated Beringia. The tephra is broadly dated to the early Middle Pleistocene by glass fission-track ages ( $0.69 \pm 0.05$  Ma;  $1\sigma$ ) and the normal polarity of the surrounding fine-grained sediments overlying reversely-magnetized gravels. Gold Run tephra has emerged as a critical marker horizon because of its stratigraphic association with ancient relict permafrost and important paleontological specimens. We report new zircon laser-ablation U-Pb dates for Gold Run tephra that confirm and refine the age of this key marker horizon. Of 25 dated grains, ten yielded a tentative isochron age of  $0.70 \pm 0.04$  Ma ( $2\sigma$ ), with a mean  $^{206}\text{Pb}/^{238}\text{U}$  age on the youngest coherent grouping ( $n=9$ ) of  $0.76 \pm 0.09$  Ma. Forthcoming analyses will allow us to refine the latter age using a  $^{230}\text{Th}$  correction, with additional support from forthcoming zircon U-Pb dating of the overlying Flat Creek tephra. These new U-Pb dates confirm the antiquity and remarkable resilience of relict early Middle Pleistocene permafrost in west-central Yukon, where Gold Run tephra overlies relict ice wedges at multiple sites in the Klondike region. The refined age of Gold Run tephra also confirms the early Middle Pleistocene age for an *Equus* fossil, recovered from relict permafrost, that yielded the world's oldest full genome sequence. The direct age constraint from Gold Run tephra also highlights the underestimation of the molecular clock age for the fossil, and more broadly the challenges and uncertainty of using these age estimates in ancient DNA studies of specimens that lack independent geochronology. Our results underscore the potential for U-Pb dating of the numerous Plio-Pleistocene tephra beds in unglaciated Yukon and Alaska, with applications as diverse as paleogenomics, paleontology, and studies of ancient permafrost.

O-1116

## Reconstructing missing terrestrial eruption records without tephra-fall layers: high-resolution chronology of lacustrine volcanic density flow deposits, Lake Inawashiro-ko, Fukushima, Japan

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### Abstract

Volcanic eruptions in geological records are often incomplete. Attempts to reconstruct eruption records from the terrestrial stratigraphy alone are sometimes hampered by limited exposure, low preservation potential of tephra layers due to erosion and reworking, and lack of precise dating owing to discontinuous strata. In order to understand the eruption history, a comprehensive approach through the analysis of volcanic deposits in fluvial, lacustrine and marine sequences is necessary. A lake system adjacent to active volcanoes can record various volcanic events such as explosive eruptions and subaqueous density flows being extensions of subaerial lahars. A lacustrine depositional sequence can constrain high time-resolution of such events because of constant, continuous, and high rates of background sedimentation.

The studied sediment core was obtained from off Lake Inawashiro-ko, Fukushima, Japan at the central and the deepest part of the lake (90 m water depth). The lake is the largest freshwater volcanic dam-lake in Japan and has active Adatara and Bandai volcanoes in its catchment. A 29-m-long core has 19 tephra-fall layers mostly sourced from remote volcanoes other than Adatara and Bandai and 71 flow event deposits in background hemipelagic clayey sediments. The age-depth model, based on the widespread tephra layers and <sup>14</sup>C dating, well constrains the ages and recurrence intervals for individual events during the past 50,000 years.

Sedimentary facies, petrography, grain size, micro-XRF and XRD analyses, and chemistry of glass shards indicate the origin of the flow event deposits as follows. 1) Gray event deposits (Gm/Gs) are usually millimeters to centimeters thick and are composed of clayey silt (Gm) and very fine sand to silt with a subunit of clayey silt (Gs). The deposits contain sulfide/sulfate minerals and have high sulfur content which point to a source from hydrothermally altered material ejected by phreatic eruptions at Adatara volcano as subaerial eruption-associated lahars entered into the lake. 2) Brown event deposits (Bm/Bs) are centimeters thick and thicker than those of Gm/Gs deposits. The deposits consist of clayey silt to silt (Bm) or very fine sand (Bs) and contain fresh glass shards derived from Bandai volcano. It is normally graded with a sharp erosive base and suggests more proximal origin. The characteristics show that the brown deposits were emplaced by density flows triggered by subaerial magmatic hydrothermal eruptions at Bandai and partial flank collapse.

The high-resolution chronology of gray and brown event deposits records subaerial volcanic activity at Adatara and Bandai and increases the known explosive eruption frequency at Bandai adding new 24 magmatic hydrothermal eruptions, and at Adatara by 3-fold number of phreatic eruptions. The results in the present study are critically important to evaluate volcanic risks including frequent eruptions and far-reaching lahars for the heavily populated downstream towns.

O-1117

## Fingerprinting basaltic tephras erupted from mid-Holocene Mounts Gambier and Schank: first analyses of glass and minerals of proximal Australian tephras

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### Abstract

Intraplate volcanoes of southeast South Australia (Mount Gambier sub-province) form the western extension to the Newer Volcanic Province of western Victoria. They comprise two groups: a northern Pleistocene group (not considered further) and a southern Holocene group consisting of the isolated Mount Gambier (MTG) and Mount Schank (MTS) complexes, the youngest volcanoes in Australia. MTG and MTS comprise complex maar and cone structures built over eruptive fissures. Strongly influenced by abundant groundwater, they are dominated by pyroclastic (tephra) deposits including scoria, lapilli, and ash, with minor lavas. The two complexes, ~10 km apart, erupted ~5000 years ago and the resultant tephras contain both “exotic” (non-volcanic) crystalline material, derived from underlying Tertiary limestone and calcareous dunes, and juvenile (new) basaltic material. Although petrological and volcanological research has been undertaken on MTG especially in recent years, usually on whole-rock lava or pyroclastic (scoria) samples, analyses of volcanic glass and crystals per se from tephras have not been reported. Ash fractions at MTG are dominated by considerable limestone and quartz, chert, and siliceous sponge spicules (~80%), together with volcanic crystals (forsteritic olivine, labradorite, clinopyroxene (mainly diopside), and Fe-Ti oxides) and comparatively low contents of glass (<20%), much of which is altered. Ash fractions at MTS contain much less exotic material (quartz and sponge spicules) and have higher glass contents (~50%), most unaltered, along with volcanic crystals as at MTG. There is little difference between glass from MTG and MTS with regard to electron microprobe-determined major oxides: mean SiO<sub>2</sub> at MTG is 49.62 ± 0.55 wt % (n = 21) and at MTS is 49.72 ± 0.86 wt % (n = 18) (normalised), with most shards classified as phonotephrites in the total alkali-silica diagram. Al<sub>2</sub>O<sub>3</sub> in glass in tephras from both volcanoes is high (16-17 wt%). “Extra” SiO<sub>2</sub> occurs at MTG because of the more abundant xenolithic silica polymorphs. Soils on MTG and MTS tephra deposits are formed under an annual rainfall of c. 700 mm in a xeric moisture regime with long dry summers, and are near neutral or alkaline. They include the only Andisols of Australia, namely Xerands, which are uncommon globally (~3.5%). Clay fractions in soils at MTG (on basaltic tephra with low glass and abundant exotic materials) are dominated by layer silicate minerals, including kaolinite, illite, interstratifications of kaolinite and smectite, and some discrete smectite. In contrast, at MTS (on basaltic tephra with common glass and relatively few exotic materials), the clay fractions are less variable and are dominated by allophane and ferrihydrite. Notably, there is no halloysite formed in any soils at either MTG or MTS. Soils on tephras at MTG are classified in *Soil Taxonomy* as Vitrixerands, Haploxerands, and Calcixerolls; at MTS they are Haploxerands and Melanoxerands.

O-1118

## Unravelling the eruptive history of volcanoes in North Sumatra, Indonesia using tephrostratigraphy

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### Abstract

The vast Indonesian archipelago spans more than 5000 km and is host to over 126 recently and historically active volcanoes. Of particular interest is Sumatra in western Indonesia, which accounts for at least 30 of these active or potentially active volcanoes across the archipelago. These volcanoes lie in close proximity to major cities in Indonesia such as Medan (estimated at 2.5 million inhabitants), Palembang (1.6 million) and Padang (1.0 million), but also not too distant from highly populated countries like Malaysia (31.7 million) and Singapore (5.6 million). And yet in spite of the inherent risk, the eruptive history of these volcanoes is poorly known, as only a handful have been studied and regularly monitored. To rectify this, tephrostratigraphy is used as a tool to unravel the history and behaviour of past Sumatran eruptions: their frequency, magnitude and spatial footprint. Tephra/cryptotephra sequences preserved in marine and peatland environments are the focal points of the study. A 17.76 m sediment core MD16-3522 was collected from the north-east Indian Ocean (3.522°N; 92.946°E; 4417 m) in July 2016 during the MD204/MIRAGE I expedition on board R/V Marion Dufresne. Between 0 and 12.20 m below seafloor, three visible centimetre- to decimetre-thick tephra layers were identified in the sediment core: i) MD16-3522-158-161 cm (VTL1); ii) MD16-3522-685-688 cm (VTL2); and iii) MD16-3522-1217-1219 cm (VTL3). <sup>40</sup>Ar/<sup>39</sup>Ar age constraints and major and trace element compositions of glass shards extracted from the three discrete tephra layers provide hints towards their volcanic source. VTL1 is genetically related to the Young Toba Tuff eruption, whilst VTL2 and VTL3 are determined to be geochemically distinct from Middle Toba Tuff and Oldest Toba Tuff layers. Other potential source volcanoes were considered, but due to the dearth of geochemical and age data available for Sumatran volcanoes, no correlations were made for VTL2 and VTL3. In addition, magnetic susceptibility, a\* (a measure of sediment redness) anomalies, positive Zr peaks acquired with a Multi-Sensor Core Logger (MSCL) and glass shard separations by dense liquids indicate the presence of up to seven cryptotephra horizons in the upper two metres of the core. Continued work on core MD16-3522 is expected to yield an expanded record of eruptions in the Quaternary, presumably with a volcanic source provenance centred on (North) Sumatra. Whilst ongoing research in the region is extended beyond the MD16-3522 core to other offshore deep-sea cores previously collected by the SO189-2 research expedition on board R/V Sonne in 2006 and to various peatlands in North Sumatra.

O-1119

## Quaternary environmental reconstruction from remobilised tephra deposits

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### Abstract

In Quaternary science, tephra layers are primarily used for chronological control, but on occasion, this application is complicated because the tephra deposits may be remobilised either as particles or as entire layers. We explore the ways in which tephra deposits may be remobilised in part, or as whole layers with a series of case studies of late Quaternary Icelandic tephra in both proximal and distal deposits. Partial layer remobilisation in the form of the particle movements may take place over a range of scales from a few millimetres to many kilometres, and involve materials ranging in size from cryptotephra to cobble-grade pieces of pumice. This type of particle mobilisation can provide data on a range of processes from small-scale sediment movements within individual profiles, to the large-scale circulation patterns of wind and water across the North Atlantic. Tephra layers may be also distorted by the movement of the sediment that encloses them, and in this circumstance, the tephra deposit still form a coherent layer, but with a changed morphology. In these cases, it is possible to assess the consequences of range of Quaternary environmental changes from the movement of glacier ice to cryoturbation, and begin to understand the processes that drove them. For example, thufur (frost hummock) formation may occur episodically through time, and because of different types of sediment movement. Tephra layers help us to understand both when episodes of hummock formation took place, and what sort of sediment movements were involved. When taking a narrow view of the utilisation of tephra in Quaternary science as solely chronostratigraphic marker horizons, post depositional movements of grains or layers can be seen as a problem, but this remobilisation also provides opportunities to learn more about both the processes and legacies of past Earth surface processes, and movements wind and water.

O-1120

## Disentangling the effect of thermal and microbial degradation on the distribution pattern of paleosol derived *n*-alkanes: Implications for paleo-fire reconstruction

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### Abstract

Biomass burning is an important component of major biomes as it acts as an ecological forcing factor in controlling the vegetation composition as well as biomass production. Thus long-term paleo-fire records are required to understand the extent to which future fire regimes will affect ecosystem health and the global carbon balance. Unfortunately, paleo-fire proxies such as charcoal analysis, dendrochronology, geochemical analysis of sediments and archaeological relicts are often fragmented and difficult to interpret owing to their poor preservation in the natural archives. To resolve the uncertainties associated with the existing paleo-fire proxies, biomarker-based investigations provide a new avenue for gaining insight into the paleo-fire events due to their relatively stable chemical property and low susceptibility to degradation. In this context, core sediments were collected from the Banni grassland located at close proximity to the archaeological site of Dholavira (Harappa Civilization), Northwest Gujarat, India. The samples showed a predominance of short-chain *n*-alkane (C<sub>14</sub>-C<sub>20</sub>) which constituted ca. 50 % to 75 % of the total *n*-alkane concentration. In addition, the samples displayed a prominent even-over-odd preference (EOP) in short-chain *n*-alkane. Higher concentration of short-chain *n*-alkane with EOP is often attributed to microbial or thermal degradation of the organic matter. During thermal degradation, short-chain *n*-alkanes are produced at the expense of long-chain *n*-alkanes while sources of short- and long-chain *n*-alkanes differ during microbial degradation. In order to disentangle the effect of thermal and microbial degradation on the distribution pattern of *n*-alkanes, available record from the microbially degraded sediments of the Ennamangalam Lake, Southern India, have been compared with the sediments collected from the Banni grassland. Here, two novel *n*-alkane indices have been developed to disentangle the influence of these degradation processes. Positive and significant correlation ( $R^2 = 0.9$ ,  $p < 0.05$ ,  $n=19$ ) between C<sub>18</sub> (dominant in short-chain) and C<sub>29</sub> (dominant in long-chain) homologues indicate that the sediments in Banni region have suffered thermal degradation. On the contrary, microbially degraded sediments from the Ennamangalam lake exhibited statistically insignificant correlation ( $R^2 = 0.2$ ,  $p < 0.05$ ,  $n=19$ ) between C<sub>18</sub> and C<sub>29</sub> homologues. To extricate the influence of microbial and thermal degradation, ratio between the relative concentration of C<sub>18</sub> and C<sub>19</sub> homologues ( $P_{\text{Factor}}$ ) have been used. For thermally degraded samples, the  $P_{\text{Factor}}$  values (11 to 62) are much higher compared to that of the microbial degraded samples (1 to 10). Thus, the observed difference in the  $P_{\text{Factor}}$  values and inter-homologue correlation can be used to disentangle the effect of thermal and microbial degradation on *n*-alkane assemblage. Moreover, the present study suggests that the *n*-alkane assemblage in sediments can be used as a molecular marker to reconstruct paleo-fire events.

O-1121

## Anthropogenic fires in agroforestry landscapes of India: Lessons from the “burnt” past for future ecological management in the tropics

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### Abstract

The effective management of human-dominated tropical forest landscapes is crucial in the wake of global climate change affecting biodiversity, ecosystem functions, and the livelihoods of billions. Among a wide range of practices, agroforestry remains one of the most promising land management strategies in the tropics, promoting intentional maintenance of trees on farmland for productive agriculture, thereby supporting the livelihoods of millions and providing avenues for climate change mitigation. Acknowledging its diverse benefits, the Government of India launched the National Agroforestry Policy (NAP) in 2014, world’s first nationwide policy with the central idea of doubling the agroforestry area concurrent with the expansion of national forest cover. As the world’s most populous country, yet its fastest growing economy, moving towards “Green India” would be a serious game-changer for this tropical country with positive environmental implications on a global scale. The effective implementation of this economically important policy falls on the shoulders of Indian Forest Departments (IFDs), who administer a strict policy of preventing fires in and around forests. Fire, however, is an integral part of forest ecosystem functioning; its strict prevention leads to accumulation of biomass, causing more severe fires. A growing body of present-day and palaeo-fire studies showing links between biomass and fire is leading nations to revisit their landscape management strategies with some (e.g. Australia, South Africa, United States) adopting prescribed burning. We argue that in the light of the NAP, understanding the role of historical fire regimes is imperative to the management of age-old, human-dominated Indian agroforestry landscapes where people have traditionally used fires in shifting cultivation. The disagreements in fire practices often instigate serious conflicts between local communities and IFDs, hampering implementation and the desired impact of the NAP and its associated benefits. In this context, we bring a new, high-resolution palaeo-fire record from Western Ghats agroforestry landscape spanning past few millennia. Utilising macroscopic and microscopic charcoal analyses, palaeoecology-driven innovative statistical modelling approaches (e.g. pollen-based REVEALS modelling, rarefaction, and multivariate ordination), and palaeoclimate databases, we present time-resolved transformations of Indian agroforestry landscapes in relation with past fires and monsoonal variability across the Common Era and beyond. Quantitative reconstructions of past landcover and land use at a time-resolution of 20-50 years allow us to: 1) deepen the fundamental knowledge of these long-term social-ecological systems; 2) render state-of-the-art understanding of the efficacy of fires in forest management in a seriously data-poor region; and 3) deliver region-specific, tangible implications for the effective implementation of NAP and its wider applications to other parts of the tropics. Our work is part of project “[EARNEST](#)” that has received funding from the European Union’s Horizon 2020 research and innovation programme under the grant agreement no. 795557.

O-1122

## Fire regimes in consumer-driven C<sub>4</sub> grassy biomes derived from sedimentary charcoal

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### Abstract

Consumption of grass biomass by fire is an important earth system process contributing to terrestrial nutrient cycling. In assessing long-term controls of fire, Whitlock et al. (2010) propose a framework of overlapping triangles ranging from flammability, fire events, to fire regimes at increasing spatial and temporal scales. However, this system is unsuitable in some C<sub>4</sub> tropical grassy biomes because large herbivores also consume grasses; grass mosaics have multiple stable states; and grass biomass is coupled to climate. Although fire events/ activity increase with the proportion of flammable C<sub>4</sub> tallgrasses, herbivory and wetness of fuels suppress it. As a result, there is confounding in long-term spatial relationships between flammability and fire regimes derived from sedimentary charcoal fire proxy. This idea is explored at persistent wetland margin grasslands using charcoal records from a lowland savanna and two montane grasslands of South Africa where C<sub>4</sub> tallgrasses, herbivory, and aridity decrease with elevation. At all sites, fire activity indicated by charcoal amounts increased along local C<sub>4</sub>-C<sub>3</sub> grass biomass gradients, peaking at intermediate values before tapering. There was low variability in charcoal amounts at low and high grass biomass, and in sites with low or high herbivory. Consequently, a single triangle was used to represent multiple regimes along a biomass/ gradient with flammability increasing toward the apex while fire events populated regime partitions. The new triangle provides a template for investigating regime shifts and multiple stable states in grassy biomes with competing consumers. Interestingly, the new framework suggests the extension of the spatial constituent of fire regimes increases uncertainty in pooled fire reconstructions from biome boundaries while indicating the value of consumers-related plant traits.

### Reference:\*

Whitlock, C., Higuera, P.E., McWethy, D. B., and Briles, C.E. 2010, Paleocological perspectives on fire ecology: revisiting the fire-regime concept, *The Open Ecology Journal*, 3(2):6:23

O-1123

## Biomass burning during the Last Glacial-Interglacial Transition (c. 17-8 ka cal. BP) in the British Isles; spatiotemporal patterning and controls

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### Abstract

Charcoal records are now widely used to reconstruct and investigate what controls wildfire activity on centennial to millennial timescales. The topic, however, has been largely overlooked in the British Isles, with most evidence of biomass burning being attributed to anthropogenic ignition on the basis that the region does not support natural burning regimes.

Here we present the first synthesis of published charcoal data for the British Isles from records that span the Last Glacial Interglacial Transition (LGIT; c. 17-8 ka cal. BP). In total, 238 sites were identified which allows detailed spatiotemporal trends to be identified. The compiled data were transformed into presence-absence, assigned to the major climatic intervals of the LGIT (GS-2.1a, c. 17-14.65 ka cal. BP; GI-1, c. 14.65-12.85 ka cal. BP; GS-1 12.85-11.25; Early Holocene, c. 11.65-8.28 ka cal. BP) and then assessed in relation to broad patterns in climate, vegetation, and anthropogenic activity.

Results demonstrate the widespread occurrence of charcoal in sediments that span the LGIT in the British Isles. Investigation into the charcoal curves has revealed several interesting patterns: 1) high charcoal values during GS-2.1a that cease with the onset of the GI-1 at c. 14.65 ka cal. BP, 2) spikey or distinct peaks in charcoal records spanning GI-1, as well as enhanced landscape burning during the latter stages of the GI-1 (~14-13 ka cal. BP), 3) high charcoal values during GS-1, and finally 4) multiple charcoal peaks in the Early Holocene with a coincident peak apparent in multiple sites throughout the British Isles at ~9.3 ka cal. BP, the timing of which has been ascertained via new Bayesian age-depth modelling.

No causal links between presence of charcoal and vegetation types can be identified, however contemporaneous burning through different floral mosaics suggests that vegetation was not the principle variable driving fire regimes. The absence of associated archeology in GS-2.1a and GS-1 (as well as the distribution of archaeological sites during GI-1) strongly suggests that humans were not the primary driver of fire regimes during the Lateglacial (i.e. GS-2.1a, GI-1, and GS-1) either. The distinct peak in charcoal identified here during the Early Holocene at c. 9.3 ka cal. BP is explored via correlation to both climatic and archeological datasets, using the 'dates as data' approach to estimate past human population intensity. Although humans on the landscape preclude any strong hypothesis to be made, the synchronicity and spatial extent this peak is evident probably points to a climatic control for the Early Holocene as well.

The findings here fit with other evidence for climatically controlled burning in Northern Europe and suggest that notions that temperate oceanic climate-landscapes such as the British Isles do not naturally burn is incorrect.

O-1124

## Holocene fire and forest histories in relation to climate change and agriculture development in southeastern China

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### Abstract

Four cores (GY1, LTY, SZY, GT-2) taken from lowland to mountain sites in southeastern subtropical China were studied. Charcoal and pollen analyses were conducted to examine the regional Holocene fire history and discuss its possible relationship with both climatic changes and anthropogenic activities. Our results show extremely low charcoal influxes between 9.5 and 3.5 cal ka BP, revealing low fire frequency. Meanwhile, high proportions of arboreal pollen demonstrated expansion of subtropical evergreen broadleaf forest. This phase is consistent with heavy precipitation during the early-mid Holocene. After 3.5 cal ka BP., the abrupt increases in fire frequency revealed by core GY1 and LTY were closely related to gradual drying towards the late Holocene, possibly due to the Asian Summer Monsoon weakening and activation of the El Niño Southern Oscillation. Our pollen records also reveal this drying trend after the mid-Holocene, demonstrating a regional retreat of subtropical evergreen forests and local development of *Glyptostrobus*-dominated wetland community around the LTY and GY1 sites. However, the intensified fires after 3.5 cal ka BP probably resulted mainly from increasing human activities during the Shang-Zhou Bronze age. Pollen results show severe damage of forest by fires, indicated by notable decrease of arboreal pollen and increase of *Dicranopteris* and herbs. After 2.0 ka, obvious growth of Poaceae, *Dicranopteris* and *Pinus* recorded in the GY1 and LTY cores demonstrate agriculture development in low- altitude plains and hills, coinciding with the first human population boom and big progress in agricultural technology during the Warring States to Western Han Dynasty period. Signs of profound human impacts and extensive agriculture in South China appeared after 1.0 cal ka BP, which is revealed by frequent local fires and intensified anthropogenic impact around the mountains sites (SZY and GT-2). Generally, our results reveal a gradual expansion of anthropogenic activities into elevated areas.

O-1125

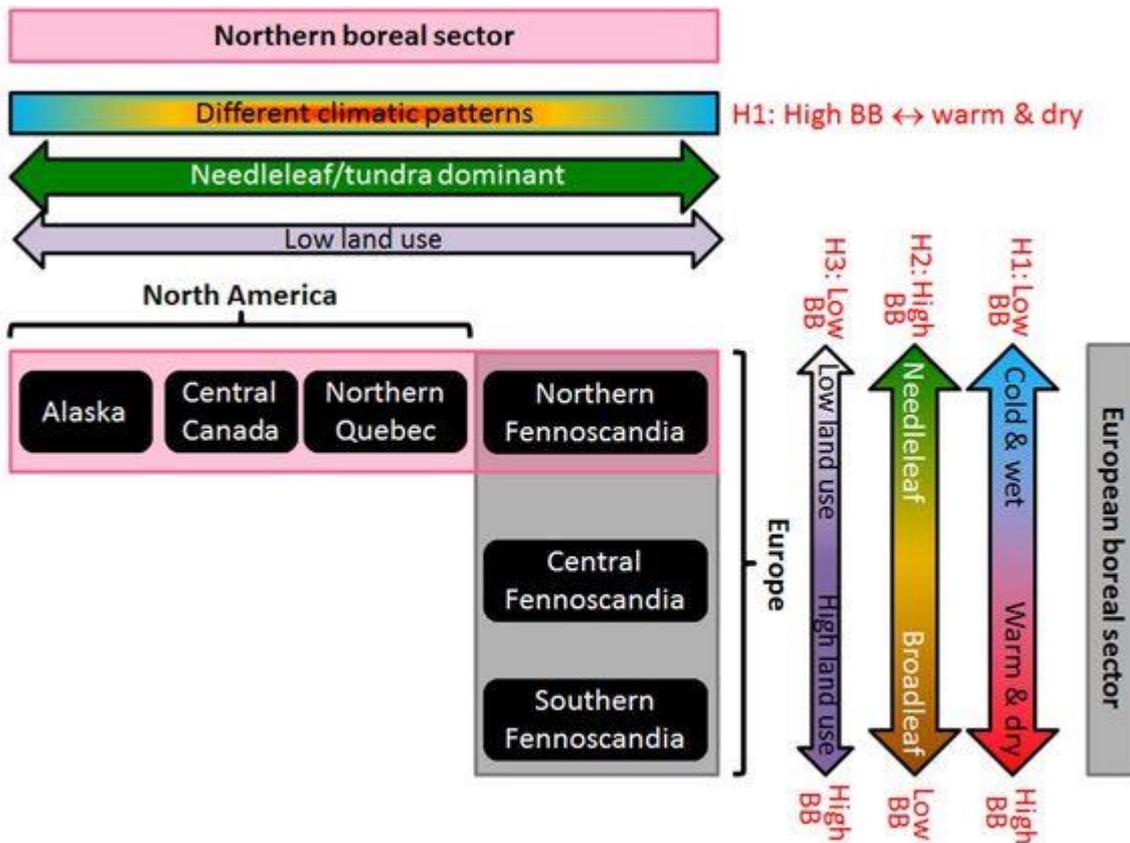
## The climate, the fuel and the land use: long-term regional variability of biomass burning in boreal forests

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### Abstract

The influence of different drivers on changes in North American and European boreal forests biomass burning during the Holocene was investigated based on the following hypotheses: land use was important only in the southernmost regions, while elsewhere climate was the main driver modulated by changes in fuel type. Biomass burning was reconstructed by means of 88 sedimentary charcoal records divided into six different site clusters. A statistical approach was used to explore the relative contribution of (1) pollen-based mean July/summer temperature and mean annual precipitation reconstructions, (2) an independent model-based scenario of past land use, and (3) pollen-based reconstructions of plant functional types on biomass burning. Our hypotheses were tested with: (1) a west-east northern boreal sector with changing climatic conditions and a homogeneous vegetation, and (2) a north-south European boreal sector characterized by gradual variation in both climate and vegetation composition. The processes driving fire dynamics in boreal forests varied from one region to another during the Holocene. However, general trends in boreal biomass burning were primarily controlled by changes in climate (mean annual precipitation in Alaska, northern Quebec and northern Fennoscandia, and mean July/summer temperature in central Canada and central Fennoscandia) and, secondarily, by fuel composition (BB positively correlated with the presence of boreal needleleaf evergreen trees in Alaska and in central and southern Fennoscandia). Land use played only a marginal role. A modification towards less flammable tree species (by promoting deciduous stands over fire-prone conifers) could contribute to reduce circumboreal wildfire risk in future warmer periods.



Conceptual study design based on boreal forest regions that contain sedimentary charcoal time series. Hypotheses linking biomass burning and different drivers are displayed in red.

O-1126

## Time, space and causality in past wildfire regimes: a paired-lake study from central Anatolia

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### Abstract

It has long been known that causal mechanisms in environmental systems are scale-dependent (Schumm and Lichty 1965, *Am. J. Sci.*, 263, 110-19). For wildfires, independent variables such as fuel load can become dependent variables over multi-millennial time-scales. Testing such scalar mechanisms in palaeo-fire research is possible if we can coax Quaternary history to conduct experiments for us (c.f. Deevey 1969, *BioScience* 19, 40-43). Here we compare charcoal records from two maar lakes 25 km apart in Cappadocia, Turkey, since 13.8 ka. For micro-charcoals, laboratory methods involved density separation of contiguous core samples and optical counting. Core dating is based on U-Th and varve counting, with vegetation history from pollen analysis.  $\delta^{18}\text{O}$  analysis of authigenic carbonates confirms that the two lakes experienced very similar hydro-climatic histories (Dean et al. 2015; *Quat. Sci. Rev.* 124, 162–174; Roberts et al., 2016; *J. Quat. Sci.* 31, 348–62).

The sedimentary sequence from Eski Acigöl spans the last ~20 ka but is poorly resolved for the last 2 ka, while that from Nar covers the last 13.8 ka, but with a probable mid-Holocene hiatus. The two records therefore overlap in time for the Late Glacial to early Holocene climatic transition, the early-mid Holocene (until 6.5 ka BP) and for part of the Late Holocene (~4.5 to 2 ka BP). There were different fire regimes and forcings for each of these three time periods. At Eski Acigöl, there is a clear correlation between  $\delta^{18}\text{O}$ -inferred hydro-climate and micro-charcoal influx throughout the record (Turner et al., 2008; *Glob. Planet. Change* 63, 317-324), with wildfires being fuel-limited and consequently increasing during wetter times with greater biomass. A similar relationship operated at Nar, but only during the Last Glacial-Interglacial Transition (LGIT). At both sites, burning was sharply reduced during the cold, dry "Younger Dryas" stadial associated with low-biomass *Artemisia*-chenopod steppe, and increased during grass-dominated periods of warmer, wetter climate. After ~10 ka BP the charcoal record at Nar lake does not exhibit the same close relationship with  $\delta^{18}\text{O}$ -inferred hydro-climate seen at Eski Acigöl. This implies that a more complex set of mechanisms controlled micro-charcoal flux at Nar during most of the Holocene, including human-induced catchment disturbance as early as 9.1 ka BP, associated with Neolithic obsidian mining near the lake. Pollen data from Nar lake (England et al., 2008, *Holocene* 18, 1229-45) indicate that by the last 2-3 ka, anthropogenic land cover change became main pacemaker for burning regimes.

We conclude that when forcings, such as LGIT climate change, were of large magnitude and multi-centennial duration then palaeo-fire regimes were spatially coherent and homogeneous. When forcings were smaller, shorter-lived or multi-causal (e.g. mid-Holocene), then a more heterogeneous pattern of wildfires would have been registered in sedimentary charcoal records.

O-1127

## The role of proglacial lakes in the decline of the terrestrial-terminating Irish Sea glacier

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### Abstract

Proglacial lakes and the subglacial topography were significant regulators of glacial dynamics during the advance and decline of an extensive former ice lobe that invaded the lowlands of northwest England and English Midlands. The eastern sector of the Irish Sea Ice Stream, at the last glacial maximum, extended onto land and then south into the English Midlands as an extensive grounded terrestrial ice lobe. These lowlands received flows from Irish Sea ice and valley glaciers exiting from Wales. New mapping of the sediment landform assemblages of Cheshire, Shropshire, Staffordshire and the Welsh borderlands has recorded the advance to maximum limits and the progressive unzipping of the different ice masses during later retreat. The sediment-landform assemblages reveal the repeated development and then abandonment of ice contact land-systems with numerous styles of proglacial lakes, sandur and moraines with glacial retreat. Major quarries in the region reveal the sedimentology of these environments and provided access to deposits for Optically Stimulated Luminescence (OSL) dating. This new chronology exploits parallel approaches of single grain and small aliquot OSL measurements of quartz, and cobble-based OSL of feldspars in outwash gravels. The new chronology constrains ice marginal retreat to the period after ~25 ka, with ice eventually vacating the region by ~22-21 ka.



Fig 1. Ice marginal retreat sequence in lowland NW England.

Active oscillation of the ice margin during retreat produced the more extensive moraine ridges, with complex terrains of ridges and kettle-basins developing in zones characterised by stagnation of the ice margin. The most substantial deglacial landform in the retreat sequence is the Oswestry-Whitchurch-Congleton moraine formed as the ice margins passed northwards of substantial bedrock highs. Lakes were an endemic component of this deglacial landsystem, and took a myriad of forms including glacial over-deepenings, both moraine and bed-rock confined ice contact lakes and ice melt-out hollows (kettle basins). Late during this deglaciation ice masses sourced from Wales took advantage of the accommodation space vacated by the Irish Sea glacier and advanced crossing-cutting and overprinting the Irish Sea Glacier retreat signature leaving a series of lobate moraine ridges exiting Wales. Retreat northwards and down-wasting of ice meant that individual ice sources increasingly regulated the ice flow dynamics producing the lobate moraine systems in the developing Dee, Weaver basins and the Manchester embayment. Pinned between the mid-Cheshire bedrock high and retreating ice margins separate proglacial lake basins developed, and extensive deltas developed at Wrexham and Delamere. Ultimately, ice marginal retreat led to the evacuation of the basins by 22-21 ka and the escape of lake waters west into a deglaciated western Irish Sea basin.

O-1128

## Large-scale deformation structures characterize glaciolacustrine kame sediments—a new kame-investigation approach

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### Abstract

Fine- and course-grained kames are commonplace forms in glacial landscapes. Here six fine-grained kames located in eastern Poland and southern Lithuania are analysed in detail. These kames were formed during MIS6 and MIS2. They consist of a distinctive suite of sediment grain sizes, being in constitution an admixture of clay, a full range of silt fractions, and fine-grained sand. Based on this granulometric composition all are classified as glaciolacustrine kames, and were formed in ice-walled depressions, subsequently infilled by ice-sheet meltwater.

A characteristic feature of all of the analysed kames is their extraordinarily rich scale of soft-sediment deformation structures (SSDS), which were observed across their entire lateral and vertical extent. Among the SSDS were: small- as well as large-scale load casts ( $\leq 120$  cm); variably-sized pseudonodules; silty/sandy injection structures—*i.e.*, mud volcanoes; flame structures; and dish structures. Typically the large-scale load casts and pseudonodules contain a few generations of smaller SSDS. The largest of these load casts can enclose two, three, four or even five generations of smaller deformations. This complexity appears to be a result of multiple-stages of kame-sediment deformation, an artefact of a significant volume of water having been present during the sedimentation process.

It should be apparent from the very fine-grained sedimentary record that a very specific water regime presents during kame formation played an essential role in SSDS formation—specifically having occurred during general deglaciation. These are depositional conditions that are quite different than those that would have existed during the formation of sandy/gravelly glaci-fluvial kames. SSDS formation depended on sediment fluidization, and on slight differences in their grain-size distribution. Additionally, that sedimentation must have taken place prior to a final consolidation and before the melting of the depressions' ice-walls, within which the kame sediments were accumulated. This is evidenced by faults observed in the marginal zones of the kames, which post-cut the SSDS. These fine-grained kames were most likely formed during the initial stages of deglaciation, occurring in isolated depressions within the ice with bottoms located above the sediment-rich subglacial zones.

The aim of our presentation is to propose that SSDS are distinctive indicators that fine-grained glaciolacustrine kame development occurred under specific and limited conditions of deposition and deformation. This work can also help in the identification of kame sedimentological environments during older glaciations in the absence of additional morphological context.

Acknowledgements. The work has been financially supported by project GREBAL from the National Science Centre Poland No. 2015/19/B/ST10/00661.

O-1129

## Architecture and structural evolution of the Late Weichselian Jasmund Glacitectonic Complex (Rügen Island, NE Germany)

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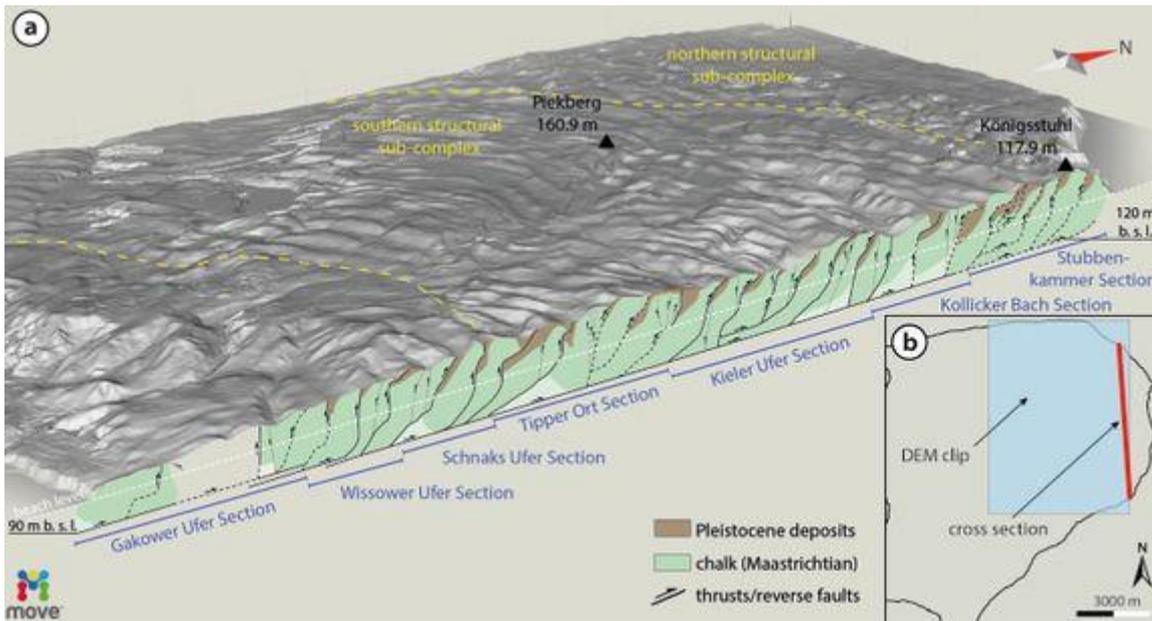
### Abstract

Glacitectonic deformation in the Late Weichselian (MIS 2) caused the tectonic framework of large-scale folds and displaced thrust sheets of Maastrichtian (Upper Cretaceous) chalk and Pleistocene glacial deposits in the southwestern Baltic Sea area, which are well exposed in Denmark and northern Germany.

A wide spectrum of methods has been compiled to unravel the structural evolution of the 100 km<sup>2</sup> large Jasmund Glacitectonic Complex. DEM analyses suggest a division into two structural sub-complexes – a northern part with morphological ridges striking NW–SE and a southern part with SW–NE trending ridges. Geological cross sections from the eastern coast (southern sub-complex) were constructed and restored using the software Move™ and the complementary module 2D Kinematic Modelling™.

The final structural model of the southern sub-complex shows a small-scale fold and thrust belt. It includes three different orders of architectural surfaces sensu Pedersen (2014): erosional surfaces and detachment faults (1st order), thrust faults (2nd order), and hanging-wall anticlines as well as footwall synclines (3rd order). Thrust faults inclined towards south indicate a local glacier push from the S/SE.

The glacitectonic structures have a surface expression in form of sub-parallel ridges and elongated valleys in between. Geomorphological mapping and detailed landform analyses together with the structural investigations provide an insight into the chronology of sub-complex formation. The northern part of the glacitectonic complex is suggested to have been formed first by an ice advance from NE, considering the partly truncated northerly ridges and their superimposition due to the slightly younger formation of the southern sub-complex. The crenulated easternmost ridges suggest a third glacier push from E/ENE. Our new genetic model of the Jasmund Glacitectonic Complex contradicts numerous models published earlier, but it is self-consistent and integrates all structural parts.



**Figure 1. Principal 3D view of the Jasmund Glacitectonic Complex. a)** Interpreted cross section of the southern structural sub-complex below the digital elevation model (DEM5), which shows the main parts of the northern and southern ridge domain. **b)** Map of the Jasmund Peninsula in the SW Baltic Sea with the DEM clip (blue) and the section trace (red line), which are shown in (a). The model is two times exaggerated. The section trace is located further towards the inland than the shown cross section, which is originally from the cliff.

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O-1130

## Glacial history and paleoenvironment in the Polar Ural Mountains and adjacent areas of Northern Russia since the last interglacial.

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### Abstract

We here present our current understanding of the glacial, environmental and climate history in the Polar Ural Mountains and adjacent lowland of the Russian Arctic. Our reconstruction of the past environment is based on a multitude of data that have been obtained from geomorphological mapping, stratigraphic examination of exposed strata, geo-archaeological investigations of Paleolithic sites and coring of lake basins. The northern rim of the continent appears to have been inundated by the Barents-Kara Ice Sheet twice during some early stages of the last Ice Age, which according to our dating results happened during Marine Isotope Stage (MIS) 5b (~90 ka) and MIS 4 (75-60 ka) respectively. These ice advances blocked the northbound drainage on the continent and led to the formation of large ice-dammed lakes that flooded the lowland areas to the south of the ice sheet. The ice-dammed lakes, which presumably drained catastrophically into the Ocean towards the end of the major glaciations, caused a dramatic cooling of the summer climate across a wide region. At least during the latter glaciation a complex of large glaciers formed within the Polar Ural Mountains and these glaciers coalesced with the Barents-Kara Ice Sheet that were flowing southwards along both flanks of the mountain chain. The large ice sheets that existed at these times appears to have melted completely away during MIS 5a (~85-80 ka) and MIS 3 (60-30 ka). During MIS 3 the northern landscapes hosted a rich and varied mega fauna, and was at least periodically colonized by humans. A new generation of glaciers started to form during a late stage of MIS 3 reaching their maximum extent during MIS 2. However, both the shelf-centered ice sheet and local glaciers in the mountains were then smaller than during the foregoing glaciation, and the major mountain valleys have remained ice-free over the last 50-60 ka. Results from a lake coring campaign indicate that the mountain glaciers during MIS 2 reached their maximum dimension just prior to 24 ka, a few thousand years before the glacial maximum of the ice sheet further to the north. The glaciers started to melt soon after the LGM, and they appears to have been gone by 14 ka. During the Early Holocene, the main valleys in the Polar Urals and the northern rim of the adjacent lowland were forested reflecting a significant warmer climate than today. The present small glaciers that exist in the mountains formed during a late phase of the Holocene and had their maximum extent were attained early in the 20.th century. Presently, almost all glaciers in the Polar Urals have melted away in response to the ongoing global warming.

**O-1131**

## **Rethinking deglaciation of the interior Cordilleran Ice Sheet, southern British Columbia**

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### **Abstract**

Conceptual models of deglaciation of the last Cordilleran Ice Sheet (CIS) in central British Columbia (BC) have historically been limited to reconnaissance-scale investigations. These early studies proposed that the Interior Plateau region of BC deglaciated by regional stagnation, with widespread downwasting and complex frontal recession of valley-confined ice tongues. This conceptual model emerged from interpretations of glacial lakes and meltwater channels identified by early research conducted over the Thompson Plateau, and has been extended to explain the lack of large recessional moraines in central BC. The stagnation model has since been widely applied to the whole interior region of the former CIS. More testing is required in order to assess this model as an analogue for current and future ice sheet decay.

Several recent studies have challenged the stagnation model. This presentation will synthesise detailed investigations of several sub-regions across the southern Interior Plateau, utilising a range of methods including exposure sedimentology, shallow geophysics, mapping from new aerial photography and c. 10 m resolution digital elevation models (DEMs). Common terrestrial and lacustrine (de Geer) glaciotectonised moraines and grounding line deposits identified on the northern Thompson and southern Fraser plateaus indicate active ice front recession to the northwest. This is supported by new constructions of palaeo ice-dammed lakes that expanded and lowered to the west and northwest as ice recession opened progressively lower outlets. Reconstructed glacioisostatic tilts of lake planes are among the highest in the world, at up to 2.3 m/km up to the north-northwest; tilts decline to the northwest, recording either rapid crustal relaxation during deglaciation, or thicker ice on the central Fraser Plateau.

These recent investigations encourage a reappraisal of conceptual models of CIS deglaciation in BC's Southern Interior; available evidence is now consistent with systematic, active recession of the CIS over the Thompson and southern Fraser Plateaus broadly to the northwest.

O-1132

## (How) can large lateral moraines be used as sedimentary archives of Quaternary glaciations? A systematic process-assessment from the European Alps

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### Abstract

Large lateral and latero-frontal moraines are prominent landforms in mountain environments globally. They have long been regarded as providing key constraints on the extent and timing of Quaternary glaciations, thus adding a crucial layer of evidence to the sedimentary and geomorphological archives left by mountain glaciations in general. Since the introduction of the precursors to the glaciated valley landsystem (e.g. Boulton and Eyles, 1979), large lateral moraines and other ice-marginal landforms in mountain environments have largely been seen as the product of 'passive' supraglacial transport (i.e. resulting from the stacking of supraglacially-released, largely angular debris). However, much of aforementioned conceptual model is without a solid evidence base, at least as far as reported evidence is concerned. This is a significant shortcoming, because – while elegant and plausible conceptually – the model and its facies inferences have clear implications for the retrograde interpretation of glacial dynamics from Quaternary lateral moraines and moraine successions. Therefore, the current perception that large lateral moraines record merely the passive release of glacially-conveyed debris perhaps unduly limits their use as a geological archive of former glacier fluctuations and glacier dynamics.

We here summarise, for the first time, systematic geomorphological and sedimentological process observations and lithofacies analyses from six different glaciated valleys in the European Alps to test the predictions of the original glaciated valley landsystem that are still seen as current today (cf. Benn and Evans, 2010). The outcome of these studies points to a complex continuum between different endmembers that are controlled by very different boundary conditions (*inter alia* different degrees of debris cover on the glaciers, transport pathways through the glaciers, depositional mechanisms, lithological and climatic influences). These are found to have pronounced and characteristic effects on the final lateral moraine products. Based on this multi-factorial analysis, we conclude that lateral moraines are far more complex and enable a far more nuanced interpretation of the depositional palaeo-environment than hitherto appreciated (in the conceptual model of the glaciated valley landsystem). We argue that our initial template should be considered as a first step towards quantitatively assessing how complex landforms such as large lateral moraines may be utilised in the reconstruction of Quaternary glaciations, notably glacier dynamics. Our template could be further enhanced by including systematic studies from other mountain ranges where other controls (such as a stronger tectonic influence, greater range of bedrock lithologies etc.) prevail. This, we predict, would lead to a more holistic understanding of the effects and significance of mountain glaciers on the evolution of their entire catchments.

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O-1133

## Glaciers extent and climate in the Maritime Alps during the Younger Dryas

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### Abstract

Our planet experienced multiple cooling episodes since the last glacial maximum. One of these, the Younger Dryas (YD), is of particular relevance because it is the most recent period (12.9 and 11.7 ka ago) during which a cooling of the order of some degrees affected a large portion of the Earth. The YD affected the Earth and its inhabitants on multiple fronts. In particular, it caused the widespread (re)advancement of glaciers and the deposition of, usually well preserved, frontal moraines. These glacial deposits are the essential ingredient for the reconstruction of former glaciers, which can then be used to extract a palaeo Equilibrium Line Altitude (ELA), which bears crucial information about the palaeoclimate. Up until recent, this kind of reconstructions has been rather time consuming and usually limited to a few glaciers/moraines. However, recent GIS advances allow for faster (and therefore larger scale) palaeoglacier reconstructions. Such large scale reconstructions could be incredibly useful not only to better understand the glaciological response to past climate changes, but also to interpret human, floral and faunal migration and interaction patterns and dynamics (including extinctions). Here, we present a moraine (Figure 1) in the (European) Maritime Alps newly dated to the YD with cosmogenic isotopes (<sup>10</sup>Be). We reconstruct the extent of the glacier that deposited such moraine and extract its ELA. The same is applied to another moraine, already dated to the YD, and located some 40 km ESE. The two ELAs are then combined to define an average, regional ELA for the Maritime Alps and this is, in turn, used to reconstruct all YD glaciers (65) that likely covered this large (615 km<sup>2</sup>) sector of the Alps. A map of the reconstructed glaciers is presented (Figure 2) along with morphological evidence demonstrating the validity of the reconstruction. Finally, the regional ELA is used to extract local palaeoprecipitations and to discuss the YD climate across the Alps.

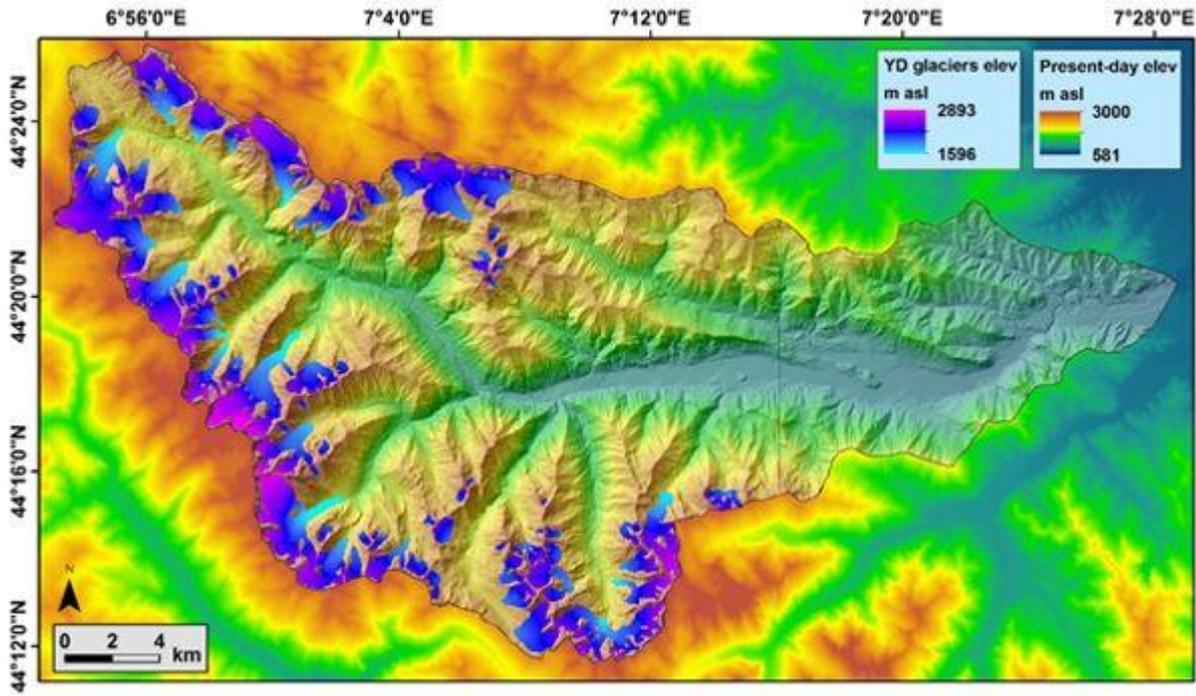
Figure 1. The moraine newly dated to the YD



Figure 2. The reconstructed YD glaciers in the Maritime Alps



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O-1134

## Pollen, people and peat: A mixed-methods approach to uncovering the prospects for Malaysia's tropical peatlands

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### Abstract

The peatland ecosystems of Southeast Asia are undergoing rapid change. Pervasive deforestation and drainage, primarily with the end-goal of large-scale land conversion to oil palm plantations, is disrupting their ability to sequester atmospheric carbon in peat deposits, in addition to causing significant negative consequences for the persistence of biodiversity, for the intensification of fire, and for multiple other processes that provide ecosystem functions of local to global significance. Conserving these peatlands in their intact state has been described as a “low hanging fruit in tackling climate change”. Yet land-use conversion continues in the peat-rich nations of Southeast Asia, where local stakeholders’ priorities are antagonistic to the calls of the international conservation community.

The goal of this project was to explore past vegetation change in these coastal peatlands and set it in the context of their current condition and potential future trajectory. Palaeoecological data were derived from cores collected from three degraded peatlands along the coast of Sarawak, in Malaysian Borneo. Changes in fossil pollen and charcoal were analysed in each core to reconstruct vegetation change and fire over the late Holocene. To understand more of the human history of interaction with the peatlands of this region, a comprehensive literature review and social surveys were performed. Semi-structured interviews were conducted with smallholder farmers, oil palm plantation managers and key informants involved in the management of Sarawak’s coastal peatlands. Enquiry focused on historical and contemporary use, management challenges and future visions for the peatlands.

In combination, the diverse datasets analysed in this study generated a cohesive narrative of peat swamp forest development, and subsequent degradation over the last several hundred years, with the reduction in forest pollen coinciding with the movement of people to the coastal swamps. Contemporary interactions with the peatlands reflected the limited understanding of the globally-significant ecosystem services provided by an intact peat swamp forest, and highlighted their immediate value as a resource to local stakeholders.

This project provides an interdisciplinary piece exploring the complex dimensions of tropical peatland management in Southeast Asia and insights for developing future conservation programs for this carbon-rich ecosystem. Authors are interested to obtain feedback on this study, as a mixed-methods contribution to *conservation* science, and to gather opinion on whether and how such work can contribute to developing effective policy.

O-1135

## Towards an ecocritical palaeoecology

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### Abstract

“Ecocriticism explores the ways in which we imagine and portray the relationship between humans and the environment in all areas of cultural production, from Wordsworth ...to Google Earth.” (Garrard 2012, frontispiece)

In this paper we aim to sketch the outlines of an ‘ecocritical palaeoecology’. Ecocritical studies focus on the relationship between the cultural origins of and responses to, current global ecological and environmental problems and crises. In its reading of texts, ecocriticism takes an earth-centred approach to literary studies. In this paper we consider the potential role of palaeoecology within ecocritical thought and in particular how an ecocritical approach effects the practice of palaeoecology itself. Specifically, how are specific ideas and representations of ‘past ecosystems’ and their relationship to human and non-human actors, created and sustained through palaeoecological work and study? What is the relationship of palaeoecology with the politics of debates such as ecosystem degradation and ‘past human impact on the environment’? Heise (2006) has drawn attention to the lack of a comprehensive model for linking contemporary perspectives and developments in ecology to ecocritical work and thought. Thus, one of our aims may be regarded as part of a broader project to form active disciplinary connections between (palaeo) ecology, ecocriticism and the Environmental Humanities.

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O-1136

## Conservation palaeoecology as a participatory science

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### Abstract

The prospect of environmental change beyond recent human experience is providing a powerful stimulus to evaluate conservation strategy and the science that underpins it. Although palaeoecologists have written about the importance of long-term data for anticipating and managing environmental change for many years, integrating this evidence into management continues to be a high priority for the palaeoecological community because our sources remain peripheral to conservation and ecology. Social science approaches are being used in conservation and environmental management to understand and bridge gaps between research, practice and policy, but very few palaeoecologists have followed this example to look more critically at how we interact with other communities.

This talk combines social science and palaeoecology to review what palaeoecologists can learn from conservation and environmental management about effective integration and communication. I present a case study on Atlantic woodland management that implements some of these guidelines via a participatory approach to conservation palaeoecology. The study used interviews with local stakeholders to identify key conservation habitats and questions with long-term relevance in the study area of NW Scotland. Stakeholders included the national conservation agency, land owners and managers, local ecologists and community interest groups. After conducting palaeoecological (pollen, charcoal, fungal spore) analyses in areas identified by interviewees, the results were communicated in presentations and evaluated through follow-up interviews with some stakeholders. This iterative approach demonstrates that palaeoecology and stakeholder experience play complementary roles. Long-term ecology can address uncertainties and test assumptions about key ecosystem processes that influence woodland composition and regeneration, while ecological and local experience provide the level of detail and practical knowledge required to translate these into locally-adapted and adaptive management strategies. The study also revealed some of the challenges involved in developing and sustaining dialogue with stakeholders whose management priorities may focus on immediate, short-term concerns, like grazing pressures from wild deer, which create tension locally, dominate management decisions and exclude longer-term issues. More studies that outline the scientific and social efforts, successes and difficulties of applying palaeoecology to management are needed to help the palaeoecological community reflect critically on how we work towards real-world impact.

O-1137

## The last 2000 years of the southern Balkans through the Lake Dojran (Greece, F.Y.R.O.M.) sediment archive and historical sources

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### Abstract

Societal and environmental processes influence and adapt each other. The complexity of past societies and the multiple possible environmental conditions bring a surprisingly varied interaction strategy. Going into detail, the interpretation of this relationship and its complex interaction require both high-resolution multidisciplinary studies and the deep understanding of the socio-economic history. This innovative approach is the base of an independent research group recently created at the Max Planck Institute for the Science of Human History in Jena that aims at developing a new methodology that will integrate traditional methods of historical research with those of the natural sciences, in particular palaeoecology and palaeoclimatology.

Lake Dojran (Greece and FYROM) provides a valuable record of the Holocene environmental change reconstructed using not only pollen and NPPs (1) but also other proxies (geochemistry and biomarkers). Here we focus on the last 2000 years of palaeoenvironmental data and in particular on the new 30-years-resolution pollen analysis to offer an insight into our approach within the historical region of Macedonia. The very high arboreal pollen percentage that characterized the mid-Holocene at Dojran strongly reduced since the first century BC (ca. 2000 yr BP). At the same time Macedonia become a Roman province and was integrated into the Roman market economy. The arboreal reduction affected mainly pine and fir, the most important timber for Romans shipbuilding. The whole Roman period (almost 600 years) shows high impact with abundance of cultivated and synanthropic taxa. The undergoing transition to drier conditions, that affects the last centuries of the Holocene, did not prevent the recovery of arboreal vegetation at the end of the Roman period. Many of the most important historical events, like the Plague of Justinian, the collapse of the Roman order in the Balkans and the coming of the Slavs (2) seems do not impact the pollen assemblage, on the contrary a hiatus in cereal cultivation is probably related to the Black Death. Soon after, in the 16<sup>th</sup> and 17<sup>th</sup> century (ca. 500-250 yr BP), the cereal pollen achieves highest values. This can be correlated to the role that Ottoman Macedonia played for the provision of the Ottoman armies and the city of Constantinople, as well as in the international grain trade in the Mediterranean.

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O-1138

## Mid-Holocene vegetal landscape evolution in the center of Rome

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### Abstract

This work is part of a multi-disciplinary investigation of Rome's Tiber River valley aimed to provide new data on the Holocene landscape evolution. The pre-urban landscape was reconstructed using a combination of deep-trench excavation, coring survey, environmental sampling and paleomagnetic analysis (Marra et al., 2018). Two cores (FB38 and FB40) out of eleven have been selected for pollen analysis on the basis of sediment features in the area known as the Forum Boarium, between the Capitoline Hill and the Palatine Hill, in the heart of the ancient city. Very little is indeed known of the natural history of Rome.

Continuous recover of the sediment was provided using a 3 m long corer with inner diameter of 97 mm. The chronology of the eleven cores was established through 28 AMS radiocarbon dates, 7 of which obtained from FB38 and FB40, in particular 2 of them were performed on pollen concentrated residues. Pollen samples often showed a low to medium pollen content, resulting in time consuming microscopic analyses. The portion of the two cores selected for palynology are probably in chronological order, with one older than the other and partially overlapping.

FB38, the older core, drilled in a wetland, shows the presence of an alder carr dating back at ca. 7000 years BP and probably lasting for few hundred years. The alders are accompanied by mesophilous, montane (oaks, hornbeams, elm, beech), evergreen elements (oaks and ericaceous) and water plants. The alder formation was probably altered by the Tiber river floods carrying floating pine pollen grains from upland regions, as it happened in the Tiber delta (Pepe et al., 2016). The increasing NPP (Non Pollen Palynomorphs) *Glomus* and *Pseudoschizaea* are the evidence of an erosion process which parallels the increase in pine. The pollen record is closed on the top by sterile in pollen sediments of the Archaic period. FB40, the younger core, shows more problems related to pollen presence/conservation, with enhanced amounts of *Pseudoschizaea*, high values of pine and evidence of land use in the top samples, the last of which dated at ca. 5600 years BP and covered by anthropic sediments of the Iron age. The two cores indicate a change from a wetland to an open landscape, probably seasonally dry and wet.

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O-1139

## The Marboré Symphony: Music for the deglaciation and Holocene in the central Pyrenees

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### Abstract

Geological sequences have been used as the main basis for musical pieces both as inspiration for musicians and as raw materials (geochemical data, stratigraphic logs, cycles and frequencies) for compositions produced by computer programs. Telling our stories of Quaternary changes with music presents an opportunity to reach a wider audience and to integrate art and science. Here we present an example of how to compose music from Quaternary lake sequences and illustrate in a new way the main changes in the Pyrenean landscapes since deglaciation. The creation of this music was undertaken within the framework of the REPLIM project, an INTERREG- POCTEFA – project aimed to create a network of climate change observatories on lakes and wetlands in the Pyrenees. Based on the sediment sequence from Marboré Lake (42°41'44.27"N, 0° 2'24.07"E, 2612 m a.s.l), we have selected lithological, compositional and pollen data (Leunda et al, 2017; Oliva et al., 2018) to represent the main changes in the lake and the region during the last 15000 years. To transform the geological data into musical notes, we have used a similar approach than in previous experiences (Simon et al, 2015) but in this case, notes were assigned to compositional range intervals and the tempos were defined using sediment accumulation rates. Different melodies and instruments were assigned at each data set: TOC and Br/Ti as lake bioproductivity, selected pollen data for vegetation dynamics in the valleys, Si/Ti as sediment influx and Pb/Ti as anthropogenic impact. An electronic version of the Marbore Symphony was created by computer software based on the raw data. The music group O'Carolan (<http://www.ocarolanfolk.com>) transformed the electronic version into a six minutes long acoustic version. The Symphony premiered in the town of Bielsa on December 14<sup>th</sup>, 2018. The Marboré music project has served to increase citizenship awareness about climate change in the Pyrenees and provided a new tool to better communicate past and future changes in the landscapes.

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O-1140

## **2A Earth Core: The Hominin Project: an art and science collaboration**

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### **Abstract**

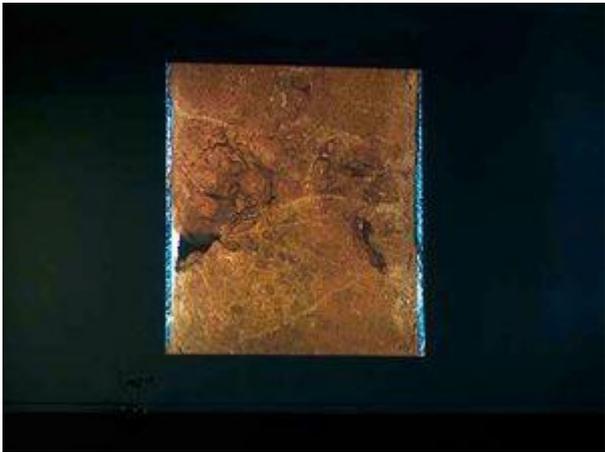
The exhibition, *2A Earth Core The Hominin Project* at Aberystwyth Arts Centre in 2017, marked the culmination of an art-science project focused on climate change. The collaboration brought together an artist undertaking a practice-based PhD at Aberystwyth University and the Hominin Sites and Paleolakes Drilling Project (HSPDP), an international scientific collaboration researching the relationship between climate and human evolution. This presentation relates the experiences of the collaborative enterprise from the perspectives of the artist and a lead scientist in the research cluster, thereby providing insight from both disciplinary fields. This leads to an examination of the creative strategies that were used in translating the data, images and ideas from the science into exhibition content.

The theoretical background to the project lies in the contrasting opinions that have emerged in recent decades regarding the value of collaboration between the arts and the sciences. Some commentators argue that the fundamental differences between art and science make interdisciplinary practice untenable, while others suggest that many potential benefits are achievable through dialogue and mutual work in areas of shared interest. Here, we examine this potential and offer some newly identified approaches to collaboration within the art-science and climate change discourse.

As background, the presentation includes information on the initial stages of the collaboration. In 2014 the artist traveled with the HSPDP team to the dried lake basin of Chew Bahir, southern Ethiopia, regarded as a significant region for early hominin evolution; the experience of the landscape seen from an artistic perspective is discussed. As observer, the artist was able to gain insight into the field research, which involved drilling nearly 300 m of sediment cores, later shown to record climate change of the last 600,000 years.

The collaborative relationship enabled a number of works to be developed, bringing together the knowledge and insight of both the artist and the science team. The exhibition contained two principal works: *2A (2017)* is a film in which hundreds of high-resolution images of the sediment cores were sequenced into a 24-hour film. *2B (2017)* is an installation made of mud from the bottom of the drill hole which, when re-hydrated and then allowed to dry, created an experimental version of the ancient playa lake surface.

The presentation concludes with a commentary on collaboration across art and science, and on the rationale for the curation of the exhibition as a hybrid space, an innovative combination of material that included art, documentary interviews with science researchers and science artifacts. In offering fresh approaches to collaboration, the presentation argues for the crucial role that art can play in enabling audiences to encounter larger narratives of humanity's relationship with a changing climate



2A (2017)



2B (2017)

O-1141

## 10Be dating of Holocene moraines in the Himalayan-Tibetan orogen: noise versus signal

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### Abstract

Cosmogenic <sup>10</sup>Be dating has been used to date young moraines in the eight glaciated valleys of the northwestern and Central Himalaya. Following the north-south (Low to high) precipitation gradient the study areas include: Stok, Lato, Karzok, and Parkachik valleys in the Zanskar range; Hamtah and Kulti valleys in the Lahul Himalaya; Bhagirathi valley in the Garhwal Himalaya; and Lhotse Nup valley in the Khumbu Himal. Also, four hundred and sixty published <sup>10</sup>Be ages are compiled to reconstruct regional stages in the 73 glaciated valleys spread throughout the Himalaya, Tibet, Pamir, and Tian Shan. Whenever possible, additional dating methods, for example, radiocarbon, are used to date moraines independently. We also measured the contribution of prior exposures (i.e., inheritance) to cosmic rays by targeting independent, historically dated moraines. To further detect climate signals from the geological spread, regional Holocene glacier chronostratigraphies throughout the orogen are developed by grouping glaciated regions with comparable climatic characteristics. Three major climatic groups (or five climatic regions) are defined across the orogen using Cluster Analysis (CA) and Principal Component Analysis (PCA). Local glacial stages in each climatic group are then compiled and analyzed for regional stage reconstruction using a combination of the radial plotter, probability density function, and Student's t-test. Extents of Holocene glacier advances are also reconstructed using detailed geomorphic mapping and estimating equilibrium-line altitudes (ELAs). Glacier sensitivities are assessed using modern glacier hypsometries, climate sensitivity ( $c$ ), and lag time ( $\tau$ ). The net changes in temperature ( $\Delta T$ ) between periods of reconstructed regional glacier advances are also reconstructed using glacial length change ( $dt$ ),  $c$ ,  $\tau$ , and a linear inverse glacier flow model in 66 glaciated valleys across the different climatic regions throughout the orogen. Our results show a high degree of uncertainty of cosmogenic dating of moraines boulders of less than 2 ka old. However, the issue of high-degree of <sup>10</sup>Be age scattering due to prior exposure is more pronounced in cold-based less erosive (<0.01 mm/a) high-altitude glaciated settings relative to erosive ( $\geq 2$  ka) temperate glaciated catchments. Our regional analysis also indicates variable glacier responses throughout the Holocene, especially in the mid-latitude westerlies dominated northwestern regions, in the arid-semiarid northeastern region, and the southern monsoonal wet-warm regions. Overall, the Himalayan-Tibetan orogen may experience at least one late glacial (~15.3–11.8 ka) and five Himalayan-Tibetan Holocene glacial stages (HTHS) at ~11.5–9.5, ~8.8–7.7, ~7.0–3.2, ~2.3–1.0, and <1 ka.

O-1142

## Holocene changes of the Nepalese Mera glacier: preliminary results

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### Abstract

Recent studies of High Mountain Asian glaciers using satellite images revealed large regional mass balance variability over the last two decades mainly attributed to distinct climate conditions. This complex pattern makes it difficult to quantify the impacts of anthropogenic forcings on this trend. Two major issues for such quantification are related to a limited knowledge of i) long term glacier changes, ii) the natural forcings effects on glacier evolution. Mera debris-free Glacier (27.7°N, 86.9°E, 5.1 km<sup>2</sup>) is one of the rare monitored glaciers in Himalaya (Dudh Koshi basin, Everest region, central Himalaya) making possible a full understanding of processes driving glacier mass change. Moreover the numerous and well preserved moraines downstream offer a unique opportunity to document Mera mass balance changes in the past. In 2014 and 2017 twenty boulders were sampled on the four largest moraines close to the front position and dated using cosmogenic method. <sup>10</sup>Be ages span the Holocene. Two fresh moraines close to the current front position were formed during the last millennium while the two lowest ones were formed during the late and early Holocene respectively. Such pattern reveals a glacier history similar to glacier in central Himalaya and in regions, such as the European Alps, out of monsoon climate conditions. We then analyzed possible climate conditions responsible for such changes by applying a glaciological model calibrated on current glaciological observations. Based on this analysis we explored the possible influence of external and internal climate drivers on such chronology.

O-1143

## Investigating asynchronous retreat of glaciers in the Khumbu region, Nepal.

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### Abstract

Himalayan glaciers comprise the most extensive body of ice outside of the Polar Regions, with their meltwaters sourcing some of the largest river systems in Central Asia (Bolch, et al., 2012). They have experienced negative mass balance since their last known maximum during the regional Little Ice Age (Rowan, 2017). Despite glaciers being an important indicator for regional climate change, the inaccessibility of Himalayan glaciers has resulted in a relative dearth of data to describe their state, both current and past. In particular, assessments of past change between modelled and measured data differ due to insufficient observations and process understanding (Hock, et al., 2017), making the prediction of glacier evolution uncertain. Investigating glacier response to past climate change through examining relict landforms offers additional validation for their long-term behaviour, advancing our understanding on what may control their response to future climate change so that predictions of meltwater input into local water resources can be more robustly assessed.

Here, we present a glacial geomorphological map of the Khumbu region, Nepal, which facilitates much greater insight into the Holocene glacial history of the Khumbu Glacier and its tributaries. The mapping was completed using SPOT7 Imagery, the NASA High Mountain Asia Digital Elevation dataset, and fieldwork. Field mapping was supported by Schmidt Hammer measurements taken from *in situ* boulders on moraine crests. We mapped Holocene moraine systems surrounding the Khumbu Glacier and two of its tributaries: the Changri Nup and Lobuche Glaciers. The Khumbu and Lobuche Glaciers are both characterised by large proximal lateral and terminal moraines surrounded by smaller, superimposed moraines. The Schmidt Hammer values collected from boulders reveal similar exposure between these two glaciers. Changri Nup Glacier has fewer moraines, with no evidence of reworking, and lower Schmidt Hammer values. There are also smaller glaciers with a series nested moraines indicative of a stepped retreat. By combining the results of the mapping and Schmidt Hammer with analysis of glacier hypsometry, we explore controls governing the pace and style of glacier retreat.

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**O-1144**

## **Quantifying post-Little Ice Age mass change in the Himalaya**

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### **Abstract**

Himalayan glaciers store the greatest volume of ice beyond the Polar ice sheets, but their response to Holocene climate change is not very well documented in the literature. Recent work has focussed on modern glacier dynamics and on reconstructing Last Glacial Maximum extents, while glacier extent during the Little Ice Age (LIA) is relatively poorly understood. The limited research undertaken so far on LIA Himalayan glacier extent has demonstrated asynchronous retreat due to local topographic controls, and suggests that the LIA glacial advancement in this region peaked around 1500 AD with widespread retreat since 1850 AD. Here, we present an inventory of LIA extents across the entire Himalayan region, and provide a first-order estimate of the mass loss since the LIA. We take the Randolph Glacier Inventory (RGI) version 6.0 to represent present day glacial extents and use these data overlaid on recently released High Mountain Asia (HMA) 8m Digital Elevation Models (DEM) and remotely sensed images to digitise interpreted LIA glacial extents. By interpolating an estimated LIA glacier surface we can then quantify areal and volumetric changes between the two epochs. In a final step, the results of their volumetric change are used to quantify the contribution of Himalayan glaciers to sea-level rise (SLR) since the LIA, and to characterise the regional variability in mass loss across the range, taking into consideration possible topographic and climatological controls.

O-1145

## Geochemical provenance of a supraglacial debris cover in relation to changing tributary discharges of a Himalayan compound glacier

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### Abstract

The century-scale mass balance of glaciers in the monsoonal Himalaya is related to the northward penetration of the summer monsoon. We test the hypothesis that large glaciers straddling climatic gradients comprise tributary catchments whose mass balances are asynchronous, by studying spatial variation in the geochemical composition of the Khumbu Glacier debris cover. This non-surging glacier comprises multiple compound sources forming a debris-covered tongue terminating 11 km south of the Himalayan Divide. 21 samples of supraglacial sediment <2000  $\mu\text{m}$  from six source tributaries achieve an unambiguous statistical differentiation using 11 major elements, reflecting geological differences between catchments. In contrast the <250  $\mu\text{m}$  fraction shows poor source area differentiation. The coarser fraction allows the provenance of debris covering the glacier tongue to be interpreted using the FR2000 unmixing model, which partitions a 'mixed' debris sample according to the proportion of debris from each source tributary. 24 debris cover samples were collected from transects in the upper, middle and lower part of the glacier tongue. In the upper tongue, debris from the western Changri Valley tributary increases downstream at the expense of debris from the Western Cwm (Himalayan Divide) and eastern (Nuptse) sources. In the lower tongue there is a marked increase towards the terminus in debris from the Western Cwm/Divide sources. We compare these patterns with a model of supraglacial debris age, derived from an updated version of the iSOSIA ice flow model applied to the Khumbu Glacier by Rowan et al. (2015). The model tracks debris as discrete particles within the ice from their points of entrainment. At the whole-glacier scale, supraglacial debris derived from the Changri valley has taken >900 years to reach the terminus; in contrast, debris from the Western Cwm has had a transport time of <700 years. Proxy evidence indicates a weakening of the summer monsoon in the early Little Ice Age c. 600 years ago, therefore the Khumbu Glacier debris cover retains an archive of debris sourced throughout the LIA monsoon transition. This may explain the reduction over time of debris from the Himalayan Divide and the increase in debris from lateral tributaries: monsoon precipitation was less able to penetrate to the higher catchments of Khumbu glacier, favouring a relative mass balance increase in eastern and western tributaries. Negative twentieth-century balances across the glacier have caused tributaries to separate and Divide sources to dominate, though stagnation of the tongue is now causing debris to accumulate kilometres upstream of the terminus. The general conclusion is that the climatic response of large compound valley glaciers is complex due to spatial variation in both forcing and response times between tributaries.

O-1146

## Holocene Glacial Fluctuations in the Himalaya: Results and Limitations

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### Abstract

The climate of Indian sub-continent is the product of the Himalaya. The huge expanse from the East to West, and South to North, not just works as a water-tower but also conditions the sub-continental climate in a variety of ways. The varied topographic configurations that exist has undergone varied and complex climate-landscape interactions over the geological past. Many phases of glacials and inter-glacial episodes are engraved in the landforms that dominate the present day landscape. Many details of the previous glacial and related processes have been obliterated in the dynamic environment. Although relationships and chronologies have been established between glacials and the ISM and the Mediterranean Westerlies, yet little is understood of the relative role of the Polar Streams and the N-Easterlies in impacting the weather and the glacial expansions within such a huge expanse.

Available chronologies define the general trends in Holocene glacier oscillations that the largest advance during early Holocene in the monsoon influenced Himalayan region. This advance is represented by impressive suites of sharp-crested moraines, dated by the numerous researchers, to between ~11.5 and 8.0 ka. The mid-Holocene moraines have been dated in several regions, with the most extensive in the semi-arid Western part. Five glacial advances have been identified (semi-arid western Himalayan-Tibetan stages for the Holocene in the semi-arid western end of the Himalayan-Tibetan orogen. On the other hand, Murari et al (2014) have reported eleven monsoonal Himalayan-Tibetan stages during the Holocene for the monsoon-influenced regions. Correlation of stages also suggest that there are strong correlations with periods of enhanced monsoonal influence in the Himalaya and Tibet. In recent study, Saha et al. (2018) also recognized seven Himalayan Holocene regional glacial stages for the northwestern end of the Himalayan-Tibetan orogeny i.e. There are immaculately preserved mid and late Holocene relict landforms in the Chenab, Beas and Ravi Basins of the Western Himalaya, constrained within 8.1 ka to 1.0 ka. However, the drumlin field indicate a gradual waning between 6.0 ka and 4.0 ka, and accelerated retreat until ~1.0 ka. The <sup>14</sup>C ages further suggest that the period between ~ 12th to 18th Century AD was relatively warmer than today, allowing settled agriculture and related activities in the glacier forefields. There is no denying that a gradual retreat of glaciers began in the 17th Century AD that increased many folds after the mid 19th Century. However, a robust relationships needs to be built of the upland-foreland basins with reference to waxing and waning of glaciers of the Himalaya and the adjoining mountains to understand relative roles of different climatic pattern that control the sub-continent.

O-1148

## Placing South Island New Zealand glacial dynamics during MIS 4-3 in chrono-stratigraphic context

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### Abstract

Reconstructions of ice growth and decay over the last 100-kyr glacial cycle on the South Island New Zealand provide important temperature and moisture proxies at a latitude where terrestrial records are otherwise limited. The maritime climatic setting of the glaciers also allows inference on past Southern Ocean conditions. As such, there has been significant focus on reconstructing ice-margin dynamics of glaciers draining the Southern Alps. Luminescence chronologies provide a much-needed perspective to clarify inferences from extensive CRN chronologies. Much insight has been gained from detailed chronologies based on CRN-dating boulders from moraine sequences. These reconstructions have been key to address important questions regarding temporal and spatial variations in glacial growth and decay across New Zealand and relationships with hemispheric and inter-hemispheric climate events and drivers. However geomorphic and CRN-derived glacial reconstructions are limited by the preservation of glacial moraines and landforms or scoured bedrock and can miss buried stratigraphy and evidence for less extensive ice advances. Here we present complimentary, luminescence-dated stratigraphic evidence for ice dynamics in the Rangitata and Wanaka/Hawea valleys of central South Island. While largely consistent with geomorphic reconstructions, age control from stratigraphic sequences and lithofacies analyses provide more detail on older advances and the styles of ice advance. We discuss chrono-stratigraphic results of glacial advances in the study catchments in context of regional glacial records, and link glacier mass balance inferences to changing climatic conditions during MIS 4-3.

O-1149

## Glacial chronology of the Bale Mountains, Southern Ethiopia

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### Abstract

The Bale Mountains in the Southern Ethiopian Highlands represent Africa's largest alpine environment. Ice caps and valley glaciers are absent nowadays, but glacial landscape features and periglacial phenomena indicate different phases of extensive glacial and periglacial activity in the region during the Pleistocene. Recent archaeological findings from the area provide evidence for the oldest high-elevation site of human activity worldwide. To reconstruct the climate and environment of these Middle Stone Age hunter-gatherers at that time, the extent and timing of different Quaternary glaciations in the Bale Mountains was determined based on comprehensive glacial geomorphological mapping and <sup>36</sup>Cl surface exposure dating of 75 moraine boulders from the western, northern and eastern valleys as well as from the central Sanetti Plateau. The established glacial chronology reveals that the local Last Glacial Maximum (LGM) occurred during MIS 3 and therefore prior to the global LGM. Back then, glaciers covered up to 265 km<sup>2</sup> of the mountain range and were a potential fresh water source for early hunter-gatherers. Intensively weathered boulders and moraines outside the local LGM ice extent probably originate from MIS 4 and 6 glaciations. However, the large spread of surface exposure ages from the oldest features prevents a precise determination. Exposure ages of the youngest moraines in the valleys suggest that the glaciers almost reached the extent of the local LGM ice extent again during MIS 2 (at ~17-18 ka). Deglaciation in the region started at the end of the Late Pleistocene (at ~14-15 ka).

O-1150

### Climatic and environmental history of northern Chiloé during MIS 3

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#### Abstract

Southern South America has remarkable morphosedimentary features for the development of Quaternary paleoclimate and paleoenvironmental studies. The finding of several sites with fossil wood of conifers in the Chiloé Archipelago is of great relevance because of the few non-infinite radiocarbon dates available, that give to these deposits an age range between 43 – 49 kyr BP (MIS 3). In the context of the last glaciation, the development of primary forests appears as evidence of warmer interstadial conditions. This study seeks to determine the environmental and climatic conditions that prevailed in northern Chiloé during MIS 3. A period in which Northern Hemisphere records have shown relatively warmer conditions, while the chronology of glacial advances in southern Patagonia indicate a local LGM. We present the stratigraphic analysis of five sites on the eastern and northern coast of Chiloé, along with a chronostratigraphic correlation and geomorphological description.

To carry out this study, we performed first a photointerpretation of northernmost Chiloé. Following, we visited and described the sites, four of which are on the eastern side of the local LGM boundary, while the other is located on the western margin (fig 1). Finally, we made the drawing and interpretations of stratigraphic columns, together with geomorphological mapping. The chronostratigraphic correlation was based on <sup>14</sup>C date of wood contained in peat layers and OSL dates of sand lenses contained in till or fluvio-glacial material.

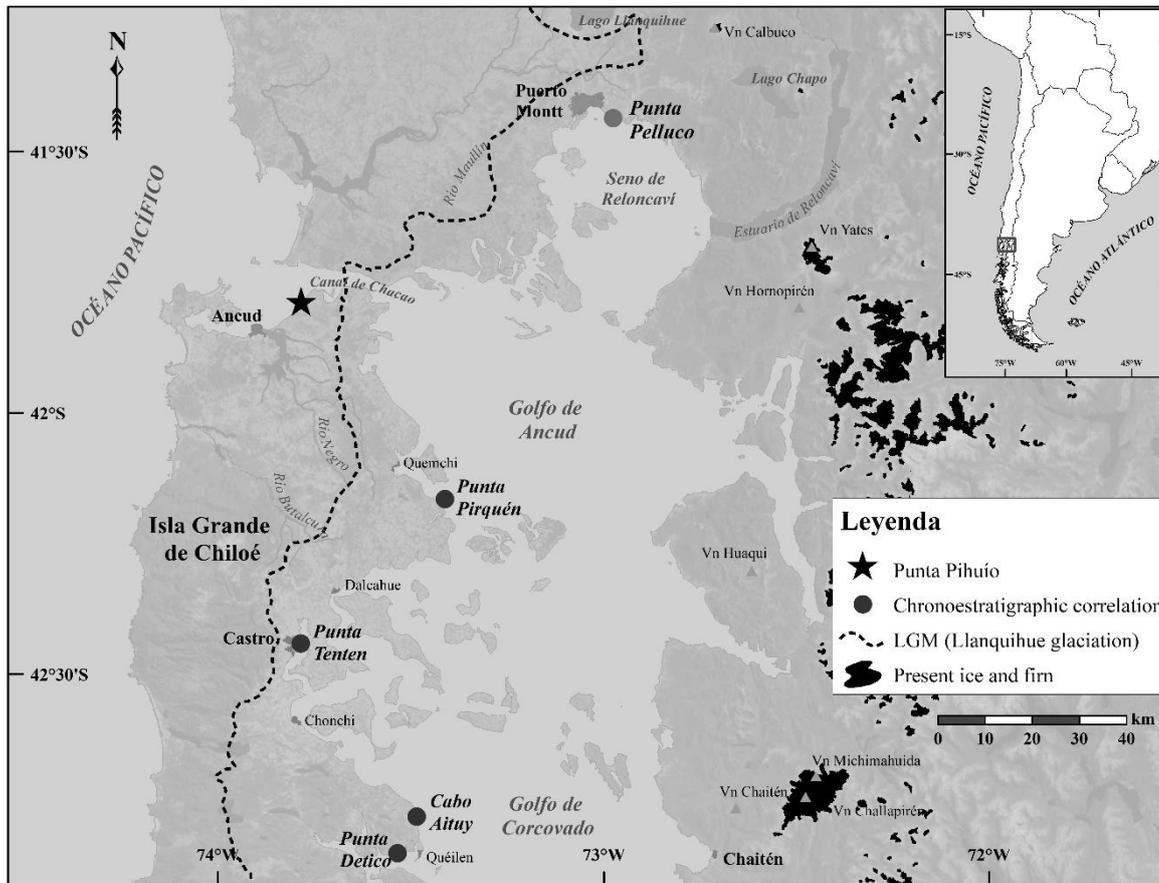


Figure 1. Map of

the study area, showing the sites of stratigraphic descriptions and correlations

The stratigraphic evidence shows in general at least two peats layer with trunks that correspond to a forest paleosol. Underlying the basal peat is possible to observe a till, whereas fluvioglacial material overlies the upper one. These deposits provide evidence to support the ice advance before and after the interstadial MIS 3. Additionally, among the peat strata we observed laminated silts with ripple marks, grey and brown silts, sand lenses and intercalations of peats without trunks and grey silt. These features indicate environmental fluctuations between phases of vegetation development and shallow flooded events linked to the advances and retreats of the glacial front.

The geomorphology shows a line of discontinuous moraine crests and ice contact margins that mark the limit of the local LGM (MIS 2). Punta Pihuío corresponds to an active marine cliff that appears in the western edge of a great fluvioglacial plain that extends from the limit of the LGM until bahía Ancud. Two large channels of glacial drainage dissect the fluvioglacial plain, which have at least one terrace directly related to deglaciation processes.

Our stratigraphic and geomorphological results provide evidence to better understanding the climatic and environmental features during MIS 3 as a prelude for LGM (MIS 2) in northern Chiloé.

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O-1151

## Constraining the age of glacial advances in the Cantabrian Mountains through multiple dating methods reveals important glaciation during MIS 3

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### Abstract

The growing application of different dating methods has brought to light two issues: (i) the most extensive glacier advance recorded in multiple mountain environments slightly pre-dates the global Last Glacial Maximum and lies within the Marine Isotope Stage 3 or MIS 3; and (ii) the numerous cases of timing differences between observed glacial advances might be caused by limitations related to the dating techniques without having paleoclimate significance. In this regard, the frequent use of a single technique to date numerically a given glacial sequence makes it difficult to address to what extent age differences can be an artifact related to biased numerical age results or a paleoclimate signature. Here we focus on the study of Pleistocene glacial advances in the central Cantabrian Mountains of the Iberian Peninsula, where numerous chronologies based on radiocarbon and Optically Stimulated Luminescence suggest a pre-LGM advance of glaciers to their maximum front positions (Serrano et al., 2017 and references therein). A preliminary study developed in the Porma valley (central Cantabrian Mountains) based on the <sup>10</sup>Be surface exposure dating of 75 boulders from moraines, erratics and rock glaciers points to a complex exposure history of glacial advances and retreats spanning the Last Glacial Cycle, where the age of the local glacial maximum advance was older than MIS 5d (Stage I: ~110 ka) (Rodríguez-Rodríguez et al., 2016). Here we present a new set of 43 numerical ages based on three dating techniques —<sup>10</sup>Be surface exposure dating; radiocarbon; and OSL— that complement the chronology of Pleistocene glacial advances in the Porma valley. Results complement previous chronologies in the area, supporting an important glacial advance during MIS 3 (Stage IIa: ~56 ka) that culminated with the LGM advance (Stage IIb: ~33–24 ka) of MIS 2 in response to increased rainfall and solar insolation minima. Glacier fronts reached elevations as low as 1130 m a.s.l. possibly without overriding evidence related to the previous Pleistocene glacial maximum extent. Glacier recession in the Cantabrian Mountains started at 21–20 ka ago, after the global LGM. We suggest that the recession was initiated by increased insolation followed by hyper-cool and dry conditions during Heinrich Stadial 1 in response to meltwater discharges in the North Atlantic.

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O-1152

## Climate and palaeoenvironmental changes in Southern and Central Poland in Interpleniglacial (MIS 3)

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### Abstract

Interpleniglacial deposits (MIS 3) separate two glacial periods (MIS 4 and MIS 2). In the European Lowlands MIS 3 mostly represents alluvia. Until recently, in Western and Central Europe, from 2 to 5 clear warmings with forest flora or tundra-forest (Oerel, Moershoofd, Glinde, Hengelo and Denekamp) were separated. There were also found horizons with periglacial structures that formed during cooling periods. Also erosive breaks have been documented (2-3 series inserted).

The development of the isotope curve of oxygen in the NGRIP ice core (Rasmussen et al. 2014) indicated the existence of more warmings and coolings in MIS 3, ca. 10-12, in addition quite quickly following each other. A large convergence with the NGRIP curve has been demonstrated by studies on changes in fluvial environment conditions in southern Poland - Oświęcim Basin, Sandomierz Basin and Carpathians (Gębica et al. 2015; Starkel et al. 2015, 2017).

At present, the studies have been extended to the areas of Central Poland Lowlands and Uplands in Southern Poland. Radiocarbon and luminescence data originating mainly from river sediments were used for analyzes. Radiocarbon data were calibrated (OxCal - Bronk Ramsey 2009; IntCal13 - Reimer et al. 2013). The probability density functions of radiocarbon dates sets supplemented with palynological information and luminescence dates distributions are presented against the background of the NGRIP curve.

In the analyzed areas, the lack of radiocarbon data from the time corresponding to LGM is marked. This confirms the harshness of climatic conditions on the closer and further foreland of the ice sheet. There was also a record of a sharp transition towards periglacial and continental conditions ca. 33-30 ka BP (end of MIS 3). This is synchronous with the beginning of the expansion of the Scandinavian ice sheet. Part of the research areas is also expressed by the accumulation of loess on river terraces. In small valleys, or closed minor depressions, only 2-3 "climatic" phases were found, which may be related to local morpho- and topographic conditions. In larger valleys in Southern and Central Poland there is a greater number of climatic changes. The issue of the speed of changes in the plant cover in the wake of episodes of warming or cooling remains open - there are no sites with long palynological records from the research area.

O-1153

## Evidence of late MIS 3 onset of the last glaciation in the southern Eastern Alps

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### Abstract

Megafans on the southern side of the Alps are known to respond to climatically-driven fluctuations of the sedimentary input from the Alpine range, especially in relation to major environmental changes related to Quaternary glaciations (Fontana et al., 2014). Aggradation/incision trends of these alluvial systems mirror the development and downwasting of valley glaciers, thus providing reliable proxy information on upland areas, which may be often scant, disjointed and difficult to date (Rossato and Mozzi, 2016; Rossato et al., 2018).

In our investigation, we could integrate OSL and radiocarbon dating in the juxtaposed megafans of the Brenta and Piave rivers, through morpho-stratigraphic correlation and sediment provenance analysis. The catchments of these rivers include the highest portion of the Dolomites mountains, with main peaks exceeding 3000 m asl and extensive plateaus above 2500 m asl. We correlated the piedmont megafan sector of the Montebelluna Piave megafan (MPM) with the terminal moraines of the LGM Piave glacier ('Quero amphitheater') and the lower Alpine valley sector.

Results show that the proximal sector of the MPM and related Piave valley alluvial fill were continuously aggrading in the 37–27 ka BP time-frame, well before the outermost positioning of the LGM glacier fronts at around 26 ka cal BP. This was accompanied by increased sediment production and fan aggradation in the unglaciated Prealpine tributary catchments, similarly to what observed in alluvial fans located to the east in the Friulian piedmont plain (Monegato et al., 2010). MPM alluvial succession shows no significant variation in lithofacies characteristics and assemblage, nor the presence of major unconformities, at the transition between MIS 3 and 2. Only sand petrography highlights a change in the drainage system just before 27 ka cal BP: a major tributary of the Piave River, the Cismon River, moved towards the Brenta catchment, probably due to the constant growth of the Piave glacier at the junction between these two systems.

We conclude that valley glaciers in the upper Piave and Cismon catchments probably started to develop in the late MIS 3. Such environmental change could be related to the climatic deterioration recognized in the pollen sequence of nearby Fimon Lake around  $38.7 \pm 0.5$  ka (Pini et al., 2010) and correlated with Heinrich Event 4.

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O-1154

## Climate triggered rapidly changing environments in the northern Alps during MIS 3

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### Abstract

Ravine slopes at the recently discovered Nesselstalgraben site (47°39.4'N, 13°02.8'E, 555-595 m a.s.l.) in south-eastern Germany provide a unique last glacial sediment record for the Northern Calcareous Alps. The top of the investigated profile is overlain by fluvio-glacial gravels and tills of the Last Glacial Maximum (LGM), while the base is formed by a diamict. The fine-grained section with lacustrine-palustrine deposits in between was dated with 29 radiocarbon analyses on wood, monocotyledon and bryophyte remains. The resulting age model provides extrapolated ages of less than 29.6 ka cal BP for the fluvio-glacial gravels and till overlaying the fine-grained deposits, and more than 59.0 ka cal BP for the diamict below. Thus the lacustrine-palustrine layers cover the entire Marine Isotope Stage (MIS) 3. The MIS 3 deposits have a highly variable lithology consisting of laminated or non-stratified carbonate silts, thin sand or gravel layers, organic-rich silts, and compressed peat. In 2016, 40 overlapping sections were sampled from the outcrops covering the entire MIS 3. These sections were scanned with an X-ray-fluorescence (XRF) core scanner at 2 mm resolution and compiled to a continuous 21 m long sediment profile based on marker layers and XRF data. Thereafter, sediment cores were subsampled at 2 cm intervals. Samples were used for pollen, element contents (C, N, S), isotope geochemistry, and grain-size analyses. Multivariate analyses of XRF data clearly separate Ca from Al, Fe, K, Mn, Si, and Ti. Carbonate contents, represented by Ca and total inorganic carbon, reach maxima in repeatedly occurring carbonate silt layers. The detrital origin of these layers is confirmed by scanning electron microscopy and energy-dispersive X-ray spectroscopy. They consist of rock flour that accumulated due to intense physical weathering of Mesozoic catchment carbonates. The high-frequency proxy variations from the Nesselstalgraben site resemble Greenland interstadial-stadial variability. We hypothesize that the carbonate silts were deposited during cold stadial periods or immediately thereafter. In contrast, organic matter and elements more resistant to chemical weathering accumulated during warmer interstadial climate conditions. Arboreal pollen also peak during several Greenland interstadials, while stadials are dominated by Poaceae pollen. Maxima of arboreal and non-arboreal pollen are, however, not always in total accordance with peaks of elements such as Ca and Si, respectively. Delays and peak shifts between geochemical and pollen records are discussed in terms of differential response times of depositional and biological systems to rapid climatic changes and in terms of the duration and intensity of the interstadials.

O-1155

## **Beyond examples: how can knowledge be used to understand social vulnerability and the future of climate change**

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### **Abstract**

Facing climate change, Science is reaching into all its ingenuity in the search for solutions. One of the most wicked problems we are facing is the impact that climate change will have over human societies, and how can we understand it and prepare for it. Tropical zones – home to over 40% of the world’s population – are particularly at risk as they bear the burden of severe changes in atmospheric circulation, including record-breaking hurricanes; shifts in ecosystems and biotic species distribution; and drowning of small islands due to sea level rise. Upon facing dire prospects, archaeologists have clamored that, given their deep-time perspective, our discipline can make significant contributions to the understanding of both social vulnerability and the process of climate change. This keynote contribution presents an example of how that can be done. Using historical socioecodynamics, the presentation identifies lessons from the past to explore the social vulnerability of maritime or coastal communities on a tropical island – Puerto Rico –, and moves one step further by using that knowledge for on-the-ground engagement towards community resilience to future change. Focusing on the role of traditional ecological knowledge, the presentation considers what is known of the impact of climate change at the end of the Pleistocene and the beginning of the Holocene; the process of decision-making to short- and long-term catastrophic events in pre-Hispanic communities on the island; and the historic evidence of adaptation to change in the early 20<sup>th</sup> Century. The knowledge recovered from these three examples is currently being applied to tackle social vulnerability and community response to expected climate impacts to a Puerto Rican coastal community. While it is insightful to identify and study individual snapshots of information correlating particular climate events with the social response to them, this application demonstrates how a long-term, deep-time perspective can move knowledge one step further, towards application. Societies have lived with the dynamic nature of coastal environments for millennia. Science can learn from the past, not only to identify isolated events, but also to recover lost knowledge and tie discourses of climate change impacts to local and personal narratives, making it useful for impacted communities in the present and their preparedness for the future.

O-1156

## Harmonizing marine and terrestrial palaeoclimate archives to reconstruct hurricane activity in the Caribbean

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### Abstract

Atlantic hurricanes are a threat to the Small Island Developing States of the Caribbean primarily because of their potentially devastating impacts on homes and infrastructure, agricultural productivity and food security. However, tropical cyclones also contribute significantly to annual rainfall across the region by replenishing water reserves and buffering national economies from the threat of drought. This 'double-edged sword' that characterises the positive and negative impacts of hurricanes, was also experienced by both pre-Colonial and Colonial inhabitants of the region and is likely to have influenced settlement decisions and patterns. Given that the impact of 21<sup>st</sup> Century anthropogenic climate change on tropical cyclones is poorly understood, it is first necessary to establish a baseline of natural variability for the Caribbean Region. To this end, we present a novel statistical approach to the reconstruction of hurricane activity in Jamaica for the last 1000 years. We link land and sea by adopting cross-correlation techniques to harmonize the chronologies of a coral-based sea-surface temperature record from the Western Caribbean and a mangrove-lagoon sediment record of lake-level change from Jamaica. Subsequent comparisons between the Jamaican lake-level record, Caribbean-wide SST reconstructions, and instrumental records of hurricane activity since 1850 CE, reveal statistically significant relationships between these variables for the period 1773-2008 CE. Given these relationships, we developed a sediment-based extended hurricane activity index (EHA), which has been extended back to the beginning of the last millennium. The record suggests that hurricane activity exhibited an increased amplitude of variability on interdecadal and multidecadal timescales during periods of low natural radiative forcing compared with a more subdued variability during the warmer mean climate states of the last millennium. Comparison of the EHA index with previously-published Colonial records of storm counts and tropical cyclone-induced Spanish shipwrecks for the period 1495 – 1825 CE, suggest that periods of enhanced hurricane activity exerted significant pressure on the Spanish Colonial fleet. A gradual increase in Atlantic hurricane activity during the industrial period (ca. 1870-present) is probably a response to a combination of natural and human-induced forcing factors. Based on the EHA index, it is clear that contemporary hurricane activity has not yet exceeded its longer-term natural variability when compared with the last 1000 years.

O-1157

## Holocene relative sea level and vegetation changes: implications for human occupation of the north coast of Isla Navarino, southernmost Patagonia.

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### Abstract

Human interactions with the coastal environment of southern Patagonia are strongly evidenced by extensive shell-midden deposits. However, evidence for sites of early Holocene occupation have yet to be found and our understanding of the nature and timing of coastal environmental change is limited. We present a new Late glacial-Holocene palaeoenvironmental record from the north-eastern coast of Isla Navarino (54°55'S, 67°2'W) on the Canal Beagle, southernmost Patagonia. The record was sampled from a mire near Caleta Eugenia located within the evergreen southern beech (*Nothofagus*) forest, pollen and spore analysis suggest a high degree of variability in the woodland cover along the coast driven by changes in effective moisture. AMS radiocarbon dating supplemented by the application of tephrochronology including the geochemical fingerprinting of three cryptotephra layers provides robust age constraint. The Cta Eugenia record commences at c.15.9 ka. The sequence of vegetation changes between c. 15.9 and 8.1 ka reflect changes in temperature and humidity after the early expansion of the southern beech forest, probably reflecting the site's proximity to southern beech refugia located in the south-western area of Tierra del Fuego. We argue that the periods of increased moisture and aridity at Cta Eugenia closely reflect the extent to which the southern westerly winds (SWWs) shifted polewards during the early to mid-Holocene before migrating towards their present latitudinal focus during the late Holocene. The Cta Eugenia site was rapidly inundated by a rise in relative sea level at c. 8.1 ka. The sediment record shows the very abrupt deposition of marine sediments with no evidence for a gradual transition from terrestrial to marine conditions. The timing and very rapid nature of the mid-Holocene marine incursion has important implications for understanding the spatial and temporal distribution of archaeological sites of early human occupation along the northern coast of Isla Navarino. The oldest site thus far identified is dated to c. 6.9 ka which is consistent with the peak of the mid-Holocene marine incursion. Later Holocene sites are found along the emergent shorelines that provided ideal locations for occupation in the coastal zone. Following the emergence of the site after c. 6.8 ka moderate to strong effective moisture levels dominated during the early Holocene until c. 6.6 ka, followed by a sustained period (c. 6.6–3.9 ka) of drier climatic conditions. After c. 3.9 ka an expansion of the forest suggests a return to more humid conditions during the late Holocene. The vegetation records indicate a period of relative climatic stability during phases of human occupation along the coastal zone (c. 6.6–3.9 ka). It is likely that early Holocene sites of occupation that predate the marine incursion have been submerged.

O-1158

## Detecting primary climate drivers of shoreline change along Southeast Queensland, Australia using historical Landsat imagery

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### Abstract

Understanding of the teleconnection between global climate and regional shoreline change in southeast Queensland, Australia has been poorly understood due to a lack of historical shoreline position data. Previous attempts at relating shoreline change to variability in the El Niño-Southern Oscillation (ENSO) cycle relied on datasets that were limited in either their spatial coverage or temporal resolution (i.e. local beach profiling and infrequent aerial photography acquisition). We have attempted to overcome the limitations of these techniques by using Landsat satellite imagery. We have constructed a very-high temporal resolution shoreline dataset covering the Cooloola Sand Mass (CSM) from January 1996 through December 2017. 147 historical positions were extracted for the 62 km-long CSM shoreline amounting to a total of 9,000 km of mapped shoreline. Shoreline positions were delineated from Landsat imagery using the Modified Normalized Difference Water Index, a spectral index that uses the middle-infrared and green visible bands to extract pixels containing water surfaces. A strong tidal influence was observed on the shoreline positions as the tide stage varies during the synchronous Landsat flyover time. Horizontal offsets due to variable tide stages were removed using local tide data available back to 1996 and by extracting seasonal intertidal widths from equilibrium beach profiles. Beach profiles were created for the austral seasons using hindcast wave data from the NOAA WAVEWATCH III dataset and known grain sizes for the CSM. Total shoreline movement over the 21 years was calculated every 500 meters along the CSM shoreline using the Digital Shoreline Analysis System. These values were used to separate the CSM shoreline into four geomorphic compartments, for which shoreline change curves were constructed and then correlated to five climate indices: ENSO, Southern Annular Mode, Pacific Decadal Oscillation (PDO), and the Subtropical Ridge Latitude and Pressure. The presence and strength of statistical relationships between the four shoreline segments and five climate indices were assessed using Pearson correlation coefficients and their associated p values. PDO shows the strongest correlation across all four shorelines, with r values ranging from 0.22 to 0.31 within the 99% confidence interval, indicating shorelines retreat (prograde) during negative (positive) PDO phases. The observable response of the shorelines to PDO variability could be linked to large-scale anomalies and trends in cyclone and anticyclone behavior in the Tasman Sea, where negative PDO phases are host to more frequent and intense cyclones. This novel and statistically significant coupling between PDO and shoreline change provides significant insight into how the CSM and other sand island shorelines in southeast Australia could respond to a potential PDO phase reversal expected within the next 4 to 7 years. Additionally, the orientation and heights of strandplain beach ridges could be used as a possible indicator of Holocene PDO phase variability.

O-1159

## Coastal living in the landscapes of prehistoric southern Denmark: a study of human-environment interactions.

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### Abstract

Postglacial relative sea level rise flooded much of the low lying landscapes of southern Scandinavia submerging the coastal shelves. These drowned landscapes potentially hold well preserved archaeology together with palaeoenvironmental archives that could allow for detailed study of past human-environment interactions. Due to restricted accessibility it is not often possible to excavate at a scale large enough to allow the necessary detailed investigation of the cultural remains together with the landscape/palaeoenvironmental reconstruction to examine these interactions. A rare opportunity to investigate just such a site has recently been possible due to a combination of historical land reclamation and the construction of the tunnel beneath the Femern Strait between Denmark and Germany. Rising relative sea levels submerged the coastal zone in the south of the island of Lolland on the southern tip of Denmark where archaeological investigations at the 187 ha site (Femern Project) suggest cultural use of this environment from the very earliest Mesolithic (from c. 11700 cal BP) and with sustained human presence beginning in the late Mesolithic, through the Neolithic and on into the Bronze age (between c. 7400 and 2500 cal BP). The cultural material is preserved in reed peats and lagunal muds which encroach landward until at least c. 1700 cal BP and here we show a series of 3D reconstructions (based on an extensive borehole survey) showing the association of the archaeological material with this dynamic coastline. The reconstructions show two fjords both containing brackish shallow water which were connected when relative sea level reached c. 1.5 m b.s.l. forming one large lagoon. The larger lagoon phase is associated with two fixed fish weirs and several other fish weir fences. Six sediment profiles/boreholes were further selected to represent the whole time period and to reconstruct both the aquatic (macrofossils, diatoms, geochemistry) and the terrestrial (pollen) palaeoenvironments. This data shows, for example, a shallow, brackish lagoon edged with reed beds which is associated with long-term ritual use of the interface between land and sea, and the economic use of the landscape with the onset of grazing c. 5700 cal BP and the later changing spatial distribution of grazing intensity and land use.

This work is attempting to place cultural activities within their spatial and temporal framework by combining sedimentological, stratigraphic and palaeoenvironmental data with archaeological evidence and landscape modelling. Although work is ongoing, this approach is showing what new knowledge can be gained when we have the unique opportunity to closely examine the relationship between coastal communities and their environment.

O-1160

## **Implications of North Atlantic Holocene coastal change and storminess: palaeoenvironmental, geochronological, and archaeological evidence from southwest Anglesey, UK.**

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### **Abstract**

Coastal environments are directly and uniquely impacted by storms, extreme weather events, and changing sea-levels. Future climate change and sea level rise will exacerbate the vulnerability of coastal habitats, infrastructure, heritage and communities. Evidence of coastal dynamics and storm activity during the Holocene provides a long term context for managing future change. CHERISH (Climate, Heritage and Environments of Reefs, Islands and Headlands) is an EU funded project which aims to investigate the past, present, and future impacts of climate change, storminess and extreme weather events on the rich cultural heritage of the Irish and Welsh coasts.

Here we present palaeoenvironmental and geochronological evidence from 3 sites on the southwest of the Isle of Anglesey, North Wales, where the coastal zone is fully exposed to the prevailing Atlantic south-westerly winds. At Llyn Maelog, Rhosneigr, a 4.5m core preserves an early Holocene record with a lacustrine environment developing into alder-carr woodland prior to c. 7.6 cal kyr BP. The alder-carr phase was terminated by a marine incursion before reverting to a fresh-water lake environment which persists to the present day. Five kilometres southeast, Llyn Coron is a small dune-impounded lake behind the 360 ha Aberffraw dune system. Previously published optically stimulated luminescence (OSL) indicate the earliest sand unit identified in the Aberffraw dune sequences was dated to  $680 \pm 140$  years (Bailey et al., 2001). New evidence from a 3m sediment core from the lake indicates 2 clear episodes of sand inundation, the earliest of which is provisionally dated to c. 2.6 cal kyr BP, based on radiocarbon dating of wood immediately below a 4cm layer of fine sand that built up prior to lake development. A more recent sand unit overlying 26cm of lake sediment, indicates a separate, period of increased dune activity. Optically stimulated luminescence (OSL) dating is being used to establish a more detailed chronology for the sand deposition through this sedimentary sequence.

Further south along the coast at the early medieval settlement at Rhuddgaer, archaeological excavations reveal up to 1.4m of wind-blown sand sitting directly on top of ridge and furrow plough soil. Archival records refer to a severe storm in 1331 CE that destroyed agricultural land and led to abandonment of the site. OSL dating is being used to date the sand sequence, to establish the rate of accumulation and also whether there were multiple phases of sand mobilisation.

Our research highlights several major phases of Late Holocene sand mobilisation at the coastal sites examined. The integration of multiple lines of palaeoenvironmental, archaeological, and historical evidence provide valuable information on the rate and magnitude of environmental change over past millennia, and highlights the present day challenges for coastal communities located on the margins of the North Atlantic.

O-1161

## The Lyonesse Project: how human, climate and landscape interactions have shaped cultural transitions over 12,000 years

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### Abstract

Dispersal of hunter gatherer populations from continental Europe into Britain followed the Last Glacial Maximum when sea levels were lower, southern Britain was connected with northwest Europe and the ice sheets melted with climate amelioration. Britain and Ireland became islands by the early Holocene, which raises questions as to how later agricultural practises and cultural changes took place. Consensus suggests a combination of indigenous transition and colonisation from continental Europe. The Isles of Scilly off the South West Peninsula, Cornwall play an important role due to their position in the western seaways, their possible archaeological affinities with northern France and Belgium, and their high concentration of archaeological sites compared to the UK mainland. Sea levels continued to rise on Scilly throughout the Holocene creating a gradual fragmentation of the island group and changes in resource availability. Understanding the roles of climate, land area, land cover and coastal resource is vital in the story of hunter gatherer to Neolithic and other cultural transitions. The aim of the Lyonesse Project was to reconstruct the physical environment of Scilly for the past 12,000 years in order to progress the discussion behind human migratory and behavioural transitions through the Holocene. We present a new relative sea-level curve for Scilly that is supported by a database of >100 precise and limiting sea-level index points. These data are used here alongside a new glacio-isostatic adjustment (GIA) model to develop verified land motion and sea-level histories for the region from deglaciation to present day. The GIA model is combined with simulated changes in tidal amplitudes of the region to calculate state-of-the-art palaeogeographies for Scilly, which provide estimates of land area and intertidal zone changes. Pollen analyses of sediment cores taken from subtidal, intertidal and subaerial exposures are combined to develop community tables of ecological biomes that existed across Scilly throughout the Holocene. Archaeological data from the Cornwall and Scilly Historic Environment Record were combined with a regional radiocarbon summed probability distribution curve to synthesise evidence of human activity. Cross-correlation of these new palaeoenvironmental time series with regional climate (temperature and precipitation) records reveal significant land cover changes occurring shortly after 7000 yrs BP that cannot be explained by climate or sea-level change alone. However, the onset of the transition from a climax ecosystem towards open, possibly cleared, grassland predates cultural evidence of Neolithic practises on Scilly by over a millennium. Cultural transitions throughout the Holocene are characterised by observed changes in natural resource availability and land cover variation that coincide with changing human occupation and land practises. This study reveals new insight into how climate and sea-level changes have influenced human migration and settlement and, in turn, how humans have shaped a previously natural environment.

O-1162

## Persistent arctic vegetation during periods of rapid climate change - 24,000 years of plant community dynamics in the Polar Urals

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### Abstract

An understanding of the nature and drivers of long-term vegetation dynamics is important for anticipating future ecosystem response and for identifying factors that might contribute to resilience in the face of climate and environmental change. Earlier attempts at reconstructing vegetation composition during and since the Last Glacial Maximum (LGM) in northern Russia have been limited by the lack of well-dated, high-resolution and continuous records. Here we present a new record of vegetation dynamics over the last 24,000 years based on relatively high-resolution pollen and ancient DNA extracted from the sediments (*sedaDNA*) of the largest and deepest lake in the Polar Ural Mountains of the Russian Arctic, Lake Bolshoye Schuchye. Preservation of both proxies are excellent throughout the sediment core. A high number of AMS radiocarbon dates ensures a good age model. Floristic richness and compositional turnover are inferred based on the pollen and *sedaDNA* data. The combined record reveals several important features of late Quaternary vegetation dynamics which earlier attempts have failed to detect; a diverse arctic-alpine herb flora in the Last Glacial Maximum (25 - 17 k yrs BP) which continues to persist through the Holocene, a switch in the dominance of functional groups and turnover in grass genera over the Pleistocene-Holocene transition, a response to Younger Dryas (YD) cooling (13 - 11.8 k yrs BP) and numerous Holocene species additions (11.8 - 1.3 k yrs BP). Of particular interest are the abrupt and short-lived fluctuations in the vegetation and land cover before and during the YD. This is observed especially in *Alnus*, *Betula*, *Artemisia*, *Dryas*, grasses and sedges, possibly an effect of local climate change. In general, over the full 24,000 year period little turnover (< 3 Stdev) is observed in both the *sedaDNA* and pollen records. Instead, a reshuffling in the dominance of individuals within and between functional groups is indicated without any loss of species. A comparison of turnover and floristic richness estimates based on *sedaDNA* and pollen highlight differences in their productivity, dispersal and taxonomic resolution. Whilst pollen shows no long-term change in floristic richness, *sedaDNA* shows a 48 % increase in richness between the LGM (25 - 17 k yrs BP) and Lateglacial (17 - 11.8 k yrs BP), and a further 4 % increase in floristic richness at the onset of the Holocene (ca. 11.8 k yrs BP). The flora has shown remarkable persistence in the face of changing climate and environmental conditions over the past 24,000 years and thus, we might expect only minor changes in floristic diversity with future climate warming.

O-1163

## Palaeo-lake Fucino (Central Apennines, Italy): a new, independently dated, multi-proxy record of environmental change during Marine Isotope Stage (MIS) 11.

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### Abstract

Past interglacial periods are important case studies in that they can help us understand the future evolution of our current warm stage. In particular, Marine Isotope Stage (MIS) 11 is the closest analogue for the Holocene since the Middle Pleistocene Transition and, being an unusually long interglacial period, can provide a good analogue for how the Earth system could operate under anthropogenically prolonged warm conditions (Tzedakis *et al.*, 2012). Intermontane basins in the Central Apennines are key sites to study past environmental and climate changes in the Mediterranean Region (*e.g.* Regattieri *et al.*, 2017). Among these, the Fucino Basin hosts a long, continuous and climatic sensitive lacustrine sedimentary succession including numerous volcanic ash (tephra) layers (Mannella *et al.*, 2018). Here we present a new 17 m long record from palaeo-lake Fucino spanning the whole of MIS 11, from Termination V to its final demise. The record is studied by means of a multi-proxy approach: a high resolution elemental profile is complemented by biogeochemical (total inorganic and organic carbon, total sulphur and nitrogen) and stable isotope ( $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) analyses on discrete samples. Preliminary geochemical analyses and high-precision  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of the rich tephrostratigraphic content (5 out of 34 tephra layers) allow us to compose an independent age model spanning ca. 440 to 368 ka.

Our record shows prominent long-term environmental changes superposed with short-term oscillations. We explore the regional climatic framework by correlating our record with other published terrestrial and marine climatic archives. We observe an initial cold phase pervaded with arid events (ca. 440-424 ka – MIS 12), which is abruptly followed by a warmer and moister phase (ca. 424-402 ka – early-middle MIS 11). This warm phase is articulated in a first part (ca. 424-417 ka), characterised by subdued short-term variability, and in a second warmer part (ca. 417-402 ka), characterised by enhanced short-term variability. In particular, we observe 3 major millennial scale cold-arid events (at ca. 417-415, 410-408 and 406-404 ka) interrupting full interglacial conditions (MIS 11c). Finally we observe a slow and progressive demise of warm conditions (ca. 402-368 ka – late MIS 11) punctuated by abrupt cooling events. Our independent chronology suggests that precession and obliquity were the main forces shaping the general structure of MIS 11, while sub-orbital scale oscillations became relevant only during the later part of MIS 11.

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O-1164

## Persistent millennial-scale climate oscillations in Southern Europe during the Penultimate Glacial

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### Abstract

Highly-resolved  $\delta^{18}\text{O}$  analysis of Greenland ice cores reveal the existence of large magnitude changes in regional climate on millennial timescales during the last glacial period. Concomitant changes in European temperature and in the strength of the Asian Monsoon (AM), for example, demonstrate the range of influence of these so-called Dansgaard-Oeschger (D-O) events emanating from the North Atlantic region, and likely propagated via changes in the strength of Atlantic meridional overturning circulation (MOC). It is important to determine the presence, spatial expression and regional character of 'D-O-like' climate oscillations during earlier glacial episodes. Such knowledge will help us to refine our understanding of Earth system sensitivity and behaviour under differing orbital and ice sheet configurations. The orbital configuration of the penultimate glacial (PG) (c.185–135 ka) differed markedly from that of the last glacial. Although beyond the temporal extent of the Greenland ice core record, the synthetic record of Baker et al (2011) predicts multiple D-O-like oscillations during the PG. Empirical evidence from Southern Europe, a region influenced by MOC variability, supports the existence of millennial-scale climate variability during the early PG, although mid-late PG climate variability appears muted in existing records (e.g. Margari et al., 2010). This contrasts somewhat with recent Chinese speleothem data, in which highly-resolved  $\delta^{13}\text{C}$  measurements revealed the existence of up to 15 Chinese interstadials during the late PG (Wang et al., 2018). Here we present the first complete high resolution Southern European diatom record capturing the PG interval, from Lake Ioannina core I-284 (NW Greece). We have previously demonstrated the sensitivity of I-284 diatom assemblages to millennial-scale variability during deglaciations (e.g. Wilson et al., 2015). We find multiple discrete episodes of high planktonic diatom species abundance throughout the entire PG, likely reflecting intervals of lake thermal improvement and perhaps episodes of higher lake level. When compared with absolutely dated Chinese speleothem records, we find correlatives of many Chinese Interstadials in our diatom planktonic record. The dataset presented here provides firm evidence for the persistent influence of millennial-scale climate oscillations in mainland Europe during the PG and provides important empirical evidence for the geographical extent of millennial-scale climate variability.

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O-1165

## Climate continentality gradient in the optimum of the Eemian interglacial: case studies of the pollen profiles from Central Poland

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### Abstract

Within the European Plains, the Garwolin area occurred to be a part of the Eemian fossil great lakeland of Central Poland (Źarski et al. 2005). More than 20 new palaeolakes of this age were found during the cartographic work for the needs of the Detailed Geological Map of Poland, scale 1:50 000. The investigated sites are located in two geomorphological positions (depressions without outflow and valleys of small contemporary watercourses). Preliminary results of palynological investigations revealed some abrupt vegetation changes recorded in the course of pollen curves resulting probably from abrupt climate changes. In general, vegetation composition during the climate optimum of the Eemian interglacial had more plant species associated with the oceanic climate (i.e. *Taxus baccata*, *Buxus sempervirens*) than the vegetation of the same age from Belarus (Granoszewski et al. 2012; Kupryjanowicz et al. 2018). According to expectations, pollen percentages of the mentioned taxa were smaller than in the German diagrams. Proximity of the deeply incised valley of the Vistula river, very active during the Eemian interglacial, additionally could have affected the climate of the fossil lakeland. The results of palynological analyses have been supported by diatoms and plant macrofossil data. Significant variation in diatom species composition and its relative abundance explained marked environmental and climatic changes during the time of deposition. The presence of taxa typical of the Eemian macrofloras (*Brasenia* sp., *Aldrovanda vesiculosa*, *Najas minor*) testifies to high air temperature. Of special importance is the occurrence of megaspores of the water fern *Salvinia natans*, that grows in warm sub-Atlantic climate zone and in a tropical climate (Aalbersberg, Litt 1998).

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O-1166

## Eemian environmental changes recorded in lake deposits from Hinterste Mühle (NE Germany) and Rzecino (NW Poland) - subfossil Cladocera data

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### Abstract

In the current study the result of subfossil Cladocera analysis of the lake sediments from two sites: Hinterste Mühle (H-M) (NE Germany) and Rzecino (NW Poland) of the Eemian Interglacial and the inferred environmental alterations are presented. The aim of the study was to reconstruct and compare the development of Eemian lakes located within north of Poland and Germany as determined on the basis of the changes in subfossil Cladocera composition in the context of local conditions, climate change and natural evolutionary processes. The studied reservoirs, fully developed during the Eemian Interglacial, were formed at the end of Late Saalian (MIS 6).

The Hinterste Mühle profile is located in Mecklenburg-Western Pomerania. The site lies in the southeastern edge of the gravel pit, at about 48 m a.s.l. The Eemian sequence is situated in a local kettle hole depression overlying basal till and glaciolacustrine deposits of the Late Saalian and finally covered by Weichselian till. The Rzecino paleolake is located near Połczyn-Zdroj, which is situated in the West Pomerania Lakeland (NW Poland), at an elevation of 104.5 m a.s.l. The sediments fill a tectonic graben, which was formed along a large faulting zone that borders the Połczyn-Zdroj salt dome in the southwest. At the initial stage of lake development, sediments within the lake basins consisted mainly of sands and silts. The full lake development periods were associated with sedimentation of gyttja and organic silts followed by peat at the Hinterste Mühle sequence.

The subfossil cladoceran fauna from the H-M palaeolake is represented by 14 species belonging to three families: Chydoridae, Sididae, Daphnidae. Three of them belong to a benthic group inhabiting mainly the bottom sediments, one to the open water zone, while the remaining species the dominant group occur among aquatic plants. Such a species composition marks a shallow water body or the littoral, macrophyte zone of a deeper lake. The Cladoceran fauna of deposits from the Rzecino paleolake are represented by 22 species that belong to four families: Bosminidae, Chydoridae, Sididae and Daphnidae. The majority of the remains consist of Chydoridae and Bosminidae. In the deposits, the ephippial eggs of the *Daphnia longispina* group, *Ceriodaphnia* spp., *Chydorus* spp., and *Bosmina* spp. are also identified. *Bosmina longirostris* is the dominant species during all development periods of the Rzecino paleolake.

Summing up, in the studied reservoirs there were identified similar stages of development on the basis of the Cladocera analysis resulting from the impact of regional climate changes. However, the time of the creation of the reservoirs and its terrestrialization was related mainly to the size and depth as well as local conditions of the lakes.

O-1167

## The climatic change and human adaption at Yuncheng Salt Lake in Loess Plateau since 30 ka BP

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### Abstract

Base on the high-resolution records of pollen and charcoal from the lacustrine deposit at Yuncheng salt lake in the south of Loess Plateau, combining high precision <sup>14</sup>C chronological data, the climatic change, climate events and controlling factors are reconstructed for the last 30 ka BP. The climate is cool and dry during period of 36.7-28.6 ka BP in Salt Lake of Yuncheng. The last glacial maximum can be divided into two periods. The climate is cold and dry between 28.6 and 21.7 ka BP. The vegetation coverage increased and climate is still cold and dry between 21.7 and 15 ka BP. Since the last 15 ka BP, the vegetation changed significantly, and the East Asian summer monsoon gradually increased and reached its peak between 7.8 and 5.3 ka BP. The climate events of Younger Dryas, 8.9 ka, 8.2 ka, 5.3 ka, 4.3 ka, 2.8 ka also occurred during the intensification of monsoon. After about 4.3 ka BP, the monsoon receded rapidly, and the climate developed cooler and drier. The climate change in Yuncheng has been mainly controlled by summer solar radiation in the northern hemisphere for the last 30 ka, but the peak of the East Asian summer monsoon lagged behind the solar radiation maximum, which possibly affected by the regulation of ice volume in the high latitudes of Northern Hemisphere. The warm-humid climate promoted the prosperity of Neolithic culture and the development of agriculture during the mid-Holocene. Since 5 ka, Longshan Culture has developed rapidly and improved the adaptive capacity to cope with the climate changes.

O-1168

## LGM climate and vegetation at the southern Alpine foreland: the view from a high-resolution paleoecological record

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### Abstract

Long and continuous lake records are renowned archives of ecosystems, climate and anthropic history over different time scales. They accurately witness paleoenvironmental and paleoclimate variability, as shown by hundreds of researches worldwide. Northern Italy hosts the first continuous archive of the environmental and climate history of the southern alpine foreland; the core drilled at Lake Fimon (Venetian Plain) contains the whole Late Pleistocene represented by lake sediments, making this record an exceptional evidence of the effects of climate variability and humans on past biodiversity (Pini et al., 2010).

We focus here on a specific time interval, corresponding to the coldest extreme of the last glacial cycle, the LGM (Last Glacial Maximum). During the LGM, Earth experienced the development of continental ice sheets complexes over Antarctica, Eurasia, North and South America. Sea-level recorded phases of relative stability followed by abrupt decreases. Terrestrial ecosystems faced major reorganizations.

The Lake Fimon paleoecological record describes vegetation changes that occurred regionally during the LGM. Boreal forests thrived for most part of the Middle Würm up to ca. 27.5 ka BP, replaced by open woodlands with xerophytes until the first part of the Lateglacial, and later on followed by broad-leaved forests. Locally, a sedge mire developed between ca. 31-27.5 ka BP, then the mire was buried beneath detrital deposits formed under deep-water conditions (Monegato et al., 2011), an evidence for the abrupt onset of fluvio-glacial activity related to the culmination of the Brenta Glacier within the valley (Rossato et al., 2018). Lake level rose suddenly, triggering slope instability and higher sedimentation rates throughout the LGM.

Pollen-based quantitative reconstructions of past climate parameters (January and July temperatures, and annual precipitation) were obtained through the application of the Modern Analogue Technique (MAT). For each fossil pollen spectra, the 5 best modern analogues were identified among a calibration set of 239 sample sites of the Euro-Siberian orbiome extracted from the larger EMPD (European Modern Pollen Database: Davis et al., 2013). Climate parameters associated to the 5 best analogues were weighted-mean according to their respective similarity coefficient and attributed to the fossil sample. Climate reconstructions were then compared and fine-tuned with other proxies of climate at alpine and global scale. Warmer Tjan reconstructed at Fimon are related to Greenland Interstadials 3 and 2, with minor shifts between chronologies remaining within the error associated with the radiocarbon determination. Colder reconstructed Tjan seem to be indeed the expression on land of cooling related to massive iceberg discharge in the North Atlantic (Heinrich events 2 and 1, the latter in the early Lateglacial). As soon as the Atlantic Meridional Overturning Circulation resumed, pollen-based climate reconstructions point to warmer and moister conditions, favoring the spread of thermophilous forests from the Lateglacial interstadial onwards.

**O-1169**

## **Transformations of socio-economic and environmental phenomena during the late antique Migration Period in Europe**

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### **Abstract**

Migrations in the Late Antiquity of Europe have concerned scholars for several centuries. These migrations are connected to different socio-economic crises. Internal and external triggers and driving forces are discussed as being responsible for these processes during the 4<sup>th</sup> to the 6<sup>th</sup> century CE. The breakdown of the Roman Empire and its shock waves are generally blamed but on a local or regional scale this might have been expressed by supply shortfalls, social stress, famines or plagues. As external drivers extreme weather events (caused by volcanic eruptions or meteorite impact) but also a longer lasting climatic shift and the spread of pathogenic germs are discussed. Most modern authors speak for a multi-factorial explanation of socio-economic and environmental changes but the order of causes and effects keep mostly unclear. In the frame of this talk I will compare data from palaeoenvironmental studies from northern Central Europe with historical data and climate proxies from the northern hemisphere. Signals for abandonment of fields and settlements during the Migration Period will be further compared to older phases of woodland regeneration in the Neolithic and Bronze Age as examples for crises and transformations.

O-1170

## Late Holocene climate implications and later prehistoric landscape modifications in the tropical and semi-arid regions of Indian Peninsula

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### Abstract

This paper stress on the number of cultural features studied as a signature for micro studies in our archaeological projects to understand the changes in economy, politics of south Indian later prehistoric population resulted at major landscape modifications, and site formation processes associated with frequent climatic variations occurred during the late Holocene. Paleoclimate studies on reconstructing the Indian Summer Monsoon (IMS) from various lakes, river and ocean sediment cores identified aridification of climate in the Indian subcontinent during last c. 4500 to 1500 ka. Unstable river behaviors such as weakening of river dynamics and occurrence of recurrent flash floods determined by the monsoon precipitation in the rivers of Western Ghats originate (example Kaveri, Krishna and Tungabhadra) in Indian Peninsula have implications on the developments of later prehistoric societies during the last three millennium BCE (Neolithic, 3000-1200 BCE and Iron Age during 1200-300 BCE). Such developments in the environment coincided with the nature of expansion of agricultural population, crop suites, subsistence changes and settlement established away from the riverine environs. However, recent archaeological studies by the present author in South India focusing on two different ecology, such as the tropical Western Ghats (Koppa Archaeological Research Project) and semiarid region of central Deccan plateau (Brahmagiri Landscape and Settlement Survey project) are showing differences in population adaptability to regional ecologies and resources. Their commonalities are relatively contemporary in the expansion of sites at such above dynamic environments bearing with similar production of cultural materials in the society. Yet in the terms of their landscape modification and how they managed space within the sites and nearby sites have major variations to record from the cultural features (stone tools, ceramics and burials) and spatial patterning beyond the cultural materials; which are associated with the ritual and economic practices invariably governed by fluctuating climate and nature of landscapes. Number of key distinctions is evident on this regards from the various sites in above study areas; one, water collection and management led by fluctuating monsoon precipitation taking shape in local politics and resource of economic importance regulated through the introduction of artificial pools/ reservoirs. Two, sites shifting from riverine to non-river environs and surrounding the natural springs in shaping the site economy; three, living in the rock shelters and open scrubs on whether imprints of rock art and sonic production due to nature of denudational and pediplain landscapes etc. They collaterally indicate at the development of new cultural landmarks with changes in climate and availability of suitable landscapes.

O-1171

## Late Holocene Deltaic Progradation Preceded the Early Southward expansion of Intensive Rice Agriculture

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### Abstract

The expansion of early rice agriculture along coastal regions of South China (SC) and into Southeast Asia (SEA) remains poorly understood despite the fact that the chronology of rice domestication and the transition to rice-dependent economies is now well documented for the lower Yangtze River area. In this study, we reconstruct the mid-late Holocene history of rice agriculture for the coastal lowlands of SC and SEA, highlighting the role of coastal plain transformation as a driver in the development of intensive agricultural systems. First, we present a comprehensive study of 23 palynological records to show that the onset of widespread rice agriculture was a broadly synchronic event throughout coastal regions surrounding the South China Sea (SCS). Next, we demonstrate that this major shift in subsistence economies accelerated with rapid deltaic progradation and the formation of coastal flat plains at around 3–2 ka. Drawing upon the available archaeological evidence, we propose that the lack of lowlands and wetlands suitable for rice farming is a vital factor that inhibited the transition to rice-dependent economies during the mid-Holocene sea level high-stand. Large-scale rice farming expanded southward rapidly following the formation of deltaic and coastal plains. This hypothesis accords well with recent ancient genome studies in SEA suggesting an additional mixture of incoming genetic material from China at around Bronze Age, which, however, is usually thought to be resulted from the civilization advance in southern China.

O-1172

## Upland economy, heathland and fire dynamics in the mountains of northern Portugal from the middle Ages to the Modern period

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### Abstract

In Europe, mountain landscapes have evolved in a long-term relationship with human communities and present-day landscapes are the reflection of that ancient interaction. The present study aims to reconstruct human activity in two mountain areas in northern Portugal using palynological analysis and integrating its findings with the available regional historical, archaeological and palaeoenvironmental resources.

Both sequences span the Medieval and Modern periods and the pollen records show that mixed agriculture and livestock grazing were consistently present in both regions throughout these times. Variations in cultural indicators show that the extent of farming fluctuated throughout time, with a general increase in cultivation during the medieval period but with contractions likely coinciding with times of social disturbance. Social-political factors and population pressure were fundamental in the utilisation of upland spaces. This study did not find any evidence to suggest that fire was ever widely used as part of a land-management strategy nor that it was a factor in heathland spread. Landscape change was more dramatic in recent centuries, following population and economic decline.

We conclude that long-term occupation of the uplands was sustained by low-intensity land-use throughout the Medieval to post-Medieval periods, and that the present landscape has assumed a very different character following depopulation of the mountain areas and a shift towards commercial forestry.

O-1173

## Anthropogenic activity shifts an ecosystem's main driving forces

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### Abstract

Ecosystem resilience and ecological tipping points may be influenced by anthropogenic activity. Relating temporal variation of multiple palaeoenvironmental proxies to find consistent trends can additionally provide an interesting tool to study the main driving forces of ecological change through time. This temporal approach also avoids the danger of circular argumentation based on falsely assumed modern analogy, obviously present in studies based on modern ecology. This paper presents a comparative study of pollen, macrofossils and non-pollen palynomorphs (NPPs) that was done on a 5500-year sedimentary record from Tårup Lund Denmark (Enevold *et al.* 2018).

Samples were prepared for NPP analysis using a non-aggressive preparation procedure which produced very rich NPP assemblages. Changes in NPP composition were then compared to changes in pollen and macrofossil frequencies from independent preparations. This led to indications about the source of NPPs; ecological affinities of some frequent NPP types and to the identification of main driving forces of NPP composition change. The results also indicated that a significant change in main drivers of NPP composition occurs at the onset of the Pre-Roman Iron Age. Evidence of an extensive Celtic Field system covering the area was furthermore found during the archaeological surveys.

Enevold R., P. Rasmussen, M. Løvschal, J. Olsen and B.V. Odgaard. 2018. Circumstantial evidence of non-pollen palynomorph palaeoecology: a 5,500-year NPP record from forest hollow sediments compared to pollen and macrofossil inferred palaeoenvironments. *Vegetation History and Archaeobotany* in press.

O-1174

## Environment and Culture Change in Kiawa, Southeastern Sokoto-Rima basin, Nigeria.

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### Abstract

Several studies on palaeo-and contemporary environment and culture change in Nigeria emphasized the impact of climate change on livelihood rather than its causes and effects to the environment. This is due to problems of unambiguous climate change indicator, as recorded in plant pollen as well as the scarcity of comparable available sites. Thus, despite records and effects of climate change on environment between the Sahara and equatorial zones of Africa, some scholars have opined that no proof yet exists of a feedback relationship between land use (at the regional level) and environmental change. However, major vegetation changes in neighbouring sites and their corresponding culture change has been recorded since the late Holocene. For instance, an abrupt biostratigraphical and sedimentological change at c. 3300 B.P. in the Lake Chad basin is interpreted as a major shift towards drier climatic conditions. Corresponding culture change from archaeological excavations reveals the introduction of pastoralism and ceramics around 4000 B.P. and the domestication of *pennisetum* from at least 3000 B.P. onwards. Since the discovery of fossil fishes, crocodile and giant turtles as well as records of fossil woods from shallow marine beds in the 1920s and the 1970s in the adjacent Sokoto-Rima basin, this area is seen as a promising build up to supply a more substantial picture of environmental change in West Africa and in relation to other parts of the African continent. Various archaeological discoveries including hand axe, disc cores and flakes along main rivers, where settlements seem to be concentrated, after the return to drier conditions indicates continuous human activity since the Late Stone Age. Recent pilot investigations as part of a PhD research at the archaeological site of Kiawa reveals Pearl millet (*Pennisetum glaucum*) as the most important staple crop in the marginal rain-fed agrarian system and is sometimes combined with corn (*Sorghum*). Tree pollen from winter thorn (*Acacia albida*), Black plum (*Vitex cienkowskii*), Locust bean (*Parkia filicoidea Balanites*) and Shea butter (*Butyrospermum parkii*) have also been recorded. The aim of the project is therefore to recover information pertinent to reconstructing human impact, climate and vegetation change in relation to other West African sites.

O-1175

## Abandonment as adaptation: prehistoric food production, settlement abandonment, and Holocene hydrological changes in the southern Yangtze Delta, China

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### Abstract

Low-lying geomorphology in lower, often densely populated, reaches of the world's large rivers is especially sensitive to changes in the equilibrium between fluvial and marine processes and variations in human activities. This paper reports sedimentary evidence from the Yangtze Delta, China, that provides a (pre-)historic analogue of human responses to this type of changing environment. We focus on two important archaeological sites – Majiabang and Chuodun – within the broader context of evidence of post-glacial environmental changes and early food production in the lower Yangtze. The Majiabang sequence records the initiation of rice-based agriculture at 7,230 cal BP. The onset could have been associated with a decline in wetland resources, indicating the possible role of population growth in triggering early agriculture. However, occupation of the site was ephemeral; agricultural practice seems to have terminated after only ca. 200 years, <sup>14</sup>C dated to 7,070 to 6,840 cal BP. Evidence of dinoflagellate cysts and Chenopodiaceae pollen suggests a major episode of marine intrusion at this time, which might account for the decline in agriculture. Abandonment within a relatively short period of first occupation appears to have been a feature of early settlement on the Yangtze Delta, and may have been an adaptation strategy to an environment characterised by high variability. Despite some investments in settled agricultural technologies, rice was not yet fully domesticated in 7,000 cal BP, and hunting for and the collection of wild foods were important for ensuring food security. Such a strategy would have required a level of mobility and this together with a relatively low population density, abandonment and migration might have been easier adaptation choices than remaining and attempting to mitigate the adverse effects of major environmental changes. Even in the late Holocene, abandonment of settlements due to environmental change was not uncommon. The Influence of an expansion of freshwater lakes on the southern Yangtze Delta – notably associated with formation and subsequent inundation of the Taihu Depression – is recorded in the Chuodun sequence, where increases in microfossils indicating the onset of lacustrine conditions correspond with evidence of a decline in traces of human activities between 2,750 and 1,950 cal BP. The expansion of lacustrine conditions may correspond with early Chinese texts that describe the southern Yangtze Delta as a less inhabitable region characterised by extensive wetlands that made large-scale farming difficult. Extensified land use activities do not appear to have occurred until relatively late in the Holocene, and may have only been established after the arrival of migrants from the Yellow River Basin, which increased population pressure. These migrants may also have possessed relatively advanced environmental management technologies. In the lower Yangtze, the change from mobility to sedentarism was a more prolonged process than previously thought.

O-1176

## How palynology and a great Dane contributed to the development of Quaternary palaeoecology

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### Abstract

Palynology became a major sub-discipline within Quaternary palaeoecology during the first decades of the 1900s under the European leadership of amongst others, Lennart von Post, Gunnar Erdtman, Knud Jessen, Johannes Iversen, Franz Firbas, Knut Faegri, Harry Godwin and Frank Mitchell. Correspondence between these scientists indicates that the Danish Geological Survey (DGU) became the pre-eminent centre where many researchers came to learn the latest techniques. Jessen recruited Iversen to the DGU in 1932 and Iversen became a central figure in the international palynological network. Study of his voluminous correspondence with other researchers during 1930-70 shows how palynological research carried out in Iversen's group contributed to the development of several new ecological insights that included 1. revelation of the extent of human impact on European vegetation as a complement to archaeology; 2. the drivers of long-term plant succession and 3. the role of climate change in ecosystem dynamics.

One measure of international interest in his research is shown by the guest book records between 1948 and 1980 of 220 researchers from 14 countries that made the trip to the remote Draved Forest field station in southern Jutland, where many of Iversen's palaeoecological theories were developed and tested, including the re-enactment of a Neolithic forest clearance using flint axes and fire. Archived letters show the international reputation of Iversen's group developed from 1. The effort and care that Iversen gave to his correspondence; 2. methodological developments that others were keen to learn; 3. acquisition of the latest top quality equipment; 4. a strong internationalisation policy; 5. a research group comprising complementary skills and interests and 6. a diverse, targeted outreach and communication policy. The establishment of Draved Forest as a field laboratory and long-term monitoring site became a well-used and influential demonstration site.

The events, factors and personalities behind the growth and subsequent decline of a successful, international research group include several lessons that are still relevant for the planning and execution of Quaternary research today.



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IRELAND

G. F. MITCHELL,  
24. ~~23~~ TRINITY COLLEGE,  
DUBLIN.

10th March, 1951.

Dear Iver,

Many thanks for the paper that reached me this morning.

After I got back to Dublin I persuaded the University to order a Leitz Ortholux microscope for me and I hope to get delivery of it without much further delay. Now I find that no one in Dublin has ever heard of Anisol. Can you tell me what the composition of this emersion fluid is ?

Yours sincerely,

*Frank*

**Figure 1.** Letter from Frank Mitchell (Dublin) to Johannes Iversen (Copenhagen) illustrating how technical developments in palynology spread from the Iversen's research group.

O-1177

## **Marginalia: Gunnar Erdtman's annotations in his copy of Fægri and Iversen's *Text-book of Modern Pollen Analysis***

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### **Abstract**

The annotation of books by users may be seen as an act of vandalism. By the same token, 'marginalia' or 'apostils' may be regarded positively as a potential source of insight and/or a reflection of the mindset of the defacing/conversing author.

This paper examines the annotations within a copy of the first edition of the 'bible' of palynology – *Text-book of modern pollen analysis* – by the Norwegian botanist Knut Fægri and his co-author, the Danish botanist Johannes Iversen, published in 1950. The marginalia are the work of Swedish geobotanist Gunnar Erdtman. All three palynologists were major figures in the history of this particular Quaternary science – indeed, a discipline-specific award within the field is the Erdtman International Gold Medal.

At the risk of indulging in academic voyeurism – after all, Erdtman was presumably unaware that his 'scribbles' would be open to scrutiny – this paper seeks to assess his written, though unpublished, observations of two would-be ecologically-orientated usurpers of his palynological crown. Erdtman himself had earlier (1943) produced *An Introduction to Pollen Analysis* and very much saw himself as the font of wisdom concerning the discipline, and especially so in the area of systematics.

Erdtman's marginalia, inscribed in pencil and ink, include notes, underlinings, drawings, exclamation and question marks. Their greatest concentration is to be found in connection with pages addressing pollen morphology. He also queries or contradicts factual statements and, pedantically, English usage and reference order. He approvingly ticks items according to primacy to himself or to his palynomorph terminology. His use of such disfigurement is to be found elsewhere within his archives, although not to the same extent as seen in Fægri and Iversen's classic tome.

Such interest might be regarded as an addition to the critical apparatus available for the appraisal of an academic's work – a more personal augmentation to such sources as reviews or commentaries of draft papers published by some journals as part of the editorial process. Whatever else it does, it allows an insight into the thinking of a pioneering Quaternary scientist, as well as revealing a spontaneity and a persona which might otherwise be hidden.

O-1178

## Pollen databases: from von Post to Neotoma

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### Abstract

In 1916, Lennart von Post introduced the pollen diagram at the 16th Convention of Scandinavian Naturalists in Kristiania (Oslo, Norway). However, not only did he introduce the pollen diagram as a means of visualizing data from single stratigraphic profiles, he also presented a transect of diagrams that depicted pollen and vegetation changes through time and space as well as a diagram of averages that summarized regional pollen changes. To construct such diagrams, von Post had to organize and summarize data, and thus assemble a “database,” a word that was not coined until the computer age in the late 1960s.

The first large computer database of pollen data was that assembled by the Cooperative Holocene Mapping Project (COHMAP). Under the direction of Thompson Webb III, original pollen-count data from North America were solicited from investigators and organized into individual flat files with defined formats for pollen data and chronologies. At the same time in Europe, John Birks and Brian Huntley assembled pollen percentage data digitized from published pollen diagrams to produce a massive compendium of isopoll maps for Europe. These projects established not only the indubitable value of pollen databases, but also the need for open access and for organization into a relational database structure. Thus, in the early 1990s, the North American Pollen Database (NAPD) and European Pollen Database (EPD) were established, and in following years a number of other database projects were launched, including pollen databases for Africa, Latin America, and other regions. Although internet technology was not yet to the point where a single global database could be contemplated, these databases established a common structure and were deployed in the same relational database management software.

The pollen databases had become essential cyberinfrastructure for global change research. Nevertheless, weaknesses included limited interoperability with databases for other paleo datatypes, limited ability for those outside the data center to upload and manage data, limited online capability to query the database, and long-term sustainability. For these reasons, the Neotoma Paleocology Database ([www.neotomadb.org](http://www.neotomadb.org)) was launched by the coordinators of existing databases for pollen, plant macrofossils, diatoms, ostracodes, vertebrate fossils, and others. The existing pollen databases have been or are being incorporated into Neotoma, along with data from other databases. However, existing database projects, such as the NAPD and EPD, still exist within Neotoma as constituent databases and are responsible for their own data upload and management. A common web-based portal to the database has been developed, and a common software interface for remote data upload and management is being developed. The scientific merit of assembling pollen data demonstrated by von Post a century ago is well positioned for the next century.

O-1179

## A short history of Bayesian chronology-building

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### Abstract

Well before Darwin, Lyell and von Post, the English statistician Rev. Thomas Bayes (c. 1701-1761) developed a scientific approach that has proven to be very useful in Quaternary research. Bayes aimed to establish how our understanding of phenomena should be updated with new evidence, for example if new dates become available for a sedimentary sequence. In the Bayesian framework, everything is expressed as probabilities – this is especially useful in areas such as Quaternary research where data points are often sparse and come with sizable uncertainties.

Bayesian models can be seen as simulations of real-world phenomena that adapt to the available data within the constraints set by prior information. For example, simulations of sediment accumulation can be used as age-depth models for lake cores with several radiocarbon-dated depths, with prior information set such that that age-reversals or abrupt changes in sedimentation rate are avoided. Millions of these simulations, each based on slightly different random numbers for the parameters involved in the sediment accumulation, will together provide estimates of the ages and their uncertainties at any core depth.

After remaining largely unused for centuries, the Bayesian approach became feasible since the 1990s as fast computers and efficient algorithms were developed. Dedicated on-line Bayesian age-modelling tools such as BCal and later OxCal were widely adopted by the archaeological and wider Quaternary community as *de facto* standard chronology-building tools, especially for users of terrestrial radiocarbon dates. However, other communities have been more reluctant in adopting the Bayesian framework for their chronology-building, even if doing so could have the potential to enhance their quantitative understanding of the uncertainties inherent to their datasets and interpretations.

Here we will discuss the history of Bayesian chronology-building tools, outline their advantages over more classical statistical tools, and explore possible reasons why they have become popular in some Quaternary communities yet less so elsewhere.

O-1180

## New $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of Armenian volcanism

Katie Preece<sup>1</sup>, Darren Mark<sup>2</sup>, Keith Wilkinson<sup>3</sup>, Jenni Sherriff<sup>3</sup>, Rhys Timms<sup>4</sup>, Christina Manning<sup>5</sup>

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### Abstract

The Southern Caucasus forms part of a land bridge between Africa and Eurasia and is the location of archaeological sites where the earliest human fossils outside Africa (Dmanisi, Georgia) [1,2] and the earliest evidence for advanced human behaviour (Nor Geghi 1, Armenia) [3] have been found, transforming understanding of the relationship between the European and African Palaeolithic. However, it is presently unclear what mechanisms drove *Homo* sp. dispersal to geographic regions beyond Africa and how technological innovations (i.e. stone tools) and ecological adaptations developed along the way.

Here we present new  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of volcanic deposits (lava flows and domes, pyroclastic deposits and discrete tephra layers) in the Hrazdan and Debed gorges in Armenia. These areas comprise volcanic deposits, intercalated with alluvial, lacustrine and aeolian sediments. Detailed geological mapping,  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology, and geochemical / petrological characterization of the volcanic deposits, shed new light on the volcanic history of the region. In addition, these results provide a stratigraphic link between archaeological sites in the Southern Caucasus and contribute towards understanding how hominin populations responded to dynamic volcanic landscapes.

[1] Ferring, R. et al., 2011. PNAS. 108:10432-10436

[2] Lordkipanidze et al., 2013. Science. 342: 326-331

[3] Adler, D.S. et al., 2014. Science. 345: 1609-1613

O-1181

**The potential for correlating records within and beyond the Caucasus using tephrochronology: tephrostratigraphic results from the Leverhulme funded PAGES project.**

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<sup>5</sup>Department of Anthropology, University of Connecticut, Connecticut, USA

**Abstract**

The PAGES project (Pleistocene Archaeology, Geochronology and Environment of the Southern Caucasus), aimed to develop a robust and independent geochronological framework for the Southern Caucasus, to combine the emerging archaeological and environmental record in the region, with a focus on the mid to late Pleistocene. A key component of this project was an attempt to identify, classify and where possible correlate distal tephra from archaeological and environmental sequences in the Hrazdan and Debed river valleys, Armenia with tephra from local (Armenian and Turkish) volcanic centres, and potentially from more distal volcanoes in the eastern Mediterranean. Here we present the results of the analyses of multiple archaeological and palaeoenvironmental records for visible and cryptotephra deposits between ~30,000 and ~400,000 ka BP. The results include the identification of cryptotephra deposits in multiple sites, along with numerous visible tephra deposits. Grain specific glass shard chemical data for these tephra are presented along with new glass analyses from proximal tephra outcrops associated with volcanic complexes in the Sevan-Hrazdan basin. These results are used to test potential correlations between: (i) archaeological and palaeoenvironmental sites within the study regions of the PAGES project; (ii) records that are being analysed as part of other ongoing collaborative projects across Armenia, and; (iii) sites of similar age within the wider region beyond the Southern Caucasus. This study highlights the challenges with dealing with multiple volcanic centres with limited geochemical and chronological information. However, it also reveals potential tephra-based correlations between a number of sites within Armenia and beyond, and suggests that the Southern Caucasus is a key region in the development of a much wider tephrostratigraphic framework that could eventually link with records from the Eastern Mediterranean, Turkey and the Greater Caucasus region.

**O-1183**

## **Source-specific biomarkers as sea ice proxies - current status and future directions**

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### **Abstract**

Dramatic changes in sea ice extent and thickness during recent decades have prompted attempts to decipher longer-term palaeo sea ice variability, in order to place modern observations into a better context. Such knowledge should also aid our understanding of sea ice within the broader climate system, and improve the reliability of various climate forecasting and hindcasting models. Reconstruction of palaeo sea ice conditions has been achieved largely through analysis of various proxies in marine sedimentary archives. Over the last decade or so, certain source-specific C<sub>25</sub> highly branched isoprenoid (HBI) lipid biomarkers have emerged as useful proxies for both Arctic and Antarctic sea ice. Thus, IP<sub>25</sub> (Ice Proxy with 25 carbon atoms) and IPSO<sub>25</sub> (Ice Proxy for the Southern Ocean with 25 carbon atoms) represent binary measures of past seasonal sea ice in the Arctic and Antarctic, respectively. A further tri-unsaturated HBI (generally referred to as HBI III) appears to provide proxy evidence for the region of open water adjacent to sea ice (i.e. the marginal ice zone (MIZ)) for both the Arctic and the Antarctic. However, several questions about the use of HBIs as sea ice proxies remain, not least, the extent to which they can provide more detailed information of sea conditions such as sea ice concentration, duration or type (e.g. landfast ice, drift ice, first-year ice, multi-year ice, etc). This presentation will provide a state-of-knowledge account of the use of HBIs as sea ice proxies, drawing on a decade of research activity. The salient features of each HBI as sea ice proxies will be described, along with their currently perceived limitations. By considering some knowledge gaps and previously unexplored areas, some avenues for possible future research efforts will also be identified.

O-1184

## Holocene records of sea-ice, sea-surface temperature and primary productivity in the North Water polynya and offshore Upernavik, northwestern Baffin Bay

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### Abstract

The observed changes in Arctic sea-ice thickness, extent and dynamics (e.g. onset of melting, length of open-water season) during the last few decades raise important concerns regarding the future functioning of Arctic marine ecosystems. The North Water (NOW) polynya (i.e. open-water area surrounded by sea ice) located in northern Baffin Bay plays a key role in fostering local biological productivity, and its intrinsic link to sea ice makes it particularly sensitive to climate change. While a number of studies have documented changes in the physical, chemical and biological characteristics of the polynya over the last decades, little information about its multi-centennial and millennial evolution is currently available.

Here, we present results from a multiproxy study including diatoms, dinoflagellate cysts (dinocysts) and sea-ice biomarkers (IP<sub>25</sub> and triene) from two Holocene sediment cores collected in the NOW polynya (AMD15-Casq1) and offshore Upernavik (AMD14-204) (see figure 1) to determine the relationship between sea ice and primary productivity at local and regional scales. These sedimentary proxy-records were further compared to atmospheric temperature reconstructions from the Agassiz ice cap and Greenland ice sheet to place the observed trends into a regional climate context. During the past ca. 4000 years, primary production has persistently been higher in the NOW polynya compared to the Upernavik site, but rapid and synchronous shifts in the sea-ice conditions, summer sea-surface temperature and productivity regimes between the two regions were recorded. These synchronous shifts were accompanied by changes in the phytoplankton community structure, as illustrated by changes in the diatom and dinocyst species composition and abundances. Our results support the notion that sea ice exerts a strong control on primary production and that future warming will likely be associated with changes in the net primary production and phytoplankton community structure in northern Baffin Bay.

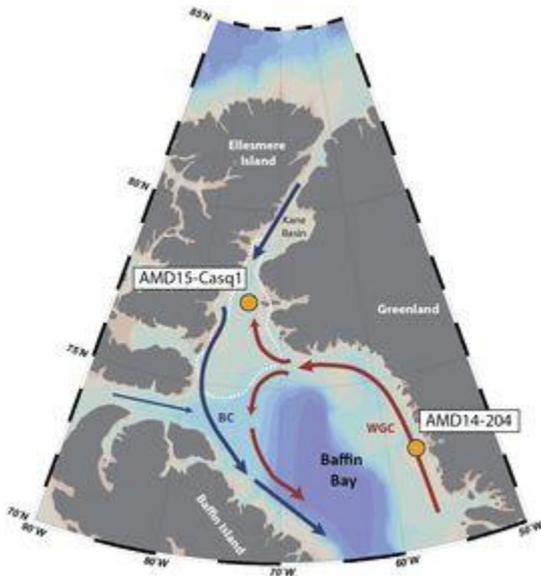


Figure 1. Location of the study sites and main ocean currents. Abbreviations: WGC: West Greenland Current; BC: Baffin Current. The white dashed line corresponds to the approximate extent of the NOW polynya.

O-1185

## Sedimentary ancient DNA reveals *Polarella glacialis* as a novel circum-polar sea ice proxy

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### Abstract

One of the most striking consequences of current climate change is the abrupt decrease in Arctic sea ice extent. Current projections indicate a blue Arctic Ocean during summers already within the next few decades. Despite its importance, sea ice is one of the most poorly understood components of the Earth System, stressing the urgency to develop new proxies for reliable past reconstructions. Here we demonstrate the potential of the sea ice dinoflagellate *Polarella glacialis* as a seasonal sea ice indicator. The species is known to inhabit sea ice in the Antarctic but only a few sightings have been reported from the Arctic. Based on microscopic observations in surface sediment, sediment traps, and sea ice we confirm that this species has a pan-Arctic distribution closely tracking first year sea ice. It forms characteristic resting cysts during its life cycle that are present in large numbers in both sea ice and sediment trap samples. Within seasonal sea ice, it can represent up to 82% of the microalgae communities while it is absent from multi-year sea ice. Although the cysts are exported from the sea ice/sea surface to bottom sediments, there are few reports of this species in sediment records. This is likely due to problematic identification, its size smaller than 20 µm, and its sensitivity to harsh palynological treatment (e.g. using warm HF) and/or cyst degradation in the sediments. Therefore, we chose to explore a paleo-DNA approach for tracing this species in sediment core records.

We designed species-specific primers of the ITS1 gene-region to detect and quantify sedimentary ancient DNA (sedaDNA) from *P. glacialis* in two dated marine sediment cores collected off West Greenland spanning the past ca. 12,000 years. Our results demonstrate that DNA of the ITS1 gene-region in *P. glacialis* can be amplified and quantified using either a standard qPCR or droplet digital PCR approach. We also quantified *P. glacialis* DNA in 53 surface sediment samples from marine and fjord settings around Greenland. The *P. glacialis* DNA results were compared against “classical” proxies such as microfossils and the isoprenoid biomarker IP<sub>25</sub> in both sediment cores and the surface sediments. Our findings are particularly relevant to fjord systems, where *P. glacialis* appears to reflect sea ice conditions more reliably than IP<sub>25</sub>. We suggest sedaDNA from *P. glacialis* as a novel and reliable sea ice proxy that can improve sea ice reconstruction both in marine and near-shore environments of the Arctic and Antarctic regions.

O-1186

## Paleo Arctic sea ice evolution during Dansgaard-Oeschger events 7 to 10: a multidisciplinary approach.

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### Abstract

In the last four decades, Arctic sea ice is experiencing an overall decrease with a notably faster rate than predicted by numerical models. Despite a huge amount of observations has been acquired since the advent of satellite era (1979) there is still a lack of knowledge about past sea ice coverage. Thus, in order to enhance future scenarios predictions, it is fundamental to combine recent observations with past long-term reconstructions. A focus on the mechanisms controlling sea ice dynamics during past abrupt temperature shifts might be crucial to better understand current changes.

A recent study identifies bromine in ice cores as a potential proxy for past sea ice conditions<sup>1</sup>. At polar latitudes in fact, the photochemical recycling of bromine is extremely efficient over first year sea ice (FYSI), resulting in enhanced concentrations of gas phase bromine (e.g. BrO) compared to the ocean surface, multi-year sea ice or snow-covered land. The net effect of this process (commonly referred as "Bromine explosion") can be detected in snow and ice samples as enrichment in bromine concentration compared to the seawater Br/Na ratio.

The Bromine Enrichment ( $Br_{enr}$ ) record from the NEEM ice core (77.45° N, 51.06° W,) has been linked to sea ice conditions in the Canadian Arctic showing a maximum during the Holocene climate optimum (about 9000 years ago) and the lowest values during the glacial stadials, suggesting a complete coverage of the Arctic Ocean by multi-year sea ice<sup>1</sup>. However, the time resolution used in that occasion (20-60 years) was unable to resolve in detail the Dansgaard Oeschger (D-O) events which occurred in a matter of decades .

Here, we present a new  $Br_{enr}$  high resolution dataset across the transitions of D-O 7, 8, 9 and 10 sub-sampled from the NEEM core. The increased resolution of 3-5 years for each sample might allow to better distinguish the amplitude of each transition, while the comparison with stable oxygen isotopes will provide information about the time lag between atmospheric warming and sea ice response. In conclusion, pursuing a multidisciplinary approach, the experimental results will be used to constrain a chemical-transport numerical model for  $Br_{enr}$  that will help to deepen the insight about sea ice extent variations during rapid climate fluctuations.

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**O-1187**

## **A seasonally sea-ice free eastern Arctic Ocean during the early-mid Holocene**

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### **Abstract**

The pre-satellite history of sea-ice cover in the Arctic Ocean is still poorly documented and the effective age of the onset of perennial sea ice remains an unresolved issue. Even at the scales of last millennium and the Holocene, information is rare and mostly indirect. We have addressed this question by the detailed examination deep-sea cores collected along the Lomonosov Ridge in the Arctic Ocean. These cores show contrasted sedimentary regimes. In the western and central part of Arctic Ocean, extremely low sedimentation rates, < 5 mm/kyr, and good preservation of calcareous microfauna characterize the present-day perennial sea ice environments. In the east, close to the Laptev Sea, relatively high sedimentation rates ranging up to ~5 cm/kyr relate to high sediment supplies from the shelf since their submergence ice and to an active Transpolar Drift. At sites near the easternmost edge of the Ridge, early-mid Holocene sediments are characterized by low to nil biogenic carbonates but contain organic-walled dinoflagellate cysts. These features indicate phytoplankton productivity but poor CaCO<sub>3</sub> preservation that we link to intense brine production rates leading to surface water convection with CO<sub>2</sub> transfer from surface to bottom water. Such conditions record an interval with seasonal sea ice in the eastern Lomonosov Ridge area until ca. 4000 years ago instead of perennial sea-ice. Hence, whereas highly resilient perennial sea ice on long time scales characterizes the western Arctic Ocean, seasonal sea ice in the Russian Arctic might be a recurrent feature of warm episodes.

O-1188

## Reconstructing sea ice in the Iceland-Norwegian seas during the Late Quaternary

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### Abstract

The role of sea ice in the climate system is becoming increasingly clear. Obtaining information on past sea ice cover and variations is important for understanding the climatic system.

The aim of this study is to advance the knowledge on sea ice in the Iceland-Norwegian sea by studying ice rafted debris (IRD). The focus of the study is on changes in IRD flux and tracing the IRD source in order to obtain additional data on sea ice coverage in the region and increase our understanding of oceanographic and climatic changes during the Late Quaternary.

Two marine sediment cores (IS-4C and IS-1C), retrieved from 1598 m water depth and 821 m water depth, are used in the study. Preliminary age models and tephra investigation indicate that the 4m long IS-4C core spans the early Holocene back to the Eemian. Work on the age model of the 6m long IS-1C core is in progress and will be based on radiocarbon dates and tephrochronology.

Both cores have been investigated with regard to source and quantity of IRD. Other proxies investigated are planktonic foraminifera and oxygen isotopes. IRD (grains larger than 125  $\mu\text{m}$ ) are counted and initially divided into three components: crystals, rock fragments and tephra. Concomitantly, planktonic foraminifera are counted and identified to species level. To attempt to differentiate sea ice and iceberg rafting, material larger than > 250  $\mu\text{m}$  have been separated from the remainder of the material.

Preliminary results show that these proxies display high amplitude variability throughout the investigated period indicating a complex history of sea ice flux. The IRD analyses show that the most common IRD are quartz crystals with sharp edges. For the most part the quartz crystals are divided into three groups: translucent quartz with sharp edges, whiteish matte and rounded quartz and hematite stained quartz. The hematite-stained quartz could indicate a source from the Devonian red beds of east Greenland. The highly weathered, rounded and matte quartz indicate fluvial or wind erosion before being transported to the ocean. These types of grains are common on the plains in north-western Siberia. Other types of IRD identified are feldspar crystals, rock fragments such as granite, sandstone and basalt. Ash and tephra grains are counted separately.

O-1189

## Last glacial maximum to Holocene biogeochemical cycling and sea ice dynamics in the Bering Sea

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### Abstract

The Bering Sea is characterized by a seasonal sea ice cycle. Together with upwelling along the eastern continental margin, sea ice provides important nutrients to maintain high rates of primary productivity. As such, low oxygen concentrations are pervasive in mid-depth waters. Changes in the ventilation and primary productivity in the past, however, are expected to affect this oxygen minimum zone. On glacial/interglacial (G/IG) timescales, sea ice likely plays a pivotal role for intermediate water ventilation in the Bering Sea. Firstly, enhanced sea ice cover limits the light availability and contributes to surface ocean stratification, restricting the nutrient supply from below and limiting the primary productivity in the surface ocean. Additionally, evidence from the Bering Sea points towards glacial formation of well-ventilated North Pacific Intermediate Water (NPIW) via brine rejection during sea ice freezing. Enhanced formation of NPIW may have important implications for the efficiency of abyssal North Pacific carbon storage, however the spatial and vertical extent of glacial NPIW remains poorly constrained.

We use a multi-proxy approach to study the interactions of sea ice and biogeochemical cycling at International Ocean Discovery Program Site U1343 in the eastern Bering Sea across the last glacial maximum (LGM) to Holocene (7-30 ka). Sedimentary redox chemistry, dysoxic benthic foraminiferal assemblages, and the  $\delta^{18}\text{O}$  composition of seawater all point towards periodic entrainment of NPIW at 2000 m water depth across the LGM and early Heinrich Stadial 1 (HS1). This is supported by biomarker-based sea ice reconstructions, demonstrating enhanced seasonal sea ice cover during the LGM and early HS1, indicating that NPIW may have been formed locally in the Bering Sea. Furthermore our results demonstrate that LGM to Holocene eastern Bering Sea sea ice dynamics are in-phase with deglacial North Atlantic climate oscillations.

O-1190

## Sudden environmental changes recorded in Late Pleistocene loess-palaeosol sequences in Poland and western Ukraine

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### Abstract

Discovery of sudden short-term climate changes during the last glaciation in the Northern Atlantic sea sediments and Greenland ice cores caused enormous interest among Quaternary researchers. An extensive research program has been initiated to find proofs of abrupt climate changes in terrestrial archives of climate proxy data, in particular in Europe. Loess is an exceptional source of paleoclimate data, because its lithological and structural features constitute an indirect record of changing environmental and climatic conditions prevailing during deposition and early diagenesis.

Late Pleistocene loess covers in Poland and western part of Ukraine were created in the proximal part of the extraglacial zone of the Scandinavian Ice Sheet, particularly exposed to changes of the meridional thermal gradient. They contain a rich inventory of deformation structures associated with dynamic climatic conditions in the periglacial zone of the Pleistocene glaciations. Relatively large latitudinal extension (about 800 km) of the study area allows to verify previous hypotheses that the development of loess cover in Central Europe reflects contemporary and Pleistocene climate: continental in the east and more oceanic in the west. This affected the spatial and stratigraphic differentiation of periglacial phenomena. Because of the intermediate geographic position of this region they form a bridge for the loess research between the western and eastern Europe.

There are a few proxies indicating rapid environmental changes within loess-palaeosol sequences (LPS) of the study area (e.g. initial soil horizons, grain-size, geochemistry, environmental magnetism, periglacial phenomena) which are discussed. However, we mainly present the problem of ice-wedge pseudomorphs in LPS. There is no agreement on some crucial questions such as the number of ice-wedge cast horizons and paleoclimate interpretation of periglacial structures. The research results obtained to date indicate the occurrence of minimum three generations of ice-wedge pseudomorphs in the Late Pleistocene LPS in study area. They are a proof of threefold permafrost development and degradation phases.

The common occurrence and large size of the youngest generation of ice-wedge casts (upper Pleniglacial = MIS 2) indicate continuous permafrost in the central and eastern parts of the research area. However, ice-wedge casts in the western part of Polish loess area were probably developed within both continuous (northern part) and discontinuous permafrost (southern part). This record indicates a considerable climatic gradient between western and eastern parts of the investigated area as well as meridional changes of periglacial climate conditions during the last glacial period.

The research was performed under the National Science Centre project No. 2017/27/B/ST10/01854 entitled “Sudden COLD events of the Last Glacial in the central part of the European LOESS Belt - in Poland and in the western part of Ukraine (COLD LOESS)”.

O-1191

## The sources and transport pathways of loess in Eastern Europe and Russia: insights from detrital zircons

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### Abstract

Loess deposits contain exceptional information on the activity of past windblown dust sources. Constraining these dust sources is an essential step in understanding the complex feedbacks between dust and climate change in the past, and allows for better interpretation of loess climate and environment proxies such as grain-size and mass accumulation rate. However, deciphering source information rests upon the ability to discriminate the different sediment sources to loess, based on some intrinsic property of the material or constituent minerals (provenance indicator). Many such provenance indicators exist but in most loess areas the results from these methods often yield conflicting or ambiguous results. In recent years, considerable breakthroughs in understanding the provenance of Chinese loess deposits have been achieved through the use of single-grain provenance indicators, particularly through the use of detrital zircon U-Pb age dating. However, in European loess, comparatively little single-grain provenance work has been conducted to date, and the specific sources of loess in different parts of European loess belt are often poorly known. Here we report on new research that seeks to address this through detailed single-grain provenance analysis of loess deposits in Eastern Europe and Russia. Using initial new detrital zircon U-Pb age data from southern Poland, the Lower Volga River area of Russia and southern Hungary we show how the technique can be used to pinpoint specific dust sources of loess deposits in Europe, and examine their temporal changes. We also discuss the limitations of this approach and ambiguities over interpretation, as well as considerations regarding the number of grains analysed and statistical treatment. In general, the results demonstrate the importance of multiple dust sources and multi-step fluvial transport of silt material in European-Russian loess formation, but also highlight the possibility of highly dominant, localised mountain sources for some loess deposits. Finally, a perspective on future challenges in deciphering loess source in Europe is given, and suggestions presented for emphasis on multi provenance proxy studies.

O-1192

## Northern European Loess belt in Germany: Distribution, similarities and differences

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### Abstract

Pleistocene loess and loess derivatives are distributed along the mountain front of the Central European Mountain Belt in northern and central Germany. The geographical distribution of aeolian sediments is characterized and controlled by different topographical situations, tectonic settings, climate, the distance to large river systems, the distance to the Scandinavian ice sheet and the distance to the shelf of the North Sea. The distribution of loess shows an increasing elevation southwards whereas sandy loess displays a characteristic elevation below 200 m. A new loess map from Germany indicates that geomorphological features like mountain ranges, valleys and graben structures variously act as barriers or sinks for loess accumulation. These features and the distribution of the aeolian sediments as well as their potential source areas, allow conclusions about the paleogeographical conditions in Germany. Such conditions could have been suitable for Paleolithic hunter and gatherer communities. In addition, examples from two regions, the Lower Rhine Embayment (LRE) and the Northern foreland of the Harz Mountains (FHM) show differences in the development of the loess-paleosol sequences (LPS). In the more humid and oceanic LRE higher humidity enhanced the periglacial processes which increased erosion, but also led to preservation of the sediments in accumulative positions. In contrast, in the more continental FHM the sediments were affected by less intensive periglacial processes and not such strong solifluction features can be detected. Finally, a synthesis of typical sediment sequences for both regions is given as an example of paleoenvironmental (landscape) development in northern Central Europe.

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O-1193

## A new reference radiocarbon chronology for Last Glacial interstadials derived from earthworm calcite granules of the Nussloch loess sequence (Germany)

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### Abstract

The climate of the last glacial period is characterized by the occurrence of numerous centennial-to-millennial interstadials. Marine and lacustrine pollen records as well as isotopic speleothem records already benefit from precise chronologies based on radiocarbon and Uranium/Thorium dating methods, which were still lacking for loess sequences.

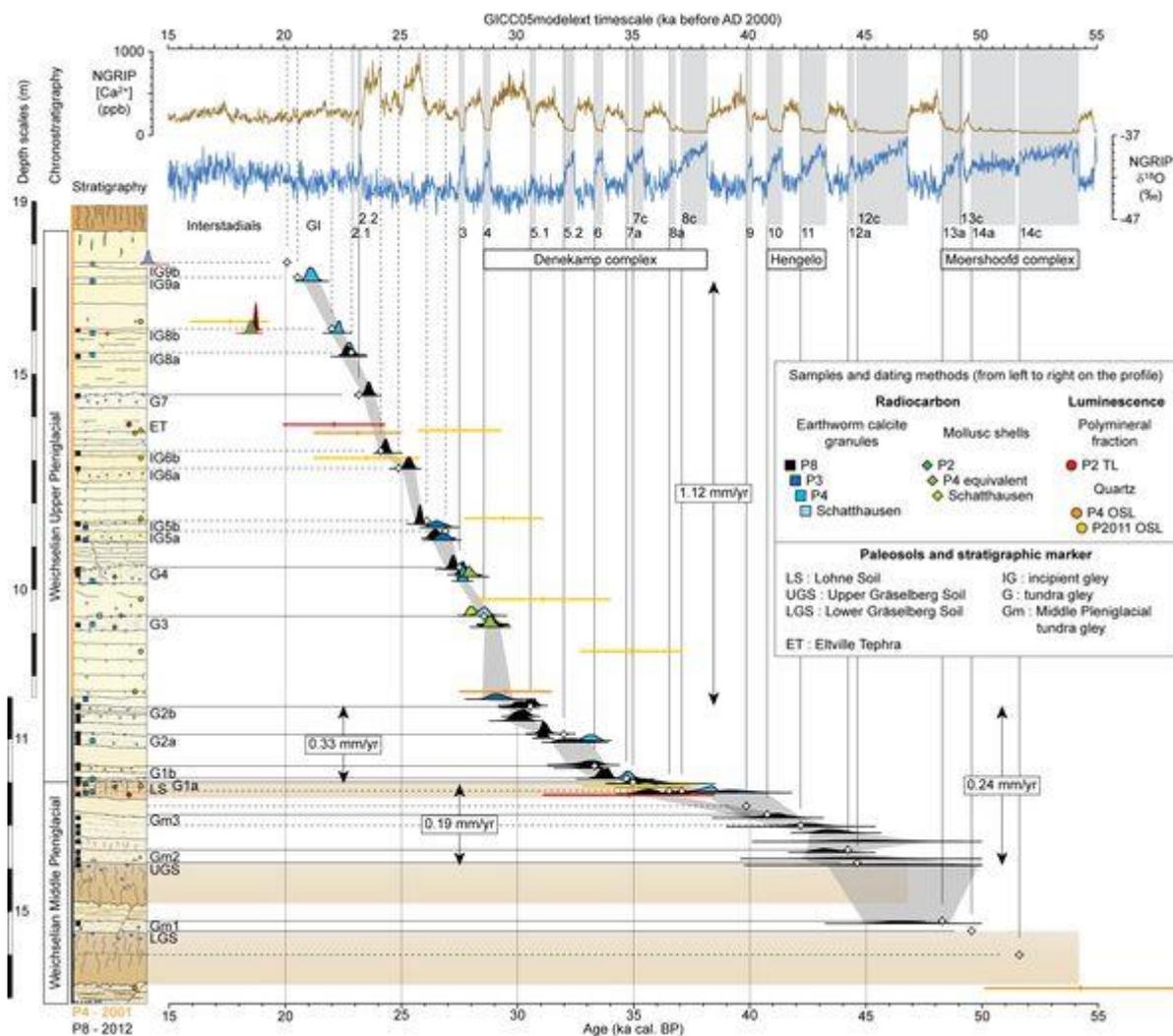
In Last Glacial loess sequences of the European Plain, typical loess units alternate with hydromorphic (tundra gleys) or pedogenic (arctic/boreal brown soils) horizons. Grain size analyses and molluscan communities respectively highlight decreased wind dynamics and higher humidity and temperatures during the formation of these horizons. Comparisons between loess grain size records and Greenland dust records led to correlate these two types of soil horizons with Greenland interstadials owing to their lower dust content compared to stadials. Nevertheless, luminescence-based chronologies were still not precise/accurate enough to define an undisputable correlation scheme.

Owing to the scarcity of organic remains (wood, charcoals and bones) in west-European loess, we developed an appropriate protocol to obtain radiocarbon ages from earthworm calcite granules. These granules, as well as terrestrial mollusc shells, are indeed present in large amounts in both types of soil horizons. This protocol has been tested on 46 samples taken from all soil horizons of the loess sequences of Nussloch (Rhine Valley, Germany), which present one of the most comprehensive records of the last glacial period in Western Europe.

The resulting chronology confirms the link between each tundra gley and arctic/boreal brown soil formed between 47 and 20 ka ago with a unique Greenland interstadial (Figure). Furthermore, we also dated minor cryogenic horizons formed between 27 and 20 ka characterized by changes in grain size and in the molluscan fauna composition comparable to those of the main soils. Despite the absence of synchronous oxygen isotopic excursions, they surprisingly correlate with dust concentration minimums in Greenland ice cores, and with changes in several other marine and continental proxy records. These results reflect the high sensibility of loess environment to climate changes and a more complex climate variability at mid-latitude than in Greenland during the Last Glacial Maximum (Moine *et al.*, 2017).

This new dating protocol thus led us expect precise correlations between distant loess sequences and, combined with other proxies, the mapping of palaeoenvironmental conditions associated with each interstadial phase across Europe for the Middle and Upper Weichselian.

**Moine O., Antoine P., Hatté C., Landais A., Mathieu J., Prud'homme C. & Rousseau D.-D. (2017) - The impact of Last Glacial climate variability in west-European loess revealed by radiocarbon dating of fossil earthworm granules. *PNAS*, 114 (24), 6209-6214. <https://doi.org/10.1073/pnas.1614751114>**



**Figure. Correlation of all soil horizons of the Nussloch loess sequence with their respective Greenland interstadials. Gray shading =  $2\sigma$  uncertainty ranges. Discarded ages are red-contoured.**

**O-1194**

## **Paleoclimate implications from grain-size analysis of loess/paleosol sequences from the Carpathian Basin**

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### **Abstract**

Great areas in the Carpathian Basin are covered by Quaternary eolian deposits, providing excellent archives for paleoclimatic and paleoenvironmental studies.

Detailed grain-size investigation of five loess-paleosol sequences (Süttő, Basaharc, Hévízgyörk, Villánykövesd, Beremend; Hungary) were carried out with sampling resolution of 2 cm. Time frame for the investigations were elaborated by luminescence (post-IR IRSL) and Amino Acid Racemization (AAR) dating.

The samples were only treated by 1% ammonium hydroxid, therefore they can be considered bulk samples. Test measurements were also carried out on samples which were also treated by HCl or H<sub>2</sub>SiF<sub>6</sub> in order to dissolve carbonates, or any other minerals but quartz, respectively. Grain-size distributions were determined using a Beckman-Coulter LS 13320 PIDS laser diffraction particle size analyzer, covering the range of 0.02-2000 µm, at the Leibniz Institute for Applied Geophysics (LIAG), in Hannover.

Clay- and sand content and U-ratio were calculated from the grain-size distribution of each sample and these values were plotted against the depth of the profiles. Comparing the variation of these values and trends, temporal and spatial changes could be concluded. Most of the individual grain size distribution curves were polimodal, therefore numerical partitioning using Weibull distribution can be applied to separate finer and coarser components of the curves. Changes in the relative proportions of these components throughout all sequences can be interpreted as temporal and spatial changes of the different transport mechanism. Limitations, practicability of the method, as well as results and their interpretation will be presented in this study.

Thanks to the Leibniz Institute for Applied Geophysics, Hannover for the grain size measurements and to the Hungarian NRDIO projects K119366 and 100315. This study was also funded by the ÚNKP-17-4 and ÚNKP-18-4 New National Excellence Program of the Ministry of Human Capacities.

O-1195

## Correlation of the loess-paleosol bassets in a short distance: reconstruction of the 350 ka development of Basaharc section, Hungary

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### Abstract

The loess-paleosol series at Basaharc superimposes the fluvial sediments of the II/b terrace of the Danube River in Northern Hungary (Gábris et al. 2012). The yard of the former brick factory exposes different parts of this series in different paleogeomorphologic positions and development. The identification and correlation of the paleosols is especially important because here are the type sections of two of the three paleosols Basaharc Double (BD<sub>1-2</sub>) and Basaharc Lower (BA) (Horváth - Bradák 2014).

The complex and multiproxy investigation was carried out in the last years including descriptions of new profiles, detailed and systematic sampling for granulometry, for secondary carbonate and for stable isotope investigation. Macro-, meso- and micromorphology of the paleosols, diffuse reflectance spectroscopy, magnetic susceptibility, luminescence and radiocarbon dating, amino acid stratigraphy were used in order to make a clear identification of the different units. The statistical analyses of the results and the precise determination of the elevation and gradient of the paleosols from different outcrops provide a complex understanding of the environmental development of the last 350 ka at Basaharc.

The existence of the characteristic BD<sub>1-2</sub> paleosols has been refuted by some new studies of the Basaharc profile (Sümegei et al. 2011). Denying the existence of this pedocomplex would seriously influence the loess lithostratigraphy of Hungary. The western wall of the quarry is a very significant part because the whole loess-paleosol succession could be identified with all paleosols. The first correlations of the new profiles with the type section of BD already provided striking results. The MS curve and the pedogenic character of the macroscopically similar paleosol showed high degree of similarity. The other proxies and the absolute ages also support the correlation of the loess and paleosol units located in distinct parts of the quarry. Thus, the BD<sub>1-2</sub> obviously exists and it can be applied further as a lithostratigraphical marker of the Hungarian loess stratigraphy. The multiproxy analyses allow the correlation among the bassets based on the identification of the isochronous heterotype of MF, BD and BA paleosols.

Research was funded by the Hungarian NRDIO K119366 project.

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O-1196

## The spatial differentiation of chemical composition of the Late Pleistocene loess-palaeosol sequences in Poland

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### Abstract

Loess-palaeosol sequences (LPSs) in Poland, because of transitional localisation in central part of Northern European Loess Belt, spatially differ in their characteristics from the west to the east. It is confirmed by different loess properties. However, little attention was paid to the geochemistry.

Concentrations of major elements in six Late Pleistocene LPSs across Poland (Biały Kościół, Dankowice, Skarszyn, Złota, Tyszowce and Strzyżów) were studied using unified AAS method (pre-processed by lithium borate fusion). All studied sequences are characterized by uneven distribution of major elements (Si, Al, Fe, Ca, Na, Mg, K, Ti and P) and geochemical indexes values (CIA - Chemical Index of Alteration, ICV - Index of Chemical Variability, Mg/Ca, K/Ca, Na/K, K/Al, Si/Al, Ti/Al, etc.) in the vertical sequences, clearly referring to palaeoclimatic conditions which control the intensity of pedogenesis. That variability is clearly visible on UCC-normalized spider-diagrams.

The most interesting are the differences in chemical characteristics between eastern and western Poland. That variability may be summarized e.g. by the CIA index, which is one of the most commonly used indicators for the reconstruction of palaeoclimatic and palaeoenvironmental conditions during the formation of LPSs. It is assumed that the CIA in the range of 50–65 corresponds to weak chemical weathering under a cold and dry climate, and the values 65–85 represent warm and moist palaeoclimatic conditions.

The results reveal that the western LPSs are much more chemically weathered and more abundant in elements commonly associated with weathering and soil processes in comparison with LPSs of eastern Poland. In western profiles, both for loess and pedocomplexes, CIA reaches values typical for moderate weathering in relatively warm and humid climate (for example in Biały Kościół the range is from 63.3 to 82.6). In eastern LPSs there is clear distinction between younger loess and older parts of the profiles. For example, in Tyszowce the S0 soil and the majority of the L1LL1 loess (up to 13.5 m in depth) were classified as weakly chemically weathered. The rest of the profile shows a similar, relatively high degree of chemical weathering (reaching a maximum value above 70 in L1SS1).

The spatial variability may be attributed to different climatic conditions during the deposition of loess, loess recycling process, different source areas or even disproportion between the thickness of the loess covers.

To explain that problem, the second stage of research began - the analysis of the major and trace elements is conducting exactly right now. The research of trace elements is performed under the National Science Centre project No. 2017/27/N/ST10/01208.

**O-1197**

## **Digital data collection methods applied to Quaternary Sediments mapping in Ireland**

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### **Abstract**

Quaternary geological mapping field record descriptions have been traditionally collected with field notebooks and field maps often eschewing standardized field record descriptions. Technological developments during the last decades have allowed the incorporation of Global Positioning System data and enabled deployment of ruggedized field computers for field mapping. Several geology mapping software tools have been developed during the last decade and are currently used by Geological Surveys, mapping agencies and industry, with software often developed for, or tailored to, the organization's needs. The increased computational capacity of tablet computers and the migration of GIS software from desktop/laptop programme to ubiquitous tablet app have further streamlined the process of data gathering.

Historically the mapping of Quaternary features by geological surveys was presented as a map which focused the interpretation of field and desk-compilation data. Under this paradigm, the data underlying the interpretation was often retained in an ad hoc manner. The inaccessibility of these data restricted the ability of other users to develop alternative interpretations. In contrast with the former situation, field data gathered during current mapping campaigns is often a companion product to the map interpretation. Central to a useful field-data product is the use of standardised data collection protocols and forms in the mapping process. These, sometimes large, datasets can be easily manipulated using database query language or incorporated into conventional GIS software for visualisation and analysis.

The Geological Mapping Programme of the Geological Survey of Ireland has been developing, since 2014, a tablet computer GIS based field-data collection tool dedicated to mapping Quaternary deposits and landforms. Offline basemaps including, topographic and cadastral datasets, aerial photography, desk-compilation data and Digital Elevation Maps (DEMs) are produced for the area of interest and loaded to the computer tablet in advance of the field campaign. These datasets provide useful contextual information to the field geologist. Field records are collected via map and form-centric data gathering GIS apps. Geomorphological, mass-movement and groundwater features are collected using a map-centric application allowing for features delineation. Quaternary sediments exposures and borehole logs including descriptions of photographs, logs of individual layers, erratics, periglacial features, and samples are gathered with a form-centric relational database enabled app. This data is collected for every field site, and synchronized daily with other field geologists working in the area. This field data collection approach allows for the collection of standardized field descriptions, de-risks data security issues, reduces data processing time, enables data quality control during the field campaign and facilitates data interpretation, map unit delineation and reporting.

O-1198

## Leaving its mark; diverse Quaternary records abound in new geological survey mapping of the UK seabed.

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### Abstract

The usage of remotely-sensed acoustic data (e.g. multibeam echo-sounder [MBES] bathymetry, and CHIRP sub-bottom profiler) have become common, and still powerful tools in characterising submarine records of the Quaternary environmental change. For example, geomorphological assessment of extensive high-resolution bathymetry datasets has led to paradigm shifts in our understanding of the style, configuration, and relative timing of former glaciation around NW Europe. Simultaneously, large volumes of data have driven scientists to explore alternative approaches to characterising the seabed to improve mapping efficiency, but also accuracy, with a better measure of map uncertainty. The British Geological Survey (BGS) is using a range of publicly available bathymetry and backscatter data to provide baseline geospatial mapping of the seafloor to underpin original research, resource development (e.g. offshore renewables), and marine-spatial-planning (better-informed management of the seabed environment). To undertake the geomorphological mapping, BGS scientists are developing and adapting semi-automated approaches to detect, delimit, and classify geomorphological features, importantly including basic morphological description. Within a large case-study area off the east coast of Orkney, a method based on the unsupervised clustering of bathymetric derivatives (e.g. bathymetric lows vs. highs) at multiple spatial scales is very effective at efficiently mapping current-induced bedforms, ice-marginal moraines, and larger glacial landforms. A further case-study area off the west coast of Anglesey is testing how including categorical co-variables (like Quaternary geomorphology – e.g. drumlins) affect the power of geostatistical and machine-learning models in predicting seabed sediment and habitat distribution. The continued development and improvement of further quantitative mapping approaches is certain (e.g. learning algorithms), but agencies like the BGS also have a pragmatic remit to actively produce maps. The BGS is therefore concentrated on producing consistent geospatial products using novel semi-automated approaches, that importantly, also prove effective when applying across multiple, diverse submarine environments.

O-1199

## Geomorphological mapping and analysis of topography using digital elevation models and their implications to Quaternary sciences

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### Abstract

Digital elevation models (DEMs) are one of the most widely used raster GIS data. They are acquired using surveying or geospatial methods and represent terrain characteristics with various spatial resolutions. Although almost all DEMs represent topography at present or in the very recent past, geomorphological mapping and analysis based on them may provide implications to Quaternary sciences which deal with long-term processes and environments in the past. We present three examples of such research conducted in Japan. The first case is topographic representation using shaded-relief maps from a 50-m DEM for a steep mountainous area in central Japan. The result indicates the presence of an unknown active fault displacing both hillslopes and small river terraces in a V-shaped valley. Terrace ages and the amount of displacement by the fault suggest a high rate of tectonic activity since ca. 50 ka. The discovery of the fault also led to a revision of glacial chronology in the area since the Middle Pleistocene, because previous studies mistook the fault scarp for a terrace scarp. The second case is an application of a 10-cm DEM obtained with terrestrial laser scanning for a coastal valley in northeast Japan. This valley was severely affected by the huge tsunami caused by the 2011 earthquake off the Pacific coast of Tohoku. The high-resolution data enabled us to detect small cliffs along the valley-side slopes, and their distribution tends to correspond to the highest inundation by the 2011 tsunami. Knowledge about regional tectonics and sea level change implies that the small cliffs were formed due to repeated wave erosion by some 100 large tsunamis since the mid-Holocene. The third case is research on a Middle Pleistocene marine terrace in northeast Japan using a 20-cm DEM obtained by SfM-MVS (structure from motion - multi view stereo) photogrammetry applied to drone photographs. The detailed topographic representation using the DEM and field surveys revealed geomorphological and sedimentological processes on the marine terrace surface induced by past large tsunamis. These examples indicate that DEMs become useful for Quaternary sciences when knowledge about paleoenvironments is appropriately introduced for effective and multidisciplinary interpretation of topography.

O-1200

## Simplifying GPR interpretations of coastal geomorphology using an image segmentation approach

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### Abstract

During the last two decades, Ground-Penetrating Radar (GPR) methods have grown in popularity for acquiring high-resolution images of the buried stratigraphy and internal structure of geomorphologic features (Switzer *et al.* 2010). GPR provides a complement to established techniques, including sediment core-logging and in-field mapping of exposures which provide sparse 2D insight into the architecture of a study area. In geomorphological settings, GPR surveys have been used alongside core sampling where they typically link transects of boreholes but cannot reveal the full morphology of a site. A more comprehensive GPR survey can expand this insight into 3D, offering rapid, non-invasive characterisation of the shallow surface (~10 m maximum depth), with data interpretable in terms of the thickness, lithology, structure and extent of subsurface depositional environments (e.g. coastal, aeolian and deltaic deposits).

However, for all these advantages, GPR data interpretation can be non-intuitive: the technique seldom gives images that immediately resemble the expected subsurface geometry. Interpretations can be especially challenging when handling the large 3D data volumes that are commonly available with modern GPR technology. Most GPR analysis approaches rely on a manual processing, which can be laborious and subjective (Tronicke and Allroggen, 2015). Approaches involving automation are therefore attractive, but current approaches can be computationally intensive and have yet to be optimized for the full suite of typical GPR responses (Dou *et al.* 2017). In this paper, we outline the first steps toward the development of a user-friendly, automated GPR analysis tool that utilizes the image processing techniques *Edge Detection* and *Thresholding*. Developed initially for medical image analysis, we investigate them as a means of assisting the analysis of GPR data for subsurface geomorphic features. By segmenting and extracting the primary reflections of interest, such algorithms provide a first-pass appraisal of the structure of a site.

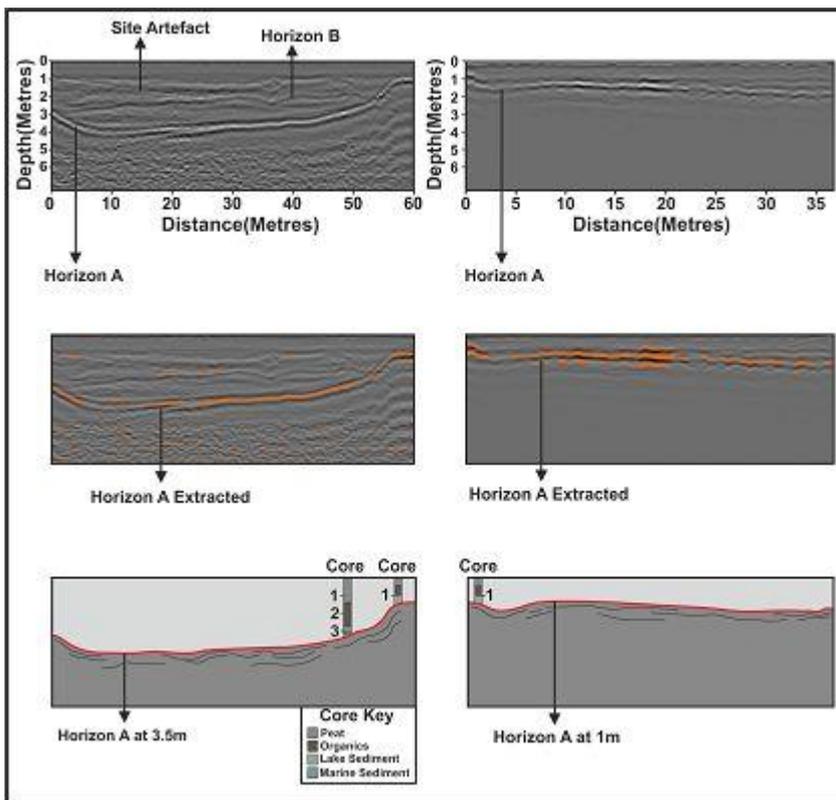
Here, we present the results of the segmentation algorithm applied to a coastal geomorphic GPR dataset. The algorithm is capable of rapidly delineating reflections from lithological layers and buried sedimentary structures (Fig. 1), hence it offers a useful tool for the GPR user to appraise the content of their GPR dataset.

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**Figure 1:** Example of GPR data collected in a coastal environment. The automated analysis algorithm has been applied and reflections of interest have been extracted.

O-1201

## Geological heterogeneity, impeded groundwater drainage and enhanced meltwater erosion in the formation of Stargard drumlin field, NW Poland

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### Abstract

Drumlins are landforms vital to our understanding of ice sheet movement over soft beds, sediment transport along the ice/bed interface, and the formation of a wide range of glacial deposits. Although investigated more than any other glacial landform, the origin of drumlins remains contentious leaving some fundamental questions of the interactions between ice sheets and their beds open. The Stargard drumlin field is one of the biggest drumlin fields in the North European Lowland - it consists of over 1300 drumlins and related streamlined bedforms nested in the terminal part of a major Weichselian palaeo-ice stream. The drumlins are typically 600-800 m long, 200-250 m wide, 3-6 m high and have elongation ratios of mostly around 2. Several morphometric subzones in the drumlin field are distinguished reflecting different ice flow dynamics. The Stargard drumlins are composed of a great variety of glacial deposits including various types of tills and meltwater sediments, which are either undisturbed or heavily deformed. The spatial characteristics of the drumlins are unrelated to the drumlin deposits and drumlin surfaces often truncate these deposits suggesting that the drumlin shaping post-dates the deposits inside the drumlins.

Numerical modelling of subglacial groundwater flow during the drumlin-forming ice advance shows a total re-organization of groundwater dynamics to a depth of up to ~200 m. A mosaic of intervening groundwater recharge and discharge areas originates whereby some areas experience multiple shifts in groundwater flow directions. A prominent time- and space-transgressive pressure pump recharges groundwater in a subglacial zone up to about 20 km within the ice margin and releases it in front of the ice sheet. Simulations suggest that the drumlins occur preferentially where groundwater upwells and discharges at the ice/bed interface.

The proposed drumlin-forming mechanism involves an excess of pressurized water at the ice/bed interface. The drumlin field was likely generated by some combination of direct glacial erosion and turbulent subglacial meltwater erosion removing antecedent material from the inter-drumlin areas and streamlining the resultant bumps. Our data yield support to the quest for a unifying theory of drumlin formation and suggest erosion as the most plausible single mechanism generating drumlin landscapes, which also explains the enigmatic diversity of drumlin deposits and the frequent lack of obvious deposit/landform relationships.

O-1202

## Erosional origin of sediment-cored drumlins and megascale glacial lineations: upper tills as thickened erodent layers

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### Abstract

The origin of drumlins is widely studied but not well understood because modern formative processes are hidden under ice and where exposed the geology of their cores is highly variable. Urban construction activity and aggregate mining across Late Wisconsin drumlins and megascale glacial lineations (MSGs) near Peterborough, Ontario, shows that they are streamlined remnants of antecedent bouldery till and (mid-Wisconsin?) proximal outwash. Cores are capped erosively by a thin (< 2 m) cap of 'upper till' formed by deformation and re-transport of antecedent sediment. The deforming till bed acted as a thin 'erodent layer' preferentially removing sediment from poorly-drained swales and flowing around stiffer, better-drained remnant drumlin highs. A bedform continuum of megadrumlins, drumlins, 'grooved' or 'cleaved' multi-crested drumlins and MSGs is evident on high-resolution LiDAR imagery and records progressive elimination of higher-standing drumlins by a faster-flowing channeled erodent layer below a developing ice stream during deglaciation.

The geological variety of drumlin cores in areas of Pleistocene glaciation has hitherto retarded development of a single formative model but the necessary conditions for erosion of many millions of genetically-related 'remnant' drumlins and MSGs with a thin upper till draped erosively over cores of widely varying antecedent sediment types (and rock) were satisfied over large parts of the glaciated mid-latitudes in North America and Europe as consequence of ice standstill and/or withdrawal and widespread proglacial sedimentation during the mid-Wisconsin. Expansion of ice sheets after 30,000 ybp resulted in overriding and subglacial re-transport of sediment and re-deposition as thick till sheets that were subsequently streamlined into drumlins that in turn, were re-fashioned into MSGs in areas of fast ice flow. Laboratory experiments on surfaces in frictional contact and observations of the surface morphology of fault planes of increasing net slip show the evolution of erosion surfaces from elongate bumps (i.e., drumlins) to geometrically simple surfaces characterized by long striations and grooves (i.e., MSGs) to reduce friction and aid movement of wear debris (i.e. deforming till) . Ice sheet beds are essentially continental-scale faults that evolve through time in a predictable manner.

O-1204

## Climate changes at Matuyama-Brunhes boundary as reconstructed from the Račiška pečina cave flowstones (SW Slovenia)

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### Abstract

Račiška pečina is a relict cave located in the Matarsko Podolje (SW Slovenia), a part of the Classical Karst massif. Unique series of sediments composed of interbedded flowstones and red clastic sediments have been preserved in the main cave passage. The studied sediment section is about 13 m long with the cumulative thickness nearly 6.5 m. Detailed paleomagnetic studies, combined with mammalian zoopaleontology and some numerical dating, allow to estimate the start of flowstone deposition on over 3.4 Ma and the termination at ca 6 ka, i.e. from early Pliocene to Holocene, with some hiatuses. Reddish light brown flowstone, ca 23.5 cm thick, was collected from the upper part of the section. The boundary of Matuyama and Brunhes Chrons (M/B) was found there at the depth of ca 17.5 cm.

Speleothems are valuable source of information on environment condition in the past. Calcite stable isotopes (O and C) composition, calcite fabrics as well as trace elements content provide data on depositional conditions of speleothems, including mean annual temperature, precipitation intensity, water drip intensity in the cave, water flow character or the amount of allogenic material supplied to the cave.

Most of studied flowstone is built of calcite micro-facies similar to dendritic fabric with characteristic high porosity, significant content of detrital material and V-shaped appearance of branching polycrystals. The most significant changes were related to the M/B boundary zone, where dendritic open fabric changed to columnar microcrystalline one (with the highest calcite crystals purity throughout the analyzed flowstone) on a relatively short distance. Other transitions are less noticeable.

Oxygen isotopic composition ( $\delta^{18}\text{O}$ ) of analyzed flowstone changes within the range of 3 ‰ (from -4.5 to -7.5 ‰). Characteristic rapid and short-lasting decrease in the  $\delta^{18}\text{O}$  value (ca.  $\sim 1$  ‰) was observed at the M/B transition. Carbon isotopic composition ( $\delta^{13}\text{C}$ ) changes within similar range ( $\sim 2.7$  ‰) from -8.3 ‰ to -11 ‰. The  $\delta^{13}\text{C}$  values drop of  $\sim 1$  ‰ at the M/B transition, i.e. similar to the oxygen isotopic record. Isotopic record was correlated with other proxies from studied flowstone section, i.e. trace elements relative content or magnetic susceptibility. All proxies have indicated clear change of paleoenvironmental conditions at the M/B boundary, namely higher amount of precipitation and decline in mean annual air temperature.

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O-1205

## A Holocene multi-proxy speleothem palaeoclimate record from Iraqi-Kurdistan

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### Abstract

A number of factors make the eastern Fertile Crescent (present day north-east Iraq) inherently suitable and attractive for palaeoclimatic investigations. Firstly, it is located at the transition zone between two major climate regimes, North Atlantic Westerlies and the Indian Summer Monsoon system, making it especially susceptible to shifts in climate. Secondly, it has a long and rich history of human occupation throughout the Holocene, making it ideal for the investigation of human-environmental relationships. Thirdly, the Fertile Crescent has been identified as a climate change 'hotspot' and palaeoclimate reconstructions can help to place modern climate into a meaningful perspective. The production of high resolution palaeoclimate records can therefore be used to test model simulations to help predict future shifts in climate, particularly changes in water availability. However, no well dated, highly resolved and long Holocene records currently exist covering the eastern Fertile Crescent.

Here we present the first high resolution multi-proxy speleothem palaeoclimate record covering the entire Holocene from northeast Iraq in an attempt to identify and investigate the presence and magnitude of Holocene climate variability. The stalagmite (SHC-03) is 3.17m long and was collected from Shalaih Cave, Iraqi Kurdistan. It is sampled at a ~5-10 yr resolution and covers the last ~10,300 years. We use a multi-proxy approach through the use of oxygen ( $\delta^{18}\text{O}$ ) and carbon ( $\delta^{13}\text{C}$ ) isotopes and trace element (Mg/Ca and Sr/Ca) analysis.

There is a strong link between the long-term changes in the SHC-03  $\delta^{18}\text{O}$  profile and changes in the  $\delta^{18}\text{O}$  of the Eastern Mediterranean Sea, implying a strong 'source effect'. Changes in the  $\delta^{18}\text{O}$  of the Eastern Mediterranean Sea during the Holocene are controlled by the amount of freshwater outflow from the River Nile related to monsoon intensity. As a result, we propose some caution should be taken when interpreting  $\delta^{18}\text{O}$  from the Eastern Mediterranean paleoclimate records as a proxy for rainfall amount.

Overall our data (including  $\delta^{13}\text{C}$ , trace element concentrations and  $\delta^{18}\text{O}$  (on shorter timescales)) provide an important understanding of variations in effective moisture throughout the Holocene as well as the environmental context for significant archaeological developments that occur during this period in this region.

O-1206

## Control of climate characteristics on accumulation of pedogenic carbonate: observations and modeling

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### Abstract

Calcic soil is one of the most widespread aridic soil groups, covering an estimated area of  $10^6$  km<sup>2</sup> in arid to semi-arid regions worldwide. Calcic horizons form through airborne supply of calcium to the soil surface with dust and rainfall, leaching of carbonate from the surface and upper horizons of the soil, and subsequent precipitation and accumulation of carbonate in lower soil horizons at a depth controlled by soil moisture and texture. In general, climatic control on soil carbonate accumulation is known for decades: depth of calcic horizon increases with increasing mean annual precipitation (MAP). This relationship is being used to estimate Quaternary (and older) MAP from buried soils. However, the effects of other climate characteristics, mainly intra-annual rainfall properties and evapotranspiration (ET), on pedogenic carbonate accumulation were rarely examined in the past. Although mostly overlooked as a controlling factor, previous preliminary qualitative results suggest that rainfall seasonality might be important in controlling the distribution and depth of calcic horizons. In this study we examine the importance of intra-annual rainfall properties in controlling the distribution of soil carbonate using two approaches: 1) Meta-analysis of hundreds profiles of soil carbonate from two arid and semi-arid regions: Israel, in which rainfall occurs only during winter, and from south-western US, in which summer rains prevail in addition to winter rains. 2) Modeling long-term soil water distribution and wetting depths, and examining how rainfall properties, such as daily rainfall, rainfall event duration and number of rainfall events, control the wetting depths (served as a proxy for pedogenic carbonate accumulation). The results of the meta-analysis reveal that 1) soil carbonate content in Israel is higher (<40%) comparing the American soils (<20%), probably due to the presence of carbonate-rich bedrock in Israel; 2) For a given MAP range, areas with higher percentage of winter rainfall exhibit lower soil carbonate content and deeper calcic horizons, comparing regions with more pronounced summer rains. This is probably due to the fact that for winter rainfall, water arrives when cool (greater CO<sub>2</sub> solubility) and less ET demand, thus water reach deeper depths, while for summer rainfall, water arrives when hot (lower CO<sub>2</sub> solubility) and most water is contributed to ET, thus shallower carbonate accumulation is observed. Our modeling results suggest that for a constant MAP, varying rainfall properties can greatly influence the depth of pedogenic carbonate accumulation. Thus, both observations and modeling results call for cautious in estimating MAP from buried calcic soils as additional rainfall properties can greatly affect the distribution of calcic horizons.

O-1207

## Farmed calcite $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ at Ascunsă Cave (Romania) and its relation with cave ventilation and drip rate

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### Abstract

During calcite precipitation in caves, its carbon and oxygen stable isotope signature could be modified by the ventilation regime of the cave (namely the  $\text{PCO}_2$  gradient between drip water and cave atmosphere) and drip rate. Here, we present measurements of these parameters within Ascunsă Cave (Romania), where they were determined following the methods described in Drăgușin et al. (2017), at the growth sites of neighbouring stalagmites POM2 and POM X.

Since early 2015, drip water  $\text{PCO}_2$  was always higher than in the atmosphere. At the POM2 monitoring site, the highest value was 0.007 atm, whereas the highest atmosphere value was 0.003 atm. Over the monitored period, the average  $\text{PCO}_2$  difference between drip water and cave atmosphere was 0.004 atm. At the same time, average drip rate was 15 drips/min, but experienced an extended baseline period between July 2017 and March 2018, at  $\sim 2$  drips/min.

To gain more insight into cave ventilation processes Radonova Radtrack<sup>2</sup> radon detectors were used to measure Rn concentrations in cave air and water-air equilibrators. Drip water has a much higher Rn concentration than the cave air. Between May and August 2018, cave air had a concentration of 3700 Bqm<sup>-3</sup>, whereas inside the equilibrator we found 27000 Bqm<sup>-3</sup>. Such a large difference was also seen between August and October 2018, with 2600 Bqm<sup>-3</sup> and 15400 Bqm<sup>-3</sup>, respectively.

Whereas in Drăgușin et al. (2017) we observed a good correlation between farmed calcite stable isotopes and a theoretical degassing gradient possibly produced by cave ventilation, here we discuss for the first time the relationship between measured stable isotope values and cave ventilation as revealed by direct observations. These insights will help us better understand Holocene stable isotope time series from these two stalagmites.

### Acknowledgements

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O-1208

## Quaternary thermophilous land snails: early climate change “immigrants” during interglacial periods in Northern France ?

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### Abstract

Quaternary climatic cycles have had a strong effect on species distributions in general and on continental mollusc expansion in particular. During glacial periods most non-marine molluscs vanished from North-Western Europe but during interglacial episodes, they progressively spread from refugia to recolonise these once periglacial territories. Interglacial malacofaunas thus provide a good proxy for evaluating biogeographical and biodiversity changes during the Pleistocene. Calcareous tufas are key-deposits for both malacological successions and palaeoclimatic reconstructions of Interglacials since they are characteristic deposits of temperate periods, favourable to shell preservation and resulting of calcite precipitation from meteoric water. In Northern France, several calcareous tufas have yielded rich molluscan successions allowing the reconstruction of faunal history for three interglacial periods from the Middle Pleistocene to the Holocene. Specific assemblages of land and aquatic snails, including several species that are now extinct or beyond their modern range, can be recognised for each temperate episode. Detailed Middle Pleistocene malacological successions described from two thick tufa sequences, respectively dated to MIS 11 (424-374 ka) and MIS 5e (~125 ka) show common features in the malacological recolonisation. At both sites, the appearance of forest species occurs as successive events related to the present-day geographical ranges of the component species. Those of the earliest forest phase at the beginning of the interglacial consist of species with North and West European ranges. Species with Central European distributions appear just before the warmest phase, whereas Eastern and Southern European species appear only later during the optimum itself. Similar successive arrival of forest land snails are registered during the Holocene but lacks the eastern and southernmost faunal elements. The very same sequences have been investigated for variations in the  $\delta^{18}\text{O}$  and the  $\delta^{13}\text{C}$  of tufa calcite to reconstruct changes in regional air temperature and rainfall amount. Geochemical data highlights the similarities and differences between the studied interglacials. While warm and wet optima are clearly identified during MIS 11 and MIS 5e, Holocene records show a distinct pattern. Diachronic comparisons show similar to slightly warmer conditions during MIS 5e compared to the Holocene, while MIS 11 interglacial appears clearly warmer. Both MIS 5e and MIS 11 were wetter than the Holocene, especially when comparing optima. In terms of amplitude, ambient moisture recorded during MIS5e shows little variations compared to MIS 11 and the Holocene. These differences have affected continental species distribution revealed in mollusc expansion and diversity.

O-1209

## The late-Holocene tufa decline in Europe: myth or reality?

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### Abstract

In 1993, Goudie and co-authors named the postulate that there would be a marked decline in the deposition of calcareous tufa in Europe since c. 2500 BP 'the late-Holocene tufa decline'. The concept got a certain success in the community of researchers working on travertines and tufas and the paper has been then extensively and regularly cited. However, its main topic was actually not to demonstrate the existence of such a decline but to discuss the role of various natural and anthropogenic changes that may have affected tufas; the authors themselves wrote: "In many parts of Europe there appears to be evidence for a decline in tufa deposition rates since the mid-Holocene. However, the veracity of this trend needs to be investigated further". Nevertheless, the 'late-Holocene tufa decline' rapidly became nearly a paradigm and then, most discussions have concentrated on its causes and mechanisms or, in the case of long Holocene sequences including recent to modern tufa depositions, on the reasons justifying the absence of a such decline. Parallel, it was also debated by authors showing that active tufa deposition were considerably underreporting; an observation that in turn suggests that the same has occurred for fossil sites.

In the last decades, the growing development of investigation on calcareous tufas in Europe and considerable improvement in dating methods, especially radiocarbon dating, have provided reliable evidence of deposits developing until our present days. Including relative dating (through bio-stratigraphy), we here discuss the reality of the 'late-Holocene tufa decline' and distinguish various cases depending on tufa types and size, and geographical settings. We show that a decline is systematically observed in riverine tufa deposits but not when (slope or mire) spring-fed tufas are considered, which emphasises the variety and complexity of involved mechanisms. Such a clarification thus appears mandatory prior discussions on the (climatic or anthropogenic?) causes of such a decline.

O-1210

## Facies characterisation of Quaternary spring-related stromatolite build-ups discovered in the Tunceli Region (East, Turkey)

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### Abstract

Systematic relationship between Quaternary stromatolite facies and their C and O isotopic composition are used to mark changes in environment conditions with regard to vent location in the Tunceli region carbonate factory. The study area consists of various facies developed from pool to barrage, and towards high gradient slope environment as follows: subaerial stromatolite, domal oncoidal stromatolite (DOS) interfingering with phyto boundstone of moss-stems, domal non-oncoidal stromatolite (DNOS), wavy laminated stromatolite (WLS), respectively. WLS and DNOS facies form upward from the bottom of slope environment, respectively. The WLS comprises of a regular alternation of sparitic dendrite to arbustiform shrubs fabric with micritic chrinomoid larval laminae; whereas, the DNOS facies consists of entirely radial palisade shrubs fabric. DOS facies, formed in a slope environment, possesses the alternating fan-shaped sparitic dendrite shrubs and thin micrite laminae. The latter facies, occurred in a barrage environment, contains a nucleus with tree trunk or phytoclasts interfingering with lime muds and a crust with chironomid larvae laminae, surrounded by sparitic dendrite shrubs and calcite spherulites. Subaerial stromatolite facies in the pool environment has a cross-bedded alternation of calcrete laminar crust containing microcodium and extraclasts, and massive peloidal micrite, with vaterite spherulites growing within lime muds, in shallow, high energy environments. Phyto boundstone composed of the stacked moss layers with rhombohedral calcites, which clumped around the eroded microbial filaments, along with oviform bacteria living in EPS in the barrages to pools environment where alluvial conglomerates wedge to the DOS facies. Etching with Hydrochloric acid revealed many microbial communities between shrub branches in the DNOS facies, besides released abundant detrital clays in the DOS facies. These communities consist of microcolonial fungi, oviform- or tabular-shaped heterotrophic bacteria and cyanobacteria filaments. The latter filaments are accompanied by clumped peloids growing in subaerial biofilm.

The  $\delta^{13}\text{C}$  values display a wide distribution stretching from +0.57‰ to +5.84‰; whereas, the  $\delta^{18}\text{O}$  has a narrow range of -9 ‰ to -11‰. The  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  signatures become heavier and much lighter, respectively, from the pool environment with subaerial stromatolite facies towards the barrage environment with the DOS and phyto boundstone facies. Moreover, the  $\delta^{18}\text{O}$  values decreases gradually, while the  $\delta^{13}\text{C}$  values remain stable from DNOS and DOS facies in the slope environment towards DOS with abundant chrinomoid larval laminae, formed in the barrage environment. These values correlate well with the observed facies and environment variations and create an inversed-L trend indicating (i) high discharge from a vent issuing closer to slope environment and (ii) an increase of  $\text{CO}_2$  degassing and precipitation temperature. These results are reported for the first time and indicate biotic-induced and spring-related carbonate build-ups, developed locally along NW-striking dextral strike-slip faults in the East Anatolian Plate of Turkey.

O-1211

## New findings from old chronologies: Establishing best practices for large workflows using Neotoma

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### Abstract

The Neotoma Paleoecology Database (<http://neotomadb.org>) contains 32,000 unique datasets representing 266,000 individual physical samples and 5.3 million unique observations. Sample ages in Neotoma are related to one (or several) of the 18,000 chronologies in the database that are modeled, based on a range of chronological controls that are calibrated using various calibration models, and reported with varying degrees of accuracy. A strength of the Neotoma Database is that, in most cases, the raw data associated with these chronologies is preserved, allowing users to re-build chronologies as new methods become available, or reassess individual dated elements as new evidence becomes available.

Recent efforts to understand biological change in the northeastern United States provided an opportunity to investigate the artifacts that these varied chronologies may have on interpretations of change in the region at an aggregate scale. This presentation highlights the workflow required to undertake such an effort and several key findings. In particular we highlight treatments for missing 210Pb uncertainty estimates. We show that newer chronologies that account for artifacts of methods and data within Neotoma show higher rates of turnover in the post-settlement period, and we present new methods for dealing with broad-scale uncertainty and variability among chronologies.

This work has been developed in close collaboration with Neotoma, and resulted in an open workflow for undertaking similar efforts globally (<https://github.com/neotomadb/bulk-baconizing>). We highlight both the findings, and the utility of community data repositories in making these findings available and reusable for the entire paleoecology community.

O-1212

## A database for annually laminated lacustrine climate archives

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### Abstract

Annually laminated (varved) lake sediments provide a unique opportunity to investigate causes and effects of past climate change on seasonal to millennial time scales. So far, most studies focused on individual records and a synthesis of varved lake records is still lacking. However, precise synchronization of such sediment records remains the main challenge to re-evaluate pre-existing records in a comprehensive synthesis and to evaluate different proxy responses to climate change. We generated a database for high-resolution climate proxies obtained from varved lake archives. It currently comprises of 150 climate proxy records (e.g. varve thickness, element composition and stable isotopes) from 55 varved lake archives, ranging in length from 41 to 47000 years. Based on varve thickness and counting, we provide estimates of sedimentation rates to modify existing age models. In combination with published <sup>14</sup>C dates, these improved estimates are used for Bayesian age-depth modeling to quantify age uncertainties. The refined age models were synchronized using event layers (e.g. tephra layers) if available. All records and refined age-depth models are standardized and stored in a graph database that allows fast access for Big Data analysis techniques.

To assess the role of local lake, catchment and environmental characteristics in modifying proxy responses to climate change, we collected and standardized lake (water body characteristics), catchment (geology and topography) and environmental (climate and vegetation) parameters from the literature and freely accessible online sources. The information is used to re-evaluate variations of varve thickness records during the last 2000 years with respect to the role of lake-catchment characteristics. We demonstrate that comprehensive databases have a great additional value for refining chronologies of paleoenvironmental archives and are essential to decode paleoclimatic information from sediment proxy records.

O-1213

## Reading past landscapes: quantified reconstructions of past land cover from pollen data

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### Abstract

Land cover is an important component of the earth system, both through the habitats it provides for living organisms and via its interactions with other major components (e.g. with the hydrosphere via modification of water flow, and with the atmosphere and climate system through albedo and evapotranspiration). Land cover is variable in both space and time, and reconstruction of past land cover is important for research into the long-term dynamics of the earth system (e.g. testing regional climate models), as well as for smaller-scale studies of ecosystem processes (which may feed into conservation management and predicting the effects of future environmental change), or of controls on and environmental impacts of past human activity.

Reconstruction of past land cover from pollen records has traditionally taken a broadly narrative approach, with relatively few attempts at hypothesis testing or formal assessment of uncertainty. The Multiple Scenario Approach (MSA) offers a radically different way to synthesise existing pollen data and reconstruct past land cover (Bunting et al. 2018) by generating spatially explicit land cover reconstructions for identified isochrones (“time windows” or “timeslices”) which can be presented visually, e.g. as maps or virtual reality reconstructions of particular sites or landscapes, or as quantitative measures of landscape properties (e.g. amount of open land) tracked over time. This method depends critically on the availability of pollen data which can be assigned to specific isochrones, and given the costs of producing high-resolution pollen records that are well-constrained chronologically, the MSA is heavily reliant on archived data.

An ideal data point for the MSA has the following properties:

- counts of all pollen taxa with clear taxonomic naming to allow for resolution of any taxonomic differences between records
- position information to <100m accuracy
- contextual information on the formation of the pollen assemblage (e.g. nature of any local vegetation, size of sedimentary basin)
- sufficient chronological information to confidently assign it to an isochrone

We present our experiences with three MSA case studies in the UK (the Somerset Levels and Moors, the Heart of Neolithic Orkney World Heritage Site, and the Humberhead Levels) and consider the challenges encountered in retrieving data and the implications for data loss more generally (for example, we identified 28 suitable pollen records for the Neolithic in the Somerset Levels and Moors, none of which were archived in the European Pollen Database or Neotoma).



Reference:

Bunting, M.J., Farrell, M., Bayliss, A., Marshall, P. and Whittle, A. (2018) Maps from mud – using the Multiple Scenario Approach to reconstruct land cover dynamics from pollen records: a case study of two Neolithic landscapes. *Frontiers in Ecology and Evolution* 6: article 36. doi: 10.3389/fevo.2018.00036

O-1214

## What if fossil pollen records had more things to say?

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### Abstract

Of all the fossil proxies that have been developed over the last century by Quaternary scientists, pollen has been the most commonly employed across a large array of environments. However, the multivariate nature of these data makes interpretations complex, and their full potential is rarely realised. To facilitate optimised interpretations and make the most of these rich datasets, robust statistical methods may be used to extract an array of significant palaeoenvironmental signals. Unfortunately, the most commonly used transfer functions (*e.g.* MAT (modern analogue technique) and WA-PLS (Weighted Averaging Partial Least Squares)) can only be used in areas where extensive datasets of modern samples are available, such as North America and Europe, have therefore have a strong spatial bias. This has led to the creation of *large quantification deserts*, *i.e.* regions where no or very few quantified reconstructions have been produced, often despite an abundance of fossil records.

The new statistical transfer function we have developed, entitled CREST for Climate REconstruction SofTware, proposes a new global solution regarding this issue. CREST uses probability density functions (*'pdfs'*) fitted on modern occurrence data to reconstruct environmental parameters, and offers many advantages over these classical approaches, such as 1) a higher flexibility of application, 2) a better capacity to estimate uncertainties, and thanks to some recent developments that will be presented in this paper, 3) is now applicable at a global scale by employing freely-available datasets. The method will be presented through a series of case studies based on the reinterpretation of southern African pollen records. These records have been extracted from the pre-existing African Pollen Database, their chronologies recalibrated and the pollen taxonomy harmonised. In these examples, we have reconstructed past temperature and rainfall dynamics from the quantification desert of southern Africa, which has led to an improved understanding of the glacial-interglacial dynamics of the African rainbelt.

In today's 'big data' world, CREST offers a unique potential to reconstruct climate from the re-evaluation of large compilations of pollen records (European Pollen Database, the Neotoma database, the Latin American Pollen Database, *etc.*) and to provide new insights about past environmental dynamics at different spatial and temporal resolutions across the globe.

O-1215

## Early to Middle Holocene paleolandscapes along the Scheldt estuary. Regional subsurface reconstruction through archaeological, geological and geotechnical legacy data

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### Abstract

During the last two decades, large infrastructure works along the Lower Scheldt river in NW-Belgium, in particular in the Waasland Scheldt polder region, have revealed deeply buried and well-preserved Late Glacial to Middle Holocene wetlands and associated Final Palaeolithic to Early Neolithic archaeological sites [1]. The combination of paleoenvironmental and archaeological data retrieved from these locations provides a unique image of the intimate relationship between prehistoric hunter-gatherers or early farmer-herders and the contemporary environment as well as the impact of rising sea- and ground water levels on both vegetation and humans [e.g. 2]. This paper presents results of new research, which has collected all available legacy lithological data from geoarchaeological coring projects, geological core descriptions and geotechnical cone penetration testing data [3]. The systematic approach to interpret these largely diverse data within a single informal lithostratigraphic framework will be addressed as well as the creation of a regional lithostratigraphic subsurface model with particular attention to uncharted Early Holocene tributaries of the river Scheldt. The potential and limitations of using such legacy data will be reviewed, perspectives and guidelines proposed for future data collection e.g. in development-led (geo-)archaeology. The results will be used to review and improve existing paleogeographic reconstructions by Missiaen *et al.* [4]. They will also illustrate changing landscape resource exploitation strategies, such as the settlement focus on sand ridges along beforementioned Early Holocene tributaries by Early Mesolithic hunter-gatherers. Next, the occupation of the floodplain gradually decreases as it is covered by (alder carr) peat and focuses on the Scheldt river banks during the Middle and Late Mesolithic. Subsequently, the floodplain is re-occupied by Early (to Middle) Neolithic farmer-herders at the time of a short period of freshwater (supra-)tidal influence [5], after which peat development resumed and the floodplain is largely abandoned by humans until historic times.

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O-1216

## Predictive site modeling for pre clovis buried materials in central Texas

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### Abstract

Deciphering the timing and migration of the settlement of early Americans has been an important question in archaeology for decades. Buried site potential models allow researchers to save time, money, and resources when searching for new excavation sites. Different layers of surface data, including landform age, landform stability, and landform type, combine in Geographic Information System (GIS) to create a map that indicates areas of low to high potential for buried materials of a particular time interval. Expediting the search for more pre-Clovis components will increase hypothesis testing to improve theories on the timing of the arrival of first Americans, including understanding migration pathways from Asia, and reconstructing settlement patterns and understanding subsistence strategies as the early settlers moved across the continent. Also, finding more pre-Clovis materials is essential to a better understanding of lithic technologies and how they compare to Clovis material. We can then see how Clovis originated and if Clovis technology developed from the earlier tools rather than independently. Reconstructing climate indicators at new sites can explain how the environment may have affected the early settlers and how they adapted their technologies. Finding more pre-Clovis sites increases the chances of finding pre-Clovis skeletal remains that will extend the genomic history of the early Americans as well as fortify the Siberian dispersal theory.

The target of this site prediction model was central Texas, specifically the Salado Creek Watershed that includes Buttermilk Creek where the Debra L. Friedkin and Gault sites are located. The location was selected because it has evidence for successive occupations dating back to, and including, pre-Clovis peoples between 13,200 and 15,500 yr BP. Because these sites are well documented, they provide an ideal background for creating a predictive model for locating other buried pre-Clovis remains in the region. Surface features determine the likelihood of locating the same buried stratigraphy as described for the Debra L. Friedkin Site in our preliminary model. Landform age and stability is delineated by flood frequency data, erosion data, soil types from soil maps, and elevations from topographic maps, or more precisely Web Soil Survey.

The preliminary buried site potential model indicates areas of high-buried site potential in the northern portion of the Buttermilk Creek-Salado Creek Subwatershed. These locations indicate the highest potential to locate subsurface data similar, if not the same, as the Debra L. Friedkin and Gault sites. Eight transects with both high and low potential were selected to validate the model. Samples were measured for particle size, organic carbon, calcium carbonate, pH, extractable cations, and most critically optically stimulated luminescence (OSL). Age dating was used to determine the relationship to the Buttermilk Creek Complex. The model shows that surface maps successfully aid in finding buried materials.

O-1217

## Commonality and variation in British MIS 9 handaxes.

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### Abstract

The notion that handaxe refinement and 'sophistication' evolved throughout the Lower Palaeolithic was largely discredited by improvements in the dating of terrestrial archaeological sites, which showed that relatively well made, refined handaxes could be substantially older than cruder, less refined types. This in turn created a justifiable reluctance to assign any chronological significance to handaxe morphologies or technological variation. However, the idea has been cautiously rehabilitated in recent studies, where certain 'diagnostic' forms have been shown to be strongly related to the age of the deposits in which they are found. Examples of this are the 'twisted' ovate handaxe (Marine Isotope Stage [MIS] 11), the first appearance of Levallois technology (MIS 9-8), and the *bout-coupé* handaxe (MIS 3). MIS 9 has only been recently identified in the terrestrial archaeological record, with the flagship site of Purfleet showing a tripartite archaeological succession (Clactonian, Acheulean, Levallois) suggestive of an important transitional phase in early prehistory. Roe's seminal (1968) study in handaxe morphometrics included several sites now thought to date to MIS 9. His sorting of these sites, based on a statistical similarity between a number of indices including planform, tip shape and elongation, successfully grouped the MIS 9 sites together (Group I) even before the 'expanded' Quaternary chronology was known. Other research into the British Lower Palaeolithic which focused on typology (notably Wymer, 1968) appeared to show a diagnostic co-occurrence of *ficrons* (pointed handaxes with biconcave edges) and *cleavers* (handaxes with a long transverse 'chisel' tip) associated with sites subsequently assigned to MIS 9. Here we will outline the preliminary results of a large scale morphometric, typological and technological study of handaxes from British MIS 9 sites based on data collected from the substantial collections held in the British Museum and elsewhere. In particular, we will outline aspects of commonality across the range of handaxes studied, testing whether Roe's groupings hold true for all MIS 9 sites, and whether *ficrons* and *cleavers* are indeed chronologically significant. We will also outline instances of significant intersite variation, and suggest how these results might be useful in reconstructing ancient culture, society and cognition in the latest Lower Palaeolithic.

O-1218

## Bedrock landsliding and fluvial landscape evolution: a field perspective

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### Abstract

Bedrock landsliding is a common landscape process in moderate-high relief landscapes, particularly dryland areas, and yet is often overlooked in terms of its role in landscape evolution. This may be due to mis-interpretation/lack of recognition of older events (and thus under-representation) within the Quaternary record, mainly due to the loss of distinctive morphology by erosion post-emplacment, or due to the compound nature of some landslide complexes. Most commonly, fluvial systems are portrayed as the drivers of hillslope processes, yet conversely there is increasing evidence that hillslope processes such as landsliding can have a significant long-term ( $10^4$ - $10^6$  yr) impact on channel and hillslope morphology, and thus associated fluvial landscape processes and evolution. For example the early phases of mountain growth are commonly associated with river gorge incision into uplifting areas, and subsequent expansion by landsliding (a consequence of slope oversteepening increasing stress on slopes, weathering reducing shear strength, and excess porewater pressures generated along discontinuity surfaces during seismic events or periods of high intensity rainfall). The topographic signature of that landsliding (in scars and deposits) will impact upon the associated developing fluvial system, often persisting over long ( $10^4$ - $10^6$  year) timescales within the landscape.

Within fluvial catchments the status of bedrock landsliding as a landscape evolution process will vary as a function of environmental factors such as climate, seismic activity, local topographic relief and attitude of the bedrock geology. Landslides may facilitate catchment expansion via drainage re-routing through capture between (and within) catchments. The landslides may influence upstream areas through the generation of new local base levels and the creation of new lacustrine environments. Downstream of landslides catchments may be impacted by significant changes in sediment flux (both suspended and bedload), as a result of direct sediment supply from the landslide itself, and landslide lake outburst flooding and flushing of upstream fines.

Through a series of field examples we will examine the role of landsliding at different landscape scales across the dryland spectrum from semi-arid (inter-montane sedimentary basin SE Spain; High Atlas Mountains, Morocco) to hyper-arid (Coastal and PreCordillera of the Atacama Desert, Northern Chile). Such examples can inform our approach to landscape evolution modeling.

O-1219

## Modelling last cycle fluvial landscape evolution of the Rio Bergantes using PARALLEM.

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### Abstract

Landscape-evolution models (LEMs) attempt to use modern day process knowledge to derive numerical formulations of how landscapes might evolve over time in response to both extrinsic and intrinsic system drivers. There are many LEMs available for the end user and these vary in complexity dependent upon the intended use. For our intended use i.e. modelling fluvial system behaviour over a full glacial-interglacial cycle (~140 ka) with comparative high spatial resolution there are many constraints that limit our options. Using event-based models over these extended timescales, which use complex representation of flood hydrology and sediment transport, is computationally challenging. More significantly, parameterization of these complex models would require synthesized data at a spatial and temporal resolution (seconds) well beyond any reasonable use of the available 'real-world' data. A more pragmatic approach is to use a reduced complexity model, which uses simplified hydrological and sediment system representations. These models tend to use annual time steps calculating annual budgets for both water and sediment discharge. Even this temporal resolution presents challenges to find climate time series inputs at matching temporal resolution.

In this paper we will present results from modelling the Rio Bergantes catchment in northern Spain using our newly-developed fluvial landscape-evolution model called PARALLEM. PARALLEM has been developed to leverage the immense computing power of General Purpose Graphics Processing Units (GPGPUs) using the NVIDIA CUDA development environment. Although PARALLEM has an event-based option in development, here it is deployed in its reduced complexity mode. The numerical formulation of PARALLEM is based upon Wainwright (2006) but with some significant process additions e.g. gelifluction, similar to those developed for CLEOPATRA (Briant *et al.*, 2018). The input climate timeseries (annual timestep) and the initial DEM (20m resolution) are those developed specifically for the FACSIMILE model-data comparison project.

The model outputs general statistics every iteration and more detailed data matrices every 500 iterations. The 140k iteration simulation currently takes ~7 weeks to complete. Here we present, for the first time, the outputs from a complete model run. Although this represents only one simulation for one parametrization set (with many more necessary to establish model sensitivity etc.) the data does nevertheless provide insight into how the processes act upon this landscape. Perhaps most significant is the critical role played by vegetation change in modulating erosion in this catchment, a key finding as many LEMs do not explicitly model vegetation feedbacks.

Briant R.M., Wainwright J., Maddy D. 2018. New approaches to field-model data comparison: Numerical modelling of the last glacial cycle in the Welland catchment, England. *Geomorphology* 323, 106-122

Wainwright, J. 2006. Degrees of separation: Hillslope-channel coupling and the limits of palaeohydrological reconstruction. *Catena* 66 93 – 106

O-1220

## Applying Pattern Oriented Sampling in current fieldwork practice to enable more effective model evaluation in fluvial landscape evolution research

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### Abstract

Field geologists and geomorphologists are increasingly looking to numerical modelling to understand landscape change over time, particularly in river catchments. The application of Landscape Evolution Models (LEMs) started with abstract research questions in synthetic landscapes. Now, however, studies using LEMs on real-world catchments are becoming increasingly common. This development has philosophical implications for model specification and evaluation using geological and geomorphological data, besides practical implications for fieldwork targets and strategy. The type of data produced to drive and constrain LEM simulations has very little in common with that used to calibrate and validate models operating over shorter timescales, making a new approach necessary. Here we argue that catchment fieldwork and LEM studies are best synchronised by complementing the Pattern Oriented Modelling (POM) approach of most fluvial LEMs with Pattern Oriented Sampling (POS) fieldwork approaches. POS can embrace a wide range of field data types, without overly increasing the burden of data collection. In our approach, both POM output and POS field data for a specific catchment are used to quantify key characteristics of a catchment. These are then compared to provide an evaluation of the performance of the model. Early identification of these key characteristics should be undertaken to drive focused POS data collection and POM model specification. Once models are evaluated using this POM / POS approach, conclusions drawn from LEM studies can be used with greater confidence to improve understanding of landscape change.

O-1221

## Late Quaternary landscape evolution of the Bergantes catchment: LAPSUS sensitivity in response to tectonic and lithological drivers

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### Abstract

Over the past decade the FACSIMILE working group (Field And Computer Simulation In Landscape Evolution) has been working on the synergy between numerical modelling and field-based approaches. The past few years the FACSIMILE working group has been focussing their attention to one single catchment: the Bergantes river, a tributary of the Guadalope river, that drains the south-east part of the Ebro basin (Northeast Spain). Various experts in the fields of computer simulation, palaeohydrology, geochronology, geomorphology and sedimentology work together in an attempt to improve the synergy and understanding of the Late Quaternary landscape evolution of the Bergantes catchment over the past 140 Ka with a multidisciplinary approach.

The different computer simulation LEM approaches in the FACSIMILE working group mainly focus on erosion and sedimentation dynamics based on the published sedimentation history, stratigraphy and geochronology of the downstream river terrace staircase. Furthermore, important landscape evolution input datasets on palaeo-DEM and palaeo-climate have been reconstructed (see this conference). By working with comparable input datasets, especially the computer simulations of the different model approaches, become more easily comparable and straight forward particularly when compared to the field evidence presented so far.

The focus of this research is to analyse the sensitivity of LEM LAPSUS to 2 unexplored controlling driving factors so far; i) regional tectonics and ii) lithological differences in the Late Quaternary Bergantes landscape development. By constructing multiple-stage scenarios, the relative contribution of each of these factors is first estimated based on field observations, before their interaction is simulated. Although their effects are spatially different and they might vary one order of magnitude, we anticipate that both factors play a role individually and together in shaping the landscape in the Bergantes catchment. Consequently these results infer a further investigation for field evidence, which may be guided by these simulations. Especially by investigating key locations of the spatial explicit erosion and sedimentation rates of these scenarios. Finally, the results serve to inform the other LEM approaches on the need to incorporate these driving factors on lithology and tectonics.

O-1222

## Using lake sediments to test millennial duration simulations of catchment hydro-geomorphology

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### Abstract

Flooding and sediment/soil erosion are a growing future concern for drainage basins, particularly with changes in climate and increasing pressure on land as populations grow. Quantifying how changes in climate and land use impact can impact on the flooding regime and on sediment delivery within catchments remains challenging. Hydro-geomorphic modelling at a catchment scale can be applied to explore these issues. This research assesses the utility of a reduced complexity hydro-geomorphic model (CAESAR-Lisflood model, Coulthard et al. 2013) in identifying the controls on sediment delivery to lake basins.

Catchment scale simulations using CAESAR (Coulthard et al., 2002) showed that the fluvial erosion and deposition, driven by precipitation and conditioned by land use failed to sustain sufficient sediment flux compared with the lake sediment record for the last 180 years (Welsh et al., 2009). The catchment geomorphology (Foster et al., 2003) revealed substantial hillslope erosion supplying sediment to the fluvial system. The representation of hillslope processes (soil creep, failure and surface erosion) in CAESAR-Lisflood (Coulthard et al. 2013) was independent of land use and changes in soil moisture. Here we present and test updates to the soil erosion, soil creep and slope failure components within the CAESAR-Lisflood model.

The model has been tested for two differing upland catchments, the Petit lac d'Annecy, French pre-Alps and Brotherswater, English Lake District. Existing sediment accumulation and compositional data with well resolved chronologies for the lake basins were pre-requisites for the selection for lake catchments. Climate and land use histories were derived from regional palaeoclimate and pollen datasets to drive the simulations. The palaeoclimate data was used to produce the hourly rainfall input series required by the model which enabled the impacts of short, high magnitude rainfall events on sediment dynamics to be explored rather than being masked within lower resolution daily/monthly values. Thus, this work presents a test of the performance of CAESAR-Lisflood over time periods longer than typical of instrumental series and compares the outputs to existing lake sediment records (Jones et al. 2013; Schillereff et al., 2016)

O-1223

## Shaping pre-modern digital terrain models – implications for early medieval human-landscape interactions

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### Abstract

The use of remote sensing techniques to identify (geo)archaeological features is wide spread. For archaeological prospection and geomorphological mapping, Digital Terrain Models (DTMs) on based LiDAR (Light Detection And Ranging) are mainly used to detect surface and subsurface features. LiDAR is a remote sensing tool that scans the surface with high spatial resolution and allows for the removal of vegetation cover with special data filters. Archaeological publications with LiDAR data in issues have been rising exponentially since the mid-2000s. The methodology of DTM analyses within geoarchaeological contexts is usually based on “bare-earth” LiDAR data, although the terrain is often significantly affected by human activities. However, “bare-earth” LiDAR data analyses are very restricted in the case of historic hydro-engineering such as irrigation systems, mills, or canals because modern roads, railway tracks, buildings, and earth lynchets influence surface water flows and may dissect the terrain. Consequently, a “natural” pre-modern DTM with high depth accuracy is required for palaeohydrological analyses.

In this presentation, we present a GIS-based modelling approach to generate a pre-modern and topographically purged DTM. The case study focuses on the landscape around the Early Medieval Fossa Carolina, a canal constructed by Charlemagne and one of the major medieval engineering projects in Europe. Our aim is to reconstruct the pre-modern relief around the Fossa Carolina for a better understanding and interpretation of the alignment of the Carolingian canal. Our input data are LiDAR-derived DTMs and a comprehensive vector layer of anthropogenic structures that affect the modern relief. We interpolated the residual points with a spline algorithm and smoothed the result with a low pass filter. The purged DTM reflects the pre-modern shape of the landscape. To validate and ground-truth the model, we used the levels of recovered pre-modern soils and surfaces that have been buried by floodplain deposits, colluvial layers, or dam material of the Carolingian canal. We compared pre-modern soil and surface levels with the modelled pre-modern terrain levels and calculated the overall error. The modelled pre-modern surface fits with the levels of the buried soils and surfaces. Furthermore, the pre-modern DTM allows us to model the most favorable course of the canal with minimal earth volume to dig out. This modelled pathway corresponds significantly with the alignment of the Carolingian canal. Our method offers various new opportunities for geoarchaeological terrain analysis, for which an undisturbed high-precision pre-modern surface is crucial.

O-1224

## The role of neotectonics in driving Plio-Pleistocene landscape evolution and drainage development in eastern England

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### Abstract

The Plio-Pleistocene record of eastern and southern England has hitherto revealed a rich and internationally significant archive of landscape evolution and environmental change. The significance of climate as a key driver of landscape change is well established through the examination of glacial deposits, river terrace records, palaeosols and marine deposits. The role of neotectonics however, remains more poorly understood. This is due to the under-representation of Cenozoic faults on published geological maps and the widely-held belief that the UK has been tectonically passive since the Miocene. Nevertheless, the crust beneath the southern UK has undergone periods of uplift and subsidence during the past 3.5 Ma. This has occurred in response to accelerated weathering and the improved efficiency of earth surface processes at recycling sediment from upland 'source' areas (zones of uplift) to lowland and basinal 'sinks' (zones of subsidence). However, significant questions remain concerning how accommodation space within the landscape was regulated and how this in-turn influenced drainage development.

To explore these questions, a bedrock surface model was constructed using elevation data from +9,000 boreholes and contoured in SKUA-GOCAD using nearest neighbour analysis. Beneath central East Anglia, the modelled bedrock surface exhibits a low-relief 'crenulated' form comprising several elongate, NE-SW trending ridges and asymmetrical troughs that possess steeper southeast flanks. Gradient analysis combined with the consistent asymmetry and orientation of the features imply an underlying structural (fault) control. One potential interpretation is that these faults originated as a Cenozoic-age (post-Eocene / pre-Pliocene) sinistral strike-slip fault system that forms a linear deformation zone extending from central East Anglia southwestwards towards Oxford. Since the Miocene, the compressive stress regime within the upper crust has waned and fault slip analyses suggest that Plio-Pleistocene motion along these faults most likely occurred by dip-slip (normal) displacement, forming a horst and graben type relief.

The overlapping geometry of shallow marine (Red Crag Formation) and coastal (Norwich Crag Formation) deposits demonstrate that sediment accommodation space was restricted to the trough ('graben') areas which were actively subsiding during the Pliocene and earliest Early Pleistocene (c. 3.6-1.8 Ma). Uplift and emergence of this structural relief during the Early Pleistocene (post c.1.8 Ma) controlled the development of major preglacial rivers that drained eastwards into the southern North Sea. Contrary to current thinking, the Ancestral Thames and Bytham rivers appear to have been confluent for much of this interval with the course of the former constrained structurally by the Framlingham Ridge to the east. Confluence of the two rivers continued until accommodation within the landscape was infilled (c.0.9-0.8 Ma) and the Framlingham Ridge was breached.

These insights provide a significant shift relative to current thinking, highlighting the importance of neotectonics and their impact on drainage development and patterns of Plio-Pleistocene sedimentation.

O-1225

## The challenges of extracting pre-instrumental storm patterns from the tree-ring record

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### Abstract

Regions where a limited number of seasonal extreme precipitation events account for a large proportion of annual precipitation totals present a challenge for paleoclimate reconstruction. The timing and form of precipitation, which can be as important as the total amount received for water availability, is not always matched well with the recording period in trees. This is particularly true on the North American West Coast, where snow is vital for water supply and atmospheric river events can provide 30-50% of annual precipitation in just a few storms. This study uses an integrated water vapor transport-based record of landfalling atmospheric rivers to assess their contribution in different regions, test if water contributed by these events are reflected in ring-width measures, and evaluate their influence on asymmetries in tree-ring based moisture reconstruction. Results from these analyses are then used to evaluate ways to improve the seasonal capture of extremes, including season-by-season precipitation reconstruction, the use of precipitation frequency as an alternative reconstruction measure, and the integration of alternative tree-ring metrics (including stable isotopes and blue intensity) to derive additional information. Results show that season-by-season reconstructions are possible in regions with abundant tree-ring chronologies. The use of alternative metrics increased our ability to distinguish the form and season of precipitation. The  $d_{18}O$  isotopes, in particular, provided more consistent information across seasons. By combining these approaches, we can more clearly resolved patterns of past moisture delivery over multiple seasons.

O-1226

## Atmospheric trigger of a two-phased Younger Dryas in western Norway: indications of local moisture addition by sea ice reduction

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### Abstract

During the Younger Dryas (YD) stadial, pronounced atmospheric changes influenced hydrological conditions all over Europe. Specifically, it was hypothesised that a southward shift of the westerlies due to an expansion of sea ice in the N Atlantic Sea starved northwestern Europe from moisture through the establishment of a high-pressure system over the Norwegian Sea, pushing the prevailing winds south beginning at ca. 12.8 ka BP.

At around 12,250 yrs BP, during the second phase of the YD apparently wetter and more variable conditions were observed in sedimentary parameters at Meerfelder Maar (W Germany) and 12,100 yrs BP at Kråkenes (W Norway), attributed to a northward retreat of the polar front, potentially driven by an increase in AMOC. These records highlight the time transgressive nature of atmospheric circulation shift. We aim to determine which moisture sources deliver precipitation over the course of the YD stadial in order to characterise the atmospheric influence on a regional scale.

Here we compare stable hydrogen isotope records of leaf-wax n-alkanes ( $\delta D_{wax}$ ), which provide insights into characteristics of palaeo-precipitation. We present new data from two records, which span the onset and termination of the YD stadial at Kråkenes and Sluggan Bog (N-Ireland) covering the W-E extent of the North Sea and compare our data to published data from Meerfelder Maar.

Our findings show that the onset of the YD at 12.8 ka BP at Kråkenes was marked by a continuous isotopic depletion, which exceeded the effect of temperature on the isotopic composition of precipitation. The remainder can be explained by changes in the origin of moisture and hence supports the notion of a southward migration of the westerlies at this time. A unique feature of the record at Kråkenes in western Norway is a rapid isotopic enrichment followed by a higher degree of variability of  $\delta D_{wax}$  values, between 12.2 and 12.1 ka BP, persisting throughout the later YD. In the absence of any strong temperature increase or strong aridification, this enrichment suggests the addition of precipitation originating from a local moisture source.

We hypothesise that a reduction in sea ice extent in the Norwegian Sea starting at 12.2 ka BP allowed for evaporation and subsequent transport of local moisture to the Norwegian coast. This is supported by climate model simulations run on a CESM1 model, suggesting a bifurcation of the westerlies airflow over Scotland during the YD, of which the northern branch flows over the Norwegian Sea toward Kråkenes. In case of an increasingly ice-free Norwegian Sea during the 2<sup>nd</sup> phase of the YD, those air masses would have been able to pick up local and isotopically enriched moisture during their movement.

O-1227

## Variability of the Aleutian Low and Westerly Jet during the Holocene

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### Abstract

The Aleutian Low (AL), the semi-permanent low-pressure system located over the Gulf of Alaska, is critically linked to environmental change in the North Pacific and surrounding continental areas. For example, recent decadal variability of the AL has been reported to affect salmon abundance in the northeast Pacific, and precipitation and snow accumulation in the western coastal area of North America (e.g., Mantua et al., 1997) by changing the Alaska Current and moisture transport from the North Pacific to inland North America. At longer-timescales, AL intensity is reported to vary on centennial to millennial scales (e.g., Anderson et al., 2005, 2016; Fisher et al., 2008; Jones et al., 2014). However, the ultimate trigger of these intensity changes has not been systematically studied or proven.

Recent meteorological records showed that the Westerly Jet (WJ) over East Asia and the North Pacific links strongly to the AL intensity and position through changes in cyclogenesis, monsoon, and storm track activity (e.g. Lau, 1998; Dole and Black, 1990; Yang et al., 2002; Nakamura et al., 2002; Nakamura and Shimpo, 2004). Here, possible AL-WJ coupled changes and potential triggering mechanisms causing AL variations were examined using proxy records from East Asia, North America, and the Patagonian region. The focus is on WJ records from the Southern Hemisphere because the WJ path of the northern and southern hemispheres trace the expansion and shrinkage of the Hadley Cell during the Holocene, which help to understand dynamic changes in Holocene atmospheric circulation.

The proxy records revealed millennial-scale coupling of the AL-WJ path with weakened AL and poleward WJ shifts in both hemispheres during 7–5.2 and 2.8–1.2 ka, and an intensified AL and equatorward shift of the WJ path during 5.2–2.8 ka and 1.2 ka onward. Centennial scale AL intensification and equatorward shifts of the WJ path in both hemispheres also appeared in the proxy records. Periods of centennial and millennial-scale AL maxima and equatorward shifts of the WJ correlate well with periods of solar activity minima, suggesting solar activity has played a primary role in the generation of the atmospheric circulation changes, possibly through dynamic Hadley cell changes.

O-1228

## Regional wet phase in northern Arabia during low-latitude early Holocene dry anomaly – proxy evidence from a unique varved lake record

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### Abstract

Precession-forced intensification of the low-latitude summer monsoons and northward migration of the associated rainfall belts during the Early Holocene Humid Period (EHHP) initiated the development of grasslands, wetlands and lakes in today's hyper-arid Saharo-Arabian desert belt. Numerous model simulations and palaeoclimate records draw a consistent picture of the EHHP in North Africa. However, our knowledge about the magnitude, timeframe and moisture sources of the EHHP in northern Arabia during the EHHP is limited due to a lack of robust proxy data.

Here we provide the first high-resolution and precisely dated multi-proxy reconstruction of the hydroclimatic variability during the EHHP for northwestern Arabia, retrieved from annually laminated (varved) sediments of the Tayma palaeolake record. This record reveals a pronounced seasonal variability during the lake's evolution, which was reconstructed through micro-facies analyses of the varved sediments. Changing lake water evaporation and the lake-internal productivity were inferred using stable oxygen and carbon isotope compositions ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ) of primary inorganic carbonates. Sedimentological, biogeochemical and micro-palaeontological proxies complete the dataset. The robust age model is constrained by a floating varve chronology, anchored through  $^{14}\text{C}$ -dated pollen concentrates and the well-dated 'S1' cryptotephra.

The results prove the existence of a shallow to max. 15 m deep lake, and subsequent wetland succession in the Tayma basin from ca. 9300 to 4200 years before present (BP, *i.e.* before AD 1950), reflecting the typical scheme of increased humidity in the northern Afro-Arabian region during the early to mid-Holocene. However, maximum humidity in northern Arabia is only evident between ca. 8500 and 7900 years BP, when varves formed in a perennial lake body. This is considerably later and shorter than the EHHP over northern Africa, which is typically defined from 10,000 to 6000 years BP. Moreover, the length and timing of this peak humid phase in the N-Arabian Desert are congruent with a low-latitude, centennial-scale dry anomaly interrupting the EHHP. This 'cool poles – dry tropics' anomaly caused a weakening of summer monsoons and Mediterranean winter rains. We suggest that cooling of the North Atlantic and Mediterranean Sea during this anomaly promoted frequent perturbations of the subtropical jet-stream, which favours intrusions of rain-bearing, winter-spring tropical plumes towards N-Arabia. Today, such synoptic-scale climate patterns contribute significantly to extreme precipitation events in the Middle East. Our findings underpin a complex regional hydrological pattern during the EHHP, and challenge climate model simulations to better explain synoptic-scale regional and seasonal rainfall dynamics.



This study is a contribution to the research project “CLEAR – Holocene Climatic Events of Northern Arabia” (<https://clear2018.wordpress.com/>), financially supported by the German Research Foundation (DFG).

O-1229

## **Cenozoic depositional sequence in Weihe Basin (central China): long-term record of Asian monsoon precipitation from the greenhouse to icehouse Earth**

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### **Abstract**

Onset and evolution of Asian monsoon has been long-time debated, the timing and monsoon intensity variation is still an open question. The modern Asian monsoon circulation started at Eocene, early Miocene, late Miocene, late Pliocene and early Pleistocene have been hypothesized, on the basis of various geological records and fossil observations, and the proxy indicators of Asian monsoon strength. However, there are many uncertain in previous investigation such as the misinterpretation of proxy indexes' implication, fragment of the geological records and poor age constraints to the depositional sequences; therefore, a long-term and continuous record of Asian monsoon is impulsive needed. Weihe Basin is a middle size basin formed in Cenozoic in central China, where is located at marginal of Asian monsoon impact region and where is sensitive to reflect monsoon precipitation change. Weihe Basin can be regarded as a monsoon rainfall gauge in Cenozoic, since there is more than 7000 meters unconsolidated fluvial-lacustrine deposit accumulated in this basin, which cover timing from middle Eocene to Holocene with nearly continuous depositional sequence. The monsoon precipitation determines runoff of Weihe River catchment, which control erosion and deposition in Weihe Basin, therefore the sedimentary sequence is an excellent archive of long-term Asian monsoon evolution. Our depositional facies and stratigraphy analyses show that Asian monsoon precipitation probably commenced at middle Eocene, and the modern monsoon circulation pattern was established at early Pleistocene, ~2.6 Ma. The collision between Indian Plate and Eurasia Plate at Paleogene could build Asian topography at that time, the great continental landmass and oceans could generate Asian monsoon circulation. This monsoon circulation was stepwise strengthened by close of Tethys Sea at late Eocene and early Oligocene, and by growth forcing of Himalayan-Tibetan Plateau at early Miocene, and high-latitude cooling at Northern hemisphere at late Miocene. The great Northern Hemisphere Glaciation took place at ~2.6 Ma could be the direct driver that push the intertropical convergence zone (ITCZ) toward equator and compress the monsoon rain belt, thus the modern monsoon circulation was finally established. The monsoon evolution has experienced greenhouse Earth and icehouse Earth which shifted at early Oligocene, along with onset of ice sheet in Antarctic, but the global cooling and Asian topography change did not completely modulated Asian monsoon circulation pattern during this time. The Northern hemisphere cooling at late Pliocene and early Pleistocene finally determined Asian monsoon circulation pattern which was finally established at this time.

O-1231

## Alaskan lake oxygen isotopes as recorders of North Pacific atmospheric circulation patterns and variability during the Holocene

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### Abstract

The coast mountain ranges of Alaska and the southwest Yukon Territory have dramatic elevation gradients in climate and isotopes of precipitation that are caused by their interaction with the atmospheric flow. These effects also lead to regionally complex spatial patterns in hydroclimate, which are also indicated by Alaska-Yukon oxygen isotope proxy records. To overlook regional and elevation differences, and the processes that cause them, will result in erroneous interpretations, which is particularly problematic for the region because current isotope enabled GCMs lack the spatial resolution to accurately simulate topographic effects. Here, we explore comparisons between oxygen isotope proxy records from a range of elevations and locations throughout southern Alaska-Yukon that reflect the interaction between regional atmospheric flow and mountain barriers. The comparisons offer opportunities to obtain more detailed paleoclimatic information such as changes in seasonality, boundary layer dynamics, and rain shadow effects. Previous work from Mount Logan ice cores and leeward Jellybean Lake sediments at ~5000 and 1700 m elevations, respectively, has provided a number of hypothesis about the effects on isotopes in precipitation caused by changes in North Pacific atmospheric circulation during the Holocene, such as variations in the strength and position of the Aleutian Low. A prominent role of the Aleutian Low during the past millennium has recently been corroborated by a new ice core record from Mt. Hunter but the effects at low, windward elevations has yet to be determined. Here we present a new full Holocene record from windward April Fools Lake, located at ~40 m elevation near upper Cook Inlet that serves to test if prominent late Holocene shifts in isotopes of precipitation at Logan and Jellybean are similarly shown to occur near sea level or not. The results will provide points of comparison for precipitation isotope model simulations and have implications for late Holocene climate trends in the Gulf of Alaska region as a long-term context for ongoing North Pacific ocean-atmosphere dynamics.

O-1232

## The timing of Antarctic Ice Sheet glaciation evidenced by Marine Isotope Stage 3 sea-level highstand records

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### Abstract

The Last Glacial Maximum (LGM) is known as the period when global ice volume reached its maximum and global temperature was lower than today. The timing of ice-sheet growth toward the LGM is essential to understand the mechanism of each continental ice-sheet glaciation and the accompanying vertical movement in the near-field by glacial isostatic adjustments (GIA). However, the erosive nature of ice-sheet expansion during the LGM and the difficulty of access in Antarctica make it challenging to obtain field-based evidence of ice-sheet and sea-level change prior to the LGM. Sedimentary records from the coastal region in East Antarctica demonstrate that relative sea level during Marine Isotope Stage 3 (MIS 3) was close to the present level (Miura et al., 1998; Hodgson et al., 2009). These relative sea-level records combined with GIA modeling provide insight into the timing of Antarctic Ice Sheet (AIS) glaciation immediately prior to the LGM.

In this presentation, we document the ice loading history in Antarctica based on the W12 model (Whitehouse et al., 2012), which can explain MIS 3 sea-level highstands in the East Antarctic coastal region. We ran over 100 GIA experiments in which we altered the timing of AIS growth before MIS 3 as well as the magnitude of ice loading during MIS 3. Initial results indicate that changing the timing of AIS growth to LGM conditions cannot explain the MIS 3 sea-level highstands. However, increasing the ice loading during MIS 3 so that it is greater than the LGM ice load in the W12 model can explain the MIS 3 sea-level highstands. This excess ice loading event indicates that the large-scale growth of the AIS may have started before MIS 3. We hypothesize that the changes in sea ice expansion and sea surface temperature in the Southern Ocean may be closely related to the growth of the AIS prior to the LGM.

O-1233

## Southwest Greenland shelf glaciation more extreme during MIS 4 than during the Last Glacial Maximum

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### Abstract

Although geological and modelling evidence indicate that the last glacial inception started in NE Canada, only little is known about the glacial response of the nearby western Greenland Ice Sheet (GIS) during the first main glacial advance of marine oxygen isotope stage 4 (MIS4). Moraine ridges on the southwest Greenland outer shelf ('Outer Hellefisk Moraines') are generally assumed to outline the maximum GIS extent during the Last Glacial Maximum (MIS2). Here we present results from a multi-proxy study of a marine sediment core collected about 60 km southwest of the Outer Hellefisk Moraines. Our study demonstrates that the most extreme SW Greenland shelf glaciation occurred during MIS 4, with another prominent glacial advance dated between 38 and 42 kyr BP. In contrast, the MIS2 glaciation appears to have been less severe. Our data further suggest a significant influx of relatively warm Irminger Sea Water transported by the West Greenland Current since MIS 4. This likely limited the extent of the MIS2 glaciation on the SW Greenland shelf. Decreased precipitation over the southwest Greenland region reported in atmospheric modelling studies as a downstream effect of a much larger MIS2 Laurentide Ice Sheet may have played an additional role.

O-1234

## Late Weichselian lake sediments with Azorean tephra reveal ice-free interval on coastal northwest Spitsbergen

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### Abstract

Empirical constraints on the style and extent of past glaciation, and its climatic boundary conditions, greatly improve the accuracy of numerical models used to predict the future behavior of Earth's cryosphere. On northwest Spitsbergen, independent lines of paleoglaciological evidence suggest that Late Weichselian ice was either restricted or extending to the shelf edge. We accommodate both these scenarios with the first pre-Holocene lake sediments reported from the Svalbard archipelago. Radiocarbon dating of three terrestrial plant fossils indicate that the investigated low-lying site (Hajeren) was ice-free and vegetated between ~30 and 20 ka BP. The presence of a geochemically homogeneous and distinct horizon of ultra-distal volcanic ash from the Azores islands provides additional evidence for sub-aerial (unglaciated) conditions. Stratigraphic indicators of sediment compaction, as well as a depositional hiatus indicate subsequent coverage by non-erosive (cold-based) ice until deglaciation at the onset of the Holocene ~12 ka BP. Comparison with regional paleoclimate records suggests that sea-ice variability played a critical role in the inferred pattern of ice-sheet evolution by modulating moisture fluxes that control ice accumulation rates. These findings also raise questions about the future stability of the Arctic cryosphere, which faces rising temperatures as well as wetter conditions.

O-1235

## Reconstructing ice sheets with glacial isostatic adjustment methods using observations of past ice sheet extent, sea level and paleo-lake shorelines

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### Abstract

Assessments of past sea-level change and climate require precise knowledge of the configuration of ice sheets. However, direct determination of the dimensions of past ice sheets are often not possible due to the paucity of geological evidence, especially prior to the Last Glacial Maximum. Because of this, reconstruction of past ice sheets rely on using glacial isostatic adjustment methods. The spatial pattern of past sea level can be used to infer how much ice was in the ice sheets, and where it was located. We present the results of a preliminary global ice sheet reconstruction covering the past 200,000 years. The ice sheets are constructed using the program ICESHEET, which allows for precise control over the extent and volume of the ice sheet. We also include proglacial lakes, which are used to assess the validity of the reconstructions in areas far from the coast. The 200,000 year period is necessary for accurate modelling of paleo-sea level, as the response time of the Earth's mantle is slow, and there is a memory of the MIS 6 glaciation even on present sea level change. The reconstructions benefit from the recent compilations of ice sheet margin reconstructions (e.g. DATED-1 for the Eurasian ice sheets) and paleo-sea level archives (e.g. HOLSEA and WALIS). We focus on three specific points of time in our reconstructions. The first is determining the late glacial configuration of the southern Laurentide Ice Sheet, using observations of paleo-lake shorelines. The second is to determine the possible configuration of the ice sheets at the Last Glacial Maximum, when there is still upwards of 15 m of "missing" ice to close the sea-level budget. The third target is the sea-level highstand during MIS 5e, which is suspected to have been caused by a partial collapse of the West Antarctic Ice Sheet. We use observations of past sea level in Patagonia to test this hypothesis.

O-1236

## Modelling ice sheet – sea level – solid Earth interactions over the Northern Hemisphere throughout the last glacial cycle

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### Abstract

Retreat or advance of an ice sheet perturbs the Earth's gravitational field, solid surface and the rotational vector, which together lead to spatially variable changes in sea level and deformation of the bedrock, feeding back onto the evolution of the ice sheet over both short-term ( $\leq O 10^2$  yrs) and long-term ( $\geq O 10^3$  yrs) timescales. Changes in elevation of the bedrock beneath an ice sheet shift the elevation of ice sheet surface, which then affects the accumulation and ablation of the ice sheet (i.e. ice elevation feedback). In the case of a marine-terminating ice sheet, solid Earth deformation and gravitational field perturbations together cause changes in the local water depth, influencing the ice flux across a grounding line and thus the stability of the ice sheet.

Over the last glacial cycle, ice sheets over the Northern Hemisphere have gone through multiple advance and retreat phases, but the dynamics during these phases are not well understood. In this study, we apply a coupled ice sheet – sea level – solid Earth model to simulate the Northern Hemisphere Ice Sheets (NHIS) over the last glacial cycle. We present the evolution of the NHIS and associated geographically variable sea-level changes and deformation of the Earth's surface. Our model captures the details of the short-term ( $\leq O 10^2$  yrs) interactions between the three components of the model within a glacial-cycle timescale simulation. We also present the results of additional simulations in which the contributions from gravitational and deformational effects are separated. From our results, we examine the ice volume, spatial and temporal distribution of the NHIS, and attribute each physical process to the growth and retreat dynamics of the NHIS.

O-1237

## The configuration of Northern Hemisphere ice sheets through the Quaternary

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### Abstract

Knowledge of the extent, volume and timing of Quaternary ice sheets is fundamental to studies of sea-level change, Earth rheology, global climate, landscape evolution, sedimentation, palaeoecology, genetic diversity and anthropology. The last few decades have seen unprecedented growth in the size and diversity of empirical datasets used to reconstruct and date palaeo-ice sheet extent, together with major improvements in our ability to simulate their dynamics in numerical models. However, the vast majority of these reconstructions focus on ice-sheet deglaciation from the Last Glacial Maximum (LGM), and comparatively little is known about global changes in ice-sheet configuration in the deeper past. Here, we synthesise available empirical evidence and model outputs related to pre-LGM ice sheets to produce hypotheses of Northern Hemisphere (NH) ice-sheet configuration over 17 key time-slices that span the last ~3 million years. Our hypothesised reconstructions are used to assess spatial differences in ice-sheet configuration within and between glacial periods, produce new first-order estimates of global sea level associated with each time-slice, and explore the implications for NH landscape evolution.

O-1238

## 'Missing Glaciations' of the Middle Pleistocene: examining controls on global glacier extent during 100 ka glacial cycles

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### Abstract

Ice volume during the last ten 100 ka glacial cycles was driven by solar radiation flux in the northern hemisphere. Early minima in solar radiation combined with critical levels of atmospheric CO<sub>2</sub> drove initial glacier expansion during the largest glaciations. Solar forcing also plays a major role in determining the size and length of glaciations. For example, the amplitude of solar precession associated with peak eccentricity can be linked to failed glacial cycles such as MIS 7d and 15b. However, even during full glacial cycles global glaciations have varied in size and magnitude since the Early-Middle Pleistocene transition (~773 ka), despite the apparent regular and high-amplitude 100 ka pacing recorded in marine isotopic records. The evidence on land indicates that patterns of glaciation varied dramatically between different glacial cycles. Some glacial cycles were characterized by limited glaciation with the terrestrial evidence consequently limited and overran by larger later glaciations. For example, MIS 8, 10 and 14 are all noticeably absent from many terrestrial glacial records in North America and Europe. However, globally, the patterns are more complicated with major glaciations recorded in MIS 8 in Asia, and MIS 10 and 8 in parts of the southern hemisphere, such as Patagonia and Tasmania for example. This spatial variability in glaciation between glacial cycles is likely to be driven by internal climatic, such as ice volume changes in Antarctica and associated interhemispheric connections through ocean circulatory changes. The largest global ice volumes were always associated with large ice masses over North America and Europe whereas smaller ice volumes occurred when glaciations were largely 'missing' from these regions. The weak global glacial imprint in some glacial cycles is related to the pattern of global ice build-up and is often characterized by large interior continental glaciation early in the glacial cycle that is then not matched by the later global glacial maxima. This is caused by feedback mechanisms within glacier systems themselves which partly result from long-term orbital changes driven by eccentricity and a weak North Atlantic conveyor associated with conditions in Antarctica and the bipolar seesaw.

**O-2000**

## **Quaternary Desert Dune Systems – A global perspective**

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### **Abstract**

Inland dune systems of Quaternary age occur on all continents and at all latitudes and are one of the most widely distributed landforms on Earth. Dune systems are dynamic geomorphic and sedimentary environments that respond directly and indirectly to climate change and variability on a range of temporal and spatial scales. The sedimentary and geomorphic record preserved in inland dune systems therefore potentially provides a valuable source of information on past climate conditions, including evidence for periods of dune activity and stability that may be interpretable as records of past aridity, as well as contributing unique data on past wind regimes.

Directly dated chronologies of periods of aeolian accumulation and stability have been developed for many areas since the widespread application of luminescence dating techniques. The INQUA Dunes Atlas chronologic database provides the first global compilation of published luminescence and radiocarbon ages for aeolian sand deposits. Although by necessity it is a work in progress, the database is a valuable resource that can be used to analyze patterns of dated dune deposits at multiple temporal and spatial scales; correlation of these patterns with other paleoclimatic proxies; and assessment of the paleoclimatic and paleohydrologic implications of periods of aeolian deposition. In addition, the dataset can be used to validate earth system and paleoclimate model simulations over the past 30-40,000 years.

Analyses of the dataset at regional and global scales are providing new insights into spatial and temporal patterns of dune system response to changes in sediment supply, availability, and sand transport capacity. More precise correlations of periods of aeolian accumulation and stability with other paleoclimatic proxies and records, enables assessment of the boundary conditions that result in dune building, reworking, or stability. As a result, the paleoenvironmental significance of periods of aeolian sand accumulation and stability can now be better constrained in many areas, highlighting, for example, the importance of sediment supply to periods of late Quaternary dune formation in North America and Europe; and mega-droughts to Holocene reactivation episodes.

The availability of large amounts of chronologic data has highlighted the complexity of dune system response to Quaternary climate change, indicating that there is a need for: (1) a systematic hypothesis-driven approach to dating programs; (2) statistical approaches to distinguish between signal and noise in the dataset; and (3) process-based interpretations of the dune record and its preservation.

O-2001

## Different responses and driving mechanisms of H1 event in the Asian Monsoon domination and its marginal region

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### Abstract

The Tibetan Plateau is affected by the westerlies and the India summer monsoon (ISM), of which the influence might be reflected through climate change signals in sedimentary records in the transition regions. The Nam Co Lake is located at the transitional zone between the westerlies and the ISM on the Tibetan Plateau. Sedimentary records of the Nam Co Lake show that climate shifted from cold-dry to warm-humid, and from the westerly domination to ISM domination reflected by pollen discriminant function since 16.5 ka BP. The same changes were also reflected by pollen records of Tangra Yumco Lake and pollen and biomarker records of Mang Co Lake in this monsoonal margin area. However, unlike the dry condition appeared in H1 event period in East Asia typical monsoon region during this shifting period, lake records in ISM margin area of the Tibetan Plateau showed that climate performed more humid in H1 period than in Last Glacial Maximum. By comparing results of full\_forcing TraCE experiment and Freshwater hosing experiment, it is found that the weakening of AMOC results in southward shift of the ascending branch of Hadley circulation. It enhances north toward trans-equatorial wind at upper layer of the troposphere, which transit to the upper-level westerly jet in middle latitude of northern hemisphere. Although the enhancement of upper westerly jet is limited due to warming effect of greenhouse gas and solar radiation in northern hemisphere, there is a structural change similar like convergence center in upper troposphere in East Asia typical monsoon regions. It limits convective activity below and reduces precipitation, while in high elevation area of monsoon margin, it is difficult to limit influence of Indian monsoon by increasing upper westerly wind, which leads to the stability of precipitation in Indian monsoon marginal region.

O-2002

## Climate variability during Late Quaternary in Tangtse Valley, Ladakh, Trans-Himalaya: inferences from grain size, environmental magnetism and loss on ignition

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### Abstract

The Tangtse River Valley, Ladakh in Trans-Himalayan range is a cold and arid desert due to the strong influence of westerlies. On the east of valley, Pangong Tso, longest lake in Ladakh has high, distinct palaeo- strand lines give clues about the wider extent of the lake area in the past. Dating of fluvial and fluvio-lacustrine sections by  $^{14}\text{C}$  (AMS) and TL(OSL) methods gives us records of changing depositional environments. Two phases of fluvial regime around 48 ka and 30-21 ka (comparatively arid conditions and dry phases) were revealed. A fluvio-lacustrine/flood phase between ~20 to ~5 ka inundating the whole valley is recorded.

In grain size analysis, most of the samples show unimodal sediments this can attribute a stable lake condition and indicates the lack of reworked fluvial, aeolian and eroded lake margin materials. In contrast, the poor degree of sorting is also observed. Fining-upward cycles, variation in mean grain size, varying bed size are the indication of changing of depositional energy. To solve the transport dynamics, End-member analysis (EMA) with 4 Ems were modeled in this study. EM modeling indicates in floodplain pool, with reworked sediments indicating riverine input. On this basis, the depositional scenario can be said a fluvio-lacustrine setting.

During warm periods, decreased catchment weathering led to the deposition of fine sediments) show decrease in values Magnetic Susceptibility (MS), Saturated Isothermal Remanent Magnetization (SIRM) and soft Isothermal Remanent Magnetization (IRM). Results opposite to these reflect a colder phase. The fluvio-lacustrine sections can be divided into 4 zones (Z1-Z4). The setup of zone1 (~20 to ~16 ka) is synchronous to LGM period with a peak around 18 ka. Zone4 (~6.7 to ~5.1 ka) is much colder than that of Z3 (~7.2 to ~6.7 ka) and having short, but intense cold phases. A stable lake condition with a warm climate record is seen in ~16 to ~7.2 ka (Z2) corresponding to a well-known enhancement of Indian monsoon (15.2 ka) and climate amelioration. LOI data shows a trough whereas MS, susceptibility of ARM and SIRM values an enhancement around 8 ka may be the signature of the prominent cold excursion 8.2 ka event in warm Holocene.

A 9.7 m thick exposed section may be a result of a later flood event (~3 ka). The cross-laminated sand, alternating layers of silt and sand as sedimentary features, along well-preserved sub fossilized faunal and wood remain points to a quick burial which was likely a result of a short-term flood event. The signal of SD magnetite which indicates less oxygenated water condition for a short while due to the turbid water, bimodal type sediment and EM modeling also suggest it as a channel or natural levee section.

O-2003

## Appearance of unique tape pine forests in Altai region (southern West Siberia)

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### Abstract

The Kulunda depression (Altai region, Russia) is located in the southern part of West Siberia and used to provide a paramount environmental connection between the Central Asian steppe and the North Asian forest-steppe and taiga. It is extensive accumulative lowland located at an altitude of 100-140 m asl. Presently, a thick layer of alluvial and eolian sediments (up to 50-60 m) covers the Kulunda depression. A distinctive feature of Kulunda is the high number of salty and freshwater lakes. Kulunda is situated in the Eurasian steppe zone with a prevalence of grass communities. Tape shape forests with *Pinus sylvestris* (so called 'tape bor') stretching from southwest to northeast are unique natural objects with unclear origin. Spreading of these forests is closely linked to existence the sandy dunes in Ob`-Irtysh interfluve.

There are at least three points of view on the origin of tape pine forest: (1) they are relics from the continuous *Pinus sylvestris* forest that was spread in Pleistocene in the humid phases across the whole Siberia; (2) they appeared in arid phase of MIS3 when the loess deposits from Ob River terrace were moved by wind and formed the sandy dunes in direction of westerlies in ancient river beds; and (3) they appeared in arid phase of late MIS2 or early Holocene when the sand dunes were formed and immediately inhabited by Scotch pine.

New pollen records covered late Pleistocene and Holocene from two lakes of Kulunda were studied to resolve this issue: 2.52 m-long core from salty lake Kuchuk (ca 13.8 kyr BP) and 4.97 m-long core from soda lake Maloye Yarovoe (ca 21 kyr BP) were obtained in 2016. *Artemisia* pollen dominates throughout both records reaching together with *Amaranthaceae* up to 90% in late Pleistocene. This reflects dry treeless landscapes. *Pinus sylvestris* pollen has only 1-5% before Holocene that means absent of pine forest in vicinity of the lakes. After ca 11.2 kyr BP in Kuchuk and ca 9.5 kyr BP in M. Yarovoye the amount of Scotch pine pollen sharp increases (up to 20-23%) and then has never disappeared or significant decreased. Broad-leaved taxa that absent in natural modern flora (*Carpinus*, *Fagus*, *Tilia*, *Corylus* and *Ulmus*) appear in low amount between ca 11.2 and 3 kyr BP. Based on this study we can preliminary conclude that the sand dunes formed in terminate arid phase of late MIS2 were inhabited by Scotch pine in early Holocene.

O-2004

## Multi-proxy evidence of palaeoenvironmental and palaeovegetation changes on southeastern Amazonia

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### Abstract

The Amazon rainforest is a fundamental source of moisture for the atmosphere with implications in the maintenance of the valuable biodiversity contained therein and on the Brazilian economy. Besides that, as a huge carbon reservoir, it plays a key role in the global climate. Many studies have been performed in order to better understand the effects of Northern Hemisphere climatic events over the rainfall regime and vegetation dynamic on southeastern Amazonia. However, there is no broad consensus, since most of the studies used only palynological data. And due to the limitations of this technique, the multiproxy approach is essential to obtain a better interpretation of climatic variations. In this way, isotopic analysis of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ , sedimentary facies, palynological, multi-elemental geochemistry, micro and macro-carbon fragments analyzes were performed on a sediment core from Amendoim Lake that covers the last ~22 ka. Relatively dry conditions during the Last Glacial Maximum (LGM) is suggested by very low sedimentation rate and diagenetic formation of a siderite layer under reduced conditions at the sediment-water interface during low lake level. The lowest pollen concentration indicates degradation of pollen and spores grains due to diagenetic process. During LGM, colder Atlantic Ocean SST probably caused a decrease in ocean moisture supply to northern South America and consequently a reduction in the precipitation regime. The Pleistocene-Holocene transition and Early Holocene are characterized by the large occurrence of fire events and precipitation of siderite nodules, besides the decrease in detrital input to the lake basin. On the other way, the record also shows a high concentration of pollen grains from forest formation and palms as well as depleted  $\delta^{13}\text{C}$  values, which suggests seasonal (warmer) climatic conditions with prolonged dry seasons. High northern insolation probably caused the northward migration of the Intertropical Convergence Zone and consequently, low precipitation amount over southeastern Amazonia. An expansion of ombrophilous forest over the plateau slopes in Serra Sul de Carajás and a change to predominantly wet climatic conditions similar to the current one was observed during the last 8 ka. Based on a multi-proxy approach, we support the hypothesis of a dipole pattern between western (wet condition) and eastern (dry condition) Amazonia during the last glacial period<sup>1</sup>. However, higher resolution records are indispensable in order to identify the palaeoenvironmental and palaeohydroclimatic changes caused by millennial events – e.g. Heinrich stages and Younger Dryas – over Amazonia.

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## O-2005

### Response of the Indian summer monsoon to global warming since the last deglaciation

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#### Abstract

The timing of the Holocene Climate Optimum in the Indian summer monsoon (ISM) area and its forcing mechanisms are controversial. In this study, a pollen-based vegetation reconstruction from a subalpine lake (Lake Tianchi, 25°52.4'N, 99°16.8'E, 2550 m above sea level) in the ISM area show that the *Tsuga dumosa* forest zone migrated at least 650 m upwards in the Hengduan Mountains from 18.6 to 7.1 kyr, indicating a gradual rise in mean annual temperature of over 3.9 °C. In response to this warming, grass, deciduous and evergreen broadleaved trees successively colonized this mountainous environment, reflecting the progressive increase in the ISM precipitation. The Holocene Optimum occurred between 10 and 4 kyr and reached a peak at 7.1–6.4 kyr, as evidenced by the maximum abundance of subtropical evergreen trees. The timing of peak Holocene warmth lagged the peak northern hemisphere summer insolation by 3.9–4.6 kyr, due to delayed ice melt in northern high latitudes. Our results indicate a strengthening of the ISM in response to warming-induced northward shifts in the Intertropical Convergence Zone. If global warming continues, the ISM is projected to intensify, the loss of habitat for alpine species is likely to accelerate.

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**O-2006**

## **A branched GDGTs-based temperature reconstruction from a tropical Maar Lake**

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### **Abstract**

High-resolution quantitative temperature records during the last deglaciation in low-latitude land are scarce but important for understanding rapid propagation of abrupt climate events throughout the northern hemisphere and the tropics. Here, we present a branched GDGTs-based temperature reconstruction from the sediments of Maar Lake Huguangyan in tropical South China. The record reveals that the mean temperature during the Oldest Dryas (18.1-15.5 kyr BP) was 17.8°C, followed by a two-step increase of 2-3°C to the Bølling-Allerød (14.6-12.8 kyr BP), a decrease to the Younger Dryas (19.8 °C, 12.8-11.4 kyr BP), and a rapid warming at onset of the Holocene. The reconstructed temperature was weighted towards the wintertime since the lake is a monomictic lake that mixing process enhances nutrients transportation from lake bottom to whole water column, and greatly facilitates organism growth and multiplication. Additionally, the winter-biased temperature change observed in tropical Lake Huguangyan was more distinct than the summer temperature records in extra tropical regions in the land area of the EASM. Within the limits of the dating uncertainties, the broadly similar pattern of winter-weighted temperature change observed in both tropical Lake Huguangyan and Greenland ice cores. We suggest that cold surges could play an important role in the rapid transmission of the temperature signal from the Arctic to the tropics.

O-2007

## Testing Possible Climatic Mechanisms of Vegetation Turnover and Novelty in North America and Europe

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### Abstract

Multiple climatic mechanisms have been hypothesized to cause community reshuffling and the emergence of novel communities. These include emergence of novel or no-analog climates, high rates of velocity or displacement, and spatial divergence among individual climatic displacement vectors. The detailed record of vegetation and climate dynamics during the last deglaciation enables tests of these hypotheses and insights into current global change. Prior work has linked climate and community novelty, or tested for disequilibrium, but no analyses have yet simultaneously assessed these multiple potential climatic drivers of ecological novelty. Using transient paleoclimatic simulations, we quantify climatic novelty, displacement, and divergence across North America and Europe from the last glacial maximum to present. Then, using over 1,200 records of fossil pollen from the Neotoma Paleoecology Database and European Pollen Database, we quantify community dissimilarity.

We use mixed-effects models and data from adjacent time steps to test hypotheses about which climatic mechanisms are most closely associated with highly novel and no-analog plant assemblages in each region. Climate dissimilarity, displacement and divergence among climate variables (seasonal temperature and precipitation,  $n = 8$ ) are treated as fixed effects, and time as a random effect. Our results suggest that climate dissimilarity is the most important predictor of community novelty for both North America and Europe, while rates of displacement are also significant for Europe. We also explore the effect of directionality and lagged baselines on our climatic mechanism patterns. We find that mid-Holocene climates for both Europe and North America are most dissimilar when compared to late-glacial climates, and that the same pattern holds true when comparing the dissimilarity of plant communities from the mid-Holocene to those of the late glacial. Our results support prior linkages between climatic novelty and community novelty, while suggesting that in some time periods and regions displacement is another important predictive factor. These results suggest that the 21st-century emergence of novel plant associations will be driven by both rapid rates of climate change and emergence of novel climate states.

**O-2008**

## **Palaeoshorelines on the Australian continental shelf and offshore islands**

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### **Abstract**

Drowned coastal landforms occur at numerous locations on the Australian continental shelf. These features influence long-term sediment transport on the shelf, provide habitat for a range of marine biological communities, and represent potential areas of human occupation during periods of lower sea level. Similar structures occur at a range of locations globally. In Australia, examples have been mapped using high-resolution multibeam echosounder (MBES) systems. Here we present our updated record of Australian palaeoshorelines, which occur at depths ranging from ~20 m to 120 m below present sea level. Given the tectonic stability of the Australian shelf, these features appear to record the more persistent or frequent stands of the sea in the Middle to Late Quaternary. The type of features preserved varies across the different shelf regions. For example, shore-parallel ridges extend along tens to hundreds of kilometres of the inner and middle continental shelf of south-western (sea level at approximately 30 m and 60 m below present) and central Western Australia (40 m); carbonate banks are common on the north-western and northern shelves (~30 m and 90 m) and outer margin of the Great Barrier Reef (~60 m); channel structures extend across large sections of the northern (80 – 90 m) and eastern shelves (30 – 55 m); and shallow shelves extend around the margins of several offshore islands (~25 – 35 m and 70 m). We present elevation models of these features, based on MBES data, which indicate they represent remnants of drowned beach-ridge strandplains, coastal dune fields, estuarine channels and platform and barrier reefs.

O-2009

## Holocene paleo tidal inlets as markers of the rising sea: a case study from the northern Adriatic shelf (Italy)

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### Abstract

We recently detected and characterized a series of abandoned and filled incised channels documented in the north-western Adriatic shelf. About 100 of them have been recognized as remnants of paleo tidal inlets which formed during the post-LGM transgression that led to the submersion of the shelf. These features were identified through the re-analysis of about 7000 km of high-resolution geophysical surveys (CHIRP-sonar profiles) and tens of stratigraphic cores carried out in the area during the last 30 years.

The preservation potential of paleo tidal inlets is usually low, as such features are often almost completely erased by the wave ravinement processes. As a matter of fact, only few examples are known in literature and they are usually confined to low-gradients shelves.

Despite their rarity, paleo tidal inlets are ideal markers for the reconstruction of the timing and impact of the sea-level rise on the transgressed coastal plain. A wealth of information can be obtained by analyzing their buried morphology, stratigraphic position and infilling sediments, such as the location of the paleo coast lines, the dimensions of the paleo lagoon systems and, in some conditions, the relative paleo sea-level. These features can therefore represent valid means to reconstruct the last marine transgression.

The paleo tidal inlets identified in the shelf of the northern Adriatic are characterized by a wide range of thickness, spanning from few to almost 20 m, and by the absence of any evidence of lateral or landward migration. These characteristics, along with the great number of recognized features, suggests the recurrent formation and overstepping of large lagoon systems during the last marine transgression.

In particular, these features can be subdivided into clusters based on the depth of their top, thus allowing to infer the position of a series of paleo coastlines and suggesting the occurrence of periods of stasis of the relative sea-level rise, which allowed the formation of such inlets.

By coupling the ages obtained for the infilling materials and the stratigraphic relations intercurring among the analyzed features, it was possible to reconstruct some of these moments and, in particular, a still stand phase of the sea level was identified around 9.5 ka cal BP, as also confirmed by other indicators available for the Adriatic Sea.

This research provides new insights on two main topics: i) it improves our knowledge on the post-LGM marine transgression, therefore contributing to reconstruct the history of sea-level rise and to constrain the modelling of future behavior; ii) it contributes to understand the evolution of tidal inlets and lagoon-barrier island systems under the forcing of high rates of sea-level rise.

**O-2010**

## **High-resolution bathymetry in select Philippine reefs and their implications on the paleosea level changes since the Last Glacial Maximum**

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### **Abstract**

Coral reefs are effective benchmarks in analyzing past sea levels due to their limited vertical range and good geologic preservation. In the Philippines, most sea level studies are only limited up to 10.2 ky records from emergent reef bodies. In this study, we analyze submerged sea level markers in several localities in the Philippines: Tubbataha Reef, Palawan; Apo Reef, Occidental Mindoro; and Patnanungan Reef, Quezon. High resolution multibeam bathymetry up to 200 m show diverse undersea features including reef mounds, reef ridges and series of multiple terraces and steep scarps. These reefs are further confirmed using diver and drop camera observations. These are interpreted as backstepping reefs that were drowned during an overall rise in sea level from the Last Glacial Maximum (LGM). Comparison of the depth distribution across reefs show clustering in four depth ranges which may correspond to four major sea level stillstands in the past 21 ky in the West Pacific Region. Variations in depth and number of terraces indicate tectonic influence in each site. This provides an opportunity to extend the relative sea level records towards the LGM in the Philippines and elucidate on the history of vertical movements in the region.

## O-2011

### New data regarding the evolution of the paleo-shorelines and paleo-hydrography in the northwestern Black Sea

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#### Abstract

Black Sea is a very peculiar basin, due to its character of a semi-enclosed sea and its episodic connectivity with the Mediterranean Sea and further with the world ocean during Quaternary. This peculiarity produced a complex pattern of paleo-shorelines and paleo-hydrography, imprinted in the sedimentary structures deposited and/or eroded, on the actual continental platform and in the shelf break area. The unsteady regressions and transgressions produced by the successive sea level variations (mainly due to the climatic changes) have controlled the formation/destruction of the paleo-shorelines and corresponding hydrographic networks in the above mentioned areas. The sea level variations has been convoluted with other local, regional or global phenomena, as differential compaction of the young sediments, regional active tectonics and glacial isostatic adjustment; as a result the morphology of the seabed and the shallow sub-structure of the sea-bottom, that are the main geological and geomorphological features we can measure and depict in order to decipher the evolution of the paleo-shorelines and paleo-hydrography in general, are very complex in the NW Black Sea.

The NW part of the Black Sea is the widest shelf area of the present basin and consequently the most prone area to record the paleo-shorelines and paleo-hydrography of this sea. This spatial development is both an advantage in studying the above mentioned evolution (being the most sensitive to the controlling parameters), but also a disadvantage, because of the complexity of the morphological patterns and sub-bottom structures that are the results of the paleo-shorelines migration/erosion, incision/filling up/erosion of paleo-valleys, former developed on the continental platform..

In the framework of the uBiogas (24PCCDI/2018) project we used multibeam echosounding and sub-bottom profiling techniques, together with the radioactive dating, in order to decipher the paleo-geography of the area during Quaternary, that further influenced/controlled the development and the deposition of the organic matter, the raw material for the biogenic methane production and accumulation. We searched for structures that could indicate via further sampling and dating the age of the incisions on the continental platform, thus documenting the timing of the large sediment supply towards the continental slope, contributing to the building up of the Danube deep sea fan edifice.

The studied area is closed to the shelf break, where the paleo-valleys are incised on the continental platform and further developed in deeper waters, on the continental slope.

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O-2012

## Looking Down Under: GPR, OSL, and LiDAR (GOaL) provide insight on sea-level and coastal change through space and time

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### Abstract

Change is constant along the coast, driven by small-scale fluctuations in water level associated with waves/tides, greater variation during periodic storms/surges, and sea level movement over longer time-periods. Deciphering coastal change caused by the imperceptible rise in sea level from shifts associated with storms, sediment supply, and human modification is not straight forward. Sensitive environments with long-term continuous records provide the best opportunity to detect past changes in coastal evolution or sea level, as well as any recent shifts related to anthropogenic global warming. Sandy coasts are vulnerable to future sea-level rise and this sensitivity gives them the potential to preserve records of past changes. Barriers that have prograded during interglacial periods preserve within their accreting sands a series of paleo-beachfaces, the elevation of these relic features is intrinsically linked to sea level and their morphology is inherently affected by storms. Utilizing Ground-Penetrating Radar (GPR), Light Detecting and Ranging (LiDAR), and Optically Stimulated Luminescence (OSL) on prograded barriers has documented changes in evolution and determined the influence (as well as extract paleoenvironmental records) of sea level, sediment supply, accommodation space, and storms.

Here we present the potential of combining GPR, OSL, and LiDAR (GOaL) systematically on several prograded barriers in far-field Australia and New Zealand to disentangle local influences of sediment supply and accommodation space from regional patterns of storms or global changes in sea level. Collecting GOaL data across composite barriers that have prograded throughout the Pleistocene and Holocene can extend these records back to when sea level was known to be higher than today, during the Eemian. Furthermore, constructing sea-level curves along these coasts using GOaL produce dense plots of a single proxy that can identify subtle changes obscured by sparse data or amalgamations of different proxies with various error bars. We will present data from multiple sites that maps the elevation of these beachfaces from the present day over millennia. This data have already contributed to ongoing debates about the elevation and duration of the mid-Holocene highstand in New Zealand and Australia. Detailed records from these more geologically stable settings are sought after to identify the relationship of global ice-equivalent and global sea-level changes in order to model their response to future climate change. These projections, combined with refined records of sea level, storm erosion, sediment supply, and human modification gained from GOaL in a coastal system, will enable more accurate models of future beach behaviour resulting from global warming. Ultimately, this can inform vulnerable coastal communities on how best to prepare for the upcoming centuries when climate change is forecast to return sea-level to elevations not seen for thousands to hundreds of thousands of years.

O-2013

## The morphology and formation of a submarine channel in the southern Irish Sea: an investigation of Wicklow Trough

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### Abstract

A number of submarine channel features have been identified on the southern Irish Sea seafloor including Lambay Deep, Codling Deep and Wicklow Trough. These bathymetric features are distinctive from the surrounding seafloor by their steep depth and morphology and have been described as major incisions (Wingfield, 1989), enclosed deeps (Wingfield, 1990) and tunnel valleys (Callaway et al., 2011; Eyles and McCabe, 1989; Whittington, 1977). They are believed to be part of a late- to post-glacial drainage network and likely represent a series of processes with varying stages of ice excavation and meltwater discharge related erosion.

In this study, we focus on data gathered from Wicklow Trough. We use the spatial integration of multibeam echosounder and sparker seismic data, supplemented by benthic grab samples, vibrocores and digital seabed photography, to characterise its present day morphology and sub-surface structure.

The current morphology and stratigraphy of Wicklow Trough exhibits a high-level of lateral variability with over-deepened sections, inferred glacial and post-glacial deposits infilling the Trough with slump deposits found on the flanks. The data invokes a time transgressive model with headward erosion during ice sheet retreat accompanied by pressurised subglacial meltwater discharge. At present the seabed within Wicklow Trough is highly dynamic and variable consisting of large, actively migrating sediment waves throughout along with scour pits and coarse sediment deposits.

With additional analyses, we aim to further investigate the formation and development of Wicklow Trough. In addition, we aim to discern the development of Wicklow Trough within the broader tunnel valley/glacial drainage system and relative to past ice-sheet dynamics. Similarly, we discuss post-glacial environments of the Wicklow Trough and assess its current geomorphology and active processes. As a result of this study, we will contribute to the growing understanding of British and Irish ice-sheet development and post-glacial, Holocene environments in the Irish Sea.

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O-2015

## REnland ice CAP (RECAP) ice core- proxies for local ice glacier extent and altitude

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### Abstract

Mapping the paleo extent of Greenland glaciers provides tie points for ice sheet models and is important for constraining Greenland's response to climate forcing and contribution to future sea level rise. Here we present a continuous ice core record from the Renland ice cap on the east coast of Greenland and proxies which constrain its local altitude and extent over the past glacial cycle.

The new REnland ice CAP (RECAP) ice core extends 584.11 metres to the bottom of the Renland ice cap located in east Greenland. Due to the unique position on a mountain saddle above 2000 metres altitude, the core archives a climate record including the entirety of the last glacial period, despite the short length. The glacial section is strongly thinned and covers just ~20 meters of the ReCAP core, but nonetheless due to the high resolution of the measurements all 25 expected DO events could be identified. Below the glacial section another ~20 meters of stratigraphically disturbed Eemian ice have been analyzed.

The results from the ReCAP ice core differ from the central Greenland deep ice cores, due to the coastal location and local ice flow. The record was analyzed for multiple ice core proxies including a continuous record (CFA) of insoluble dust particles by means of Abakus laser particle counter and the dust proxy calcium, as well as discrete samples of total air content (TAC).

During both the Holocene and the previous interglacial period (the Eemian), the ice core dust record is dominated by coarse particles from local East Greenlandic sources, whereas the dust from the last glacial period consists mainly of smaller particles from remote sources. The fraction of coarse particles in the record is a proxy for glacier extent in the Scoresbysund area, as the reduction of coarse particles during the glacial indicates that most local dust sources were inactive and/or ice covered.

We find no indication that the Renland ice cap has significantly changed in altitude from the last glacial to the present interglacial period. The Total air content (TAC) in ice cores depend primarily on the altitude and thus we can reconstruct altitude changes for Renland. We find no indication that the Renland ice cap has significantly changed in altitude from the last glacial to the present interglacial period showing the significance on the glacier shape by the surrounding mountains. However high resolution TAC was not possible to obtain in warmest phase of the Holocene as ReCAP was predominantly affected by melt then.



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1. ISCCG ice core location in eastern Greenland.

## O-2016

### **<sup>10</sup>Be CRE dating of moraines in the Isortup valley (Greenland): Evidence of limited glacial advances over the last three millennia**

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#### **Abstract**

Glacial fluctuations during the Holocene have not yet been investigated much in southern Greenland. This work aims to establish an absolute chronology using <sup>10</sup>Be cosmic-ray exposure dating from glacial moraines formed by three mountain glaciers located in the Isortup Valley near one of the largest sites colonized by the Vikings at the end of the 10<sup>th</sup> century. The sample preparation was realized at the CALM laboratory (Meudon, France) and analysed at the CEREGE by the ASTER Team (Aix en Provence, France).

The ages of the moraines suggest at least three phases of glacial advances over the last three millennia. The oldest ice age identified was about 2300 years ago. The second phase synchronous for the three glaciers occurs 1100 years ago, i. e. about 900 CE, and precedes the warm period of the Medieval Climate Anomaly (MCA: ~950 CE to 1250 CE), while the last phase of glacial advance identified corresponds to the Little Ice Age (LIA: ~1450 CE to 1850 CE). Surprisingly, these moraine stages are close to each other and close to the current front (>1 km) for the three glaciers studied. Therefore they show limited glacial extensions and suggest fairly similar climatic conditions to the present one for the three periods identified. Our chronology of glacial fluctuations is then compared with local paleoenvironmental studies of lake sediment core in order to better understand the climatic variations responsible for these glacial advances in relation to Norse settlement patterns.

Our results are consistent with the cold periods identified from other environmental proxies studies conducted in southern Greenland and show that the Norse occupation occurred between two glacial advances. This study provides a new dataset and explores climate variability in southern Greenland. Also provides a better understanding of the factors responsible for the abandonment of Norse settlements.

**O-2017**

## **The expected inception of Icelandic Ice Caps**

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### **Abstract**

Observational constraints of glacier inception are important because they reveal the timing of past periods of cooling, most notably the Neoglacial period. Inception occurs when the equilibrium line altitude (ELA) lowers and intersects the highest bedrock capable of accumulating ice. While the concept of inception is simple, observational constraints of inception are rare because glaciers override and erode sedimentological evidence. Erosional censoring is especially prevalent for the Pleistocene ice caps. Inception evidence is more abundant from the Holocene, but is known for at most, a few glaciers within a region. Here we present a new, efficient method to assess the timing of glacier birth and apply it to Iceland where constraints of inception are relatively abundant. We model the ELAs of 20 ice caps, and in doing so produce the first regional estimates of inception across a population of glaciers. We force the model with lake-, sea- surface-temperature-, and ice-core-derived temperature reconstructions. We also explore the effect of glacial-isostatic adjustment and variable precipitation. Mass balance parameters are tuned for each ice cap using modern data. We use inception constraints based on lake sediments to evaluate the success of individual model simulations. Icelandic glacier inception likely ranged from before the Holocene to the Little Ice Age.

Topography is the primary control of the timing of glacier inception in Iceland. The onset of Holocene (Neoglacial) cooling could be better established using new, simple topographic metrics to identify the glaciers most likely to form first. Our modeling reveals that these simple metrics, easily measured from global data sets, exert a first-order control on inception, and can be used as a rapid means of contextualizing ongoing and future glacier change.

**O-2018**

## **Changes in the drainage pattern of the Eastern Antarctic Ice Sheet since the Late Miocene**

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### **Abstract**

The assessment of the stability of Antarctic ice sheets and of their contribution to the global sea level change as a response to climate change requires the reconstruction of their past volume variations. For instance, dramatic surface lowering of East Antarctic Ice Sheet (EAIS) during the last million years have been recently reported. However, the spatial distribution of this lowering remains unexplored. Today, Sør Rondane Mountains in the Queen Maud Land acts as a barrier to the EAIS. This is displayed by the difference in altitude of the ice surface to the south and north of the mountain chain. To the south, ice surface reaches altitudes above 2500 meters above sea level. Lowlands of ice are found at altitudes of around 1500 meters to the north of the mountain chain. In this study, we aimed to use suite of cosmogenic nuclides (<sup>10</sup>Be, <sup>14</sup>C, <sup>26</sup>Al and <sup>36</sup>Cl) in 38 rock surface samples to decipher the timing, magnitude and frequency of the surface lowering history and change in drainage pattern of the EAIS in the western Sør Rondane Mountains.

During the BELARE 2017-2018 Expedition, we identified abandoned valleys situated at elevations few hundred meters above today's ice surface, which point to a dramatic surface lowering of EAIS in the western Sør Rondane Mountains and thus a change in drainage pattern in time. Based on our first results, we propose that the surface of the EAIS was at least 400 meters higher than today. This indicates a linkage between the south and north of the mountain range and a major drainage towards northeast over the mountain range during the late Miocene. At the beginning of Pliocene, ice surface started to decrease, and the south-north linkage was broken by prior to ca. 1.3 Ma as a result of ca. 400 m of lowering. This caused the ice drainage to be channelized into either few main valleys or around the mountain range. Afterwards, the glaciation continued until around 130 ka, when a dramatic decrease in the ice surface elevation occurred in the ice lowlands to the north of the mountain chain. However, the ice plateau to the south seems not to be affected by the dramatic changes occurred on the northern side of the mountain range.

O-2019

## Response of glaciers since last 20 ka in the transitional climate zone of the Southern Zaskar Ranges (NW Himalaya)

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### Abstract

The transitional climatic zone of the Southern Zaskar Range, NW Himalaya is investigated for the relics of glacier advances and retreats as glaciers responded to the temporal changes in the Indian Summer Monsoon (ISM) and mid-latitude westerlies. Four glacier advances named from the oldest to youngest as the Southern Zaskar Glacier Stage-4 (SZS-4) to SZS-1 are identified. The SZS-4 remains undated, however based on the existing chronology of the stratigraphically equivalent moraines/trimlines in the region; it is conjectured to the Marine Isotope Stage-4 (MIS-4). The SZS-3 is dated using optical chronology to  $22.8 \pm 1.9$  -  $19.1 \pm 1.9$  ka and corresponds to the Last Glacial Maxima (LGM). The SZS-2 is dated to  $15.7 \pm 1.3$  -  $14.3 \pm 1.3$  ka (late Glacial period) whereas, based on the chronology of the recessional moraines ( $4.9 \pm 0.4$  -  $4.5 \pm 0.3$  ka) the youngest SZS-1 is assigned to  $\sim 6$  ka (mid-Holocene). The snout proximal moraines are attributed to the Little Ice Age (LIA)/historical times. The recessional moraines and outwash gravel terraces represent the pulsating deglaciation associated with each advance in last 20 ka. The older gravel terrace is dated between  $10.8 \pm 0.9$  and  $6.5 \pm 0.5$  ka and is attributed to SZS-2 retreat which is also manifested by the deposition of sandy facies in a relict lake sequence ( $6.7 \pm 0.6$  ka) and development of palaeosol ( $5.6 \pm 0.5$  ka). We propose that the glacial advances were triggered by the millennial scale cooling events during the periods of strengthened westerlies and thus, suggest a synoptic scale coupling with the Northern Atlantic. The glacier retreat is suggested to occur during the warmer ISM dominated phases. The late Holocene climatic instability that followed the recession of SZS-1 is manifested by the development of rhythmities ( $3.8 \pm 0.5$  ka), loess ( $2.5 \pm 0.2$  ka), and palaeosol ( $2189 \pm 296$  cal yr BP).

**O-2020**

## **First absolute dating chronology of glaciers variations in the Northern Caucasus**

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### **Abstract**

The glaciers of the Greater Caucasus (42°N; 46°E) are a vital economic and water resource for indigenous peoples. These glaciers are currently declining but it is still difficult to quantify the impacts of anthropogenic activities on this trend. One of the major issues for such quantification is linked to our poor knowledge of the natural forcing effects on glacier evolution. These glaciers can offer an opportunity to document environmental changes in the past

Here we present the first absolute dating chronology of glaciers variations in this region based on cosmogenic <sup>10</sup>Be dating, <sup>14</sup>C ages from paleo-soils and tree ring sampling. 25 rock samples were collected on the largest moraines close to the front position of 5 glaciers in Elbrus region. <sup>10</sup>Be and <sup>14</sup>C ages span the Late glacial and Holocene period. More than 300 trees were cored at the moraines and glacier forefields either at breast height (1.5 m) or at the lowest possible level near the soil surface in order to identify the minimum age of the landforms.

These methods made it possible identifying the major glacier advances over the last 15 000 years. Our precise <sup>10</sup>Be chronology revealed glacier culmination during the oldest Dryas even if the length of the glaciers at that time remains elusive due to pure moraine preservation. We did not identify any deposit directly related to the Younger Dryas. A second major advance occurred during the earliest Holocene ~11.4 k.y. ago. We did not find so far any moraine deposits of similar amplitude accumulated until ~2 k.y. ago, when the glaciers reached last millennium limits. The age of a soil layer buried between two horizons of the moraines of Bolshoy Azau glacier however indicates that at least one large earlier Neoglacial advance occurred before 2880±20 years BP (IGRAS ams – 6827).

Interestingly, at least one glacier advance is observed during the Medieval Climate Anomaly (~950 to 1250 CE). or during the first stage of the Little Ice Age (late 13th century CE). A number of advances between 500 and 170 yr are documented by <sup>10</sup>Be records. Tree-ring minimum dates indicate that the advances occurred in the late 18th century and in the early-mid 19th century CE. General glacier retreat started in the late 1840s CE. A number of minor readvances are identified in the 1860s–1880s CE, as well as in the 1910s, 1920s and 1970s–1980s CE. Based on this glacier chronology we applied a glaciological model making possible to document past climate conditions responsible for these glacier changes.

O-2021

## The significance of interannual variability for paleoclimatic interpretation of glacial moraine sequences

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### Abstract

Mountain glaciers respond to both long-term climate forcing and interannual forcing. Anderson et al. (2014) pointed out that kilometer-scale fluctuations in glacier length may result from interannual variability in temperature and precipitation during a period of “steady” climate with no long-term trends in mean or variability of temperature and precipitation. They cautioned that due to the effect of interannual forcing on glacier length, use of outermost moraines from the Last Glacial Maximum (LGM) as indicators of mean LGM climate will result in overestimation of the magnitude of long-term temperature depression and/or precipitation enhancement. Here we assess the implications of these ideas by examining the effect of interannual variability on glacier length and on the inferred magnitude of LGM climate change from present, under both an assumed steady LGM climate and an LGM climate with low-magnitude, long-period variations in summer temperature and annual precipitation. We use both the original one-stage linear glacier model (Roe and O’Neal, 2009) used by Anderson et al. (2014) and a newer three-stage linear model (Roe and Baker, 2014). We apply the models to reconstructed LGM glaciers in the Colorado Sangre de Cristo Mountains, employing Monte Carlo analysis to assess the effects of multiple glaciological and climatic variables on the magnitude of glacier length variations introduced by interannual variability, and on the resultant overestimation of mean LGM temperature depression introduced by such variability.

Three-stage-model results indicate that, absent long-term climate variations through a 7500-year-long LGM, interannual variability alone would result in glacier length variations of  $\pm 400 - 1210\text{m}$  ( $2\sigma$ ). If the outermost ice-marginal position produced in each model run is taken to indicate mean LGM conditions, this would result in overestimation of mean LGM temperature depression by  $0.17 - 0.45^\circ\text{C}$  ( $2\sigma$ ). If low-magnitude cyclic variations of temperature and precipitation during the LGM are introduced in the model, the magnitude of overestimation of mean LGM temperature depression due to interannual variability decreases, and in a small number of model runs the effect of interannual variability is to cause an *underestimation* of mean LGM temperature depression. If cyclic variations of temperature ( $\pm 1.0^\circ\text{C}$ ) and precipitation ( $\pm 10\%$ ) are introduced, the  $2\sigma$  error in inferred mean LGM temperature depression ranges from a  $0.14^\circ\text{C}$  underestimation to a  $0.31^\circ\text{C}$  overestimation.

O-2022

## The Quaternary history of yew (*Taxus baccata*) — an overview from an Irish perspective

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### Abstract

The Quaternary history of *Taxus baccata* (yew) is readily traceable in the macrofossil record on the basis of its distinctive fruit and leaves and, at a microscopic level, its wood anatomy. Its pollen on the other hand, though distinctive especially at high magnification, is easily confused with other common pollen types including Cyperaceae (sedges), *Quercus* (oak) and *Juniperus* (juniper). This is particularly so in the case of profiles where *Taxus* pollen occurs with low frequencies and is not abundant.

As a result of the difficulties involved in recognising its pollen, it can be assumed that, in many Irish pollen diagrams up to and including most of the 1980s, its pollen went largely unrecognised. A notable exception is the pollen profile from Gort, Co. Galway which is regarded as the standard profile for the Gortian interglacial (Jessen et al. 1959. *Proc. R. Ir. Acad.* **60B**, 1–77). *Taxus* pollen is dominant or at least important for most of this pollen profile which serves to highlight the importance of yew during the Gortian interglacial (equivalent to the Hoxnian/Saalian and Oxygen Isotope Stage (OIS) 11) at this western Ireland location.

Recent investigations have shown that yew also made substantial contribution to Holocene woodlands in Ireland, locally and also regionally, and especially during a period of low human impact in the late Neolithic (ca. 4900 cal. BP). In this presentation, emphasis will be placed on new data that relate to the post-glacial history of yew in Ireland, and the interactions between climate change and human impact in mediating the exceptional post-glacial history of this conifer.

**O-2023**

**Intensive dairying in 4th millennium BC Ireland? The Ceide Fields complex, Co. Mayo, northwest Ireland**

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**Abstract**

The Céide complex of drystone co-axial field systems in north Mayo, northwest Ireland, has been extensively mapped and partly excavated over a number of decades and is argued to be the oldest in Europe, emerging in the 4th millennium BC. While recent research has demonstrated dairying is contemporary with the arrival of farming in Ireland, by at least 3800 BC, there is as yet no proven relationship between the sophisticated land management evidenced at Céide and dairying, although soil lipid analyses have indicated arable farming is unlikely. This landscapes/foodscapes relationship will be elucidated through molecular and isotopic analyses of lipid residues preserved in Neolithic pottery sherds recovered from excavations within the field systems, which provide a powerful proxy for animal husbandry and consumption practices. This new evidence will be set alongside detailed analysis of the dating evidence for the Ceide Fields complex, demonstrating unequivocally the Neolithic date of the field systems and rebutting recent suggestions of a later, Bronze Age date for the activity.

O-2024

## Direct Push sensing and geoaerchaeological sounding at Neolithic Pestenacker settlement (Lech catchment, SW Germany)

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### Abstract

Wetland margins are valuable geoaerchaeological archives due to their preferential settlement conditions in prehistoric time. A high groundwater level usually provides excellent preservation conditions for palaeoecological and geoaerchaeological proxies, as well as for archaeological artefacts. However, this advantage also impairs classical archaeological excavations as a result of the increased groundwater inflow. Alternative percussion drillings offer inaccurate depth data due to the increased compaction rates in organic rich sediments. The direct push sensing technology, rarely used for palaeoenvironmental and geoaerchaeological research, offers the opportunity to overcome this problem. Different probes (soil colour, electrical conductivity, cone penetration testing) provide undisturbed and *in-situ* information with a high resolution in a time-effective manner.

The Neolithic settlement of Pestenacker in the Upper Bavarian Alpine foothills (SW-Germany), represents an exceptionally well-preserved wooden house settlement in a wetland environment. It is located at the *Verlorener Bach* floodplain edge and was dated to the year 3495-3476 BC according to dendrochronological investigations. Its great archaeological and transregional importance led to the inclusion in the UNESCO list of World Heritage Sites in 2011 as a part of the “Prehistoric Pile Dwellings around the Alps”.

The talk combines the first results of the different methods and discusses the floodplain stratigraphy at high vertical resolution and the stratigraphic coupling with the Neolithic settlement layers. By using the direct push technology in combination with classical percussion drilling and sediment analysis, we detect a significant change in the Holocene floodplain lithostratigraphy that correspond with the occurrence of Neolithic Pestenacker settlement. Human impact might induced a significant change in catchment hydro-sedimentary dynamics.

**O-2025**

## **Between the peat layers - evaluating wetland archaeological sites through multi-proxy studies in Ireland's Midlands**

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### **Abstract**

Archaeological excavations undertaken in a wetland environment in Ireland's midlands have uncovered a multitude of well-preserved archaeological sites over the last 5 decades. In particular, areas of dense archaeological activity have been recorded on the peatlands during the Bronze Age/ Iron Age transition. Several well-constructed and interconnecting trackways and wooden platforms are shown to extend out into the bog during this transitional period. Many theories abound as to why these sites were constructed particularly during this time period. The Late Bronze Age climatic downturn, social occasions, ritual beliefs, an unstable society and/or economic resources have all been debated in relation to the construction and use of these sites. The evidence from this transitional period indicates that people were moving around and within bogs as opposed to across them and there are relatively few longer trackway structures. Can we determine patterns of construction and use in relation to other environmental factors (e.g. vegetation change - local and regional)? This paper will discuss pollen analysis undertaken in tandem with plant macro, wood and insect analysis as important proxies in sourcing motives for wetland archaeological site construction as well as anthropogenic landscape change throughout the Bronze and Iron Age in Ireland's Midlands.

**O-2026**

## **Agricultural management practices in Bronze Age Ireland: insights from archaeobotany**

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### **Abstract**

In common with much of Europe, resource management during the Bronze Age in Ireland (2500–700 cal BC) has largely been considered in terms of metal production. The role of agricultural production has received less attention, even though plant macro-remains and pollen records indicate significant levels of crop cultivation during this period.

Although agriculture was introduced into Europe at the beginning of the Neolithic period (4000 cal BC in Ireland), archaeological studies often suggest that intensive systems of agricultural production were not practiced until the Bronze Age. In the case of Ireland and Britain, the increased appearance of archaeologically identifiable fields and farmsteads during the Bronze Age is often understood to represent agricultural intensification. The intensification of agriculture in Bronze Age Europe is considered to be a precursor to increasing social stratification, with the creation of a strong agricultural economic base enabling the development of hierarchies that controlled the means of production and distribution of produce.

This model of increasing intensity over time will be challenged in this paper through detailed consideration of agricultural terminology and archaeological evidence for intensification, with a focus on archaeobotany. As well as ‘traditional’ methods of archaeobotanical analysis, the paper will show how isotope analysis of charred cereal grains is enabling an exciting new approach to understanding agricultural management in prehistoric Ireland. It will be shown that intensification represents just one of many agricultural strategies available to prehistoric farmers in Europe and cautions against an over-focus on this mode of production.

O-2027

## Splitting the stones! Examining the occurrence and societal impact of drought events in mid- to Late Holocene Ireland

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### Abstract

The maritime climate of Ireland has no doubt had a bearing on Irish identity, encapsulated by the national colour and the island's poetic epithet, the "Emerald Isle", both of which reflect the lush, green pastures that characterise much of the landscape. The weather – specifically, the persistent rain – is a long-standing topic of conversation and humour across the island, and spells of "good weather" (i.e., warm sunshine) are cherished for their relative rarity. But have past populations in Ireland always experienced the same conditions? Discussions of climate impact on prehistoric and early Medieval societies in Ireland have tended to consider how shifts to wetter and/or colder conditions will have negatively impacted the subsistence economy, leading perhaps even to social turmoil and demographic catastrophes (e.g. Turney et al. 2006). Dendrochronological, peatland proxy and early literary evidence demonstrate, however, that Ireland has at times experienced extended (decadal to centennial) phases of drier conditions (Kerr et al. 2009; Swindles et al. 2010; 2012; Torbenson et al. 2012), and documentary evidence highlights the detrimental impact short-term drought has sometimes had on societies. Here we review the palaeoenvironmental evidence for warmer and/or drier periods on the island over the last 9,000 years. With reference to the archaeological and palynological records, we consider the possible socio-economic repercussions of these phases and evaluate whether or not such events played any role in cultural transformations.

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O-2028

## Mining activities in the Bernese Alps from the geochemical analysis of alluvial sediments

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### Abstract

Mining and smelting activities can release large amounts of metals into the atmosphere, hydrosphere, sediments and soils. Despite the current pollution levels, this contamination is not exclusive of modern industrialisation. For instance, various studies have identified large-scale metal pollution during the Roman and Medieval Periods. The aim of this study centres on the detection of such contamination periods during the last 2500 years, inferred from sedimentary records of the Hasli-Aare delta plain, at the Bernese Alps. The identification of the metal contamination signal is achieved by the analysis of the geochemical responses of four chemical elements: iron (Fe), copper (Cu), zinc (Zn) and lead (Pb). This analysis was performed primarily by X-ray fluorescence (XRF), but results were also compared with conventional XRF, from the analysis of 82 pearl samples. To detect the metal pollution signal, chemical element peak anomalies were selected from values higher or equal to  $\bar{X}+SD$  of the entire record. Additionally, we use archaeological and historical sources to corroborate our findings and establish an index of mining activities.

Results from the analysis of the three sedimentary records facilitated identification of the most significant trends of Fe, Pb, Zn and Cu contamination, which correlate with periods of mining activity in the Upper Aare catchment. Considering the positive anomalies of the metal concentration index, four major clusters of higher metal concentrations can be identified. The first major cluster occurs during the prehistoric period, at the end of the Iron Age, between 160 and 100 BCE; the second major cluster occurs at the end of the Roman Period and the beginning of the Early Medieval Period, between 250 and 590 CE; the third major cluster occurs in the Late Medieval Period between 1100 and 1250 CE; and the fourth major cluster occurs at the end of the Late Medieval Period and continues throughout the Modern Period.

The high metal concentration during the prehistoric period is associated with the middle/end of the La Tène culture, which made extensive use of metal and were considerably advanced in their metal-working. The contamination cluster during the Roman Period and beginning of the Early Medieval Period is in accordance with the importance of metal in the roman economy and is also largely corroborated by other sedimentary records that show similar anomalies. The pollution signal from the end of the Late Medieval Period until the Modern Period is supported by various historical records and a few archaeological remains.

Periods of lower metal concentrations and shifts in contamination trends correspond quite accurately with social and economic changes in Central Europe, regional migratory events within Switzerland and significant demographic fluctuations.

O-2029

## Patterns of modern pollen and plant richness and functional diversity across northern Europe

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### Abstract

Pollen data is often used to characterise past vegetation composition and diversity. To improve the interpretation of sedimentary pollen data, it is essential to understand the relationship between pollen and plant richness in contemporary landscapes. This study presents a regional-scale comparison of pollen and plant diversity from northern Europe and evaluates the importance of environmental variables on both pollen and plant diversity. We use a pollen dataset of 511 lake-surface pollen samples ranging through temperate, boreal, and tundra biomes. To characterise plant diversity, we use a dataset formulated from the two largest plant atlases available in Europe. We compare richness estimates and functional diversity estimates based on plant and pollen data.

Pollen richness is significantly positively correlated with plant richness ( $r=0.53$ ). The highest correlation is found between pollen and plant richness of trees and shrubs ( $r=0.83$ ) suggesting that these are the best measures of broad-scale plant richness over several thousands of square kilometres. Data of trees and shrubs is therefore used to test how well pollen data can reflect functional diversity. Community weighted mean values of seven quantitative traits (seed weight, leaf area etc.) are all significantly ( $p<0.05$ ) positively correlated in pollen and plant data of trees and shrubs. The highest correlations are found for seed weight ( $r=0.75$ ) and leaf area ( $r=0.68$ ). For functional diversity (the standardised effect size of mean pairwise distance), the correlations between pollen and plant data are significantly positive for seed weight, leaf weight and leaf area.

Our results confirm that pollen data can provide insights into past plant diversity changes in northern Europe. Reconstructions of mean trait values and functional diversity of chosen traits allow to investigate trends in functional vegetation diversity over long timescales and under changing climatic and habitat conditions.

**O-2030**

## **Are communities unsaturated? A millennial scale palaeoecological approach**

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### **Abstract**

Over the last 540 million years, the diversity of life on Earth has increased despite the occurrence of five catastrophic mass extinctions events. Under the current global change, habitat destruction and the introduction of exotic species are the main causes of a worldwide species extinction. However, beyond the global speciation and extinction events, at ecological time scales local diversity is currently increasing in many assemblages. Assuming that communities are saturated, the observed increase in richness could be due to an extinction debt, a transient phenomenon between two ecological states. However, several theoretical developments and empirical data showed that there is no reason to assume an upper bound (other than space) for local and regional richness. Hence, under an open community scenario richness could increase over time. To improve conservation policies is necessary to solve the saturation debate, at least at ecological time scales. Actually, predictive biodiversity models for species composition and richness are mainly considering that there is a limit in the number of species that can coexist in a community. Hence, there is a need for long-term data to include long-term processes and slow variables to understand community assembly and saturation. Here we show a Holocene lake sediment record of benthic and planktonic protist assemblages indicating that communities still unsaturated after 10.000 years (Fig. 1). We observed an early establishment of core functional species that are responding to long-term changes in Holocene climate and lake biogeochemistry. Protist productivity and the abundance of core species declined during north hemispheric cold spells, which lead to a transient increase in rare species. However, after these cold spells species gains was always higher than species losses, which results in the observed increasing trend in richness all through the Holocene. These results points on the relevance of disturbances to maintain and increase local diversity. However, at this stage, we do not know if the local increase on richness is related to a transference of diversity from b-diversity to a-diversity, which would cause a long-term regional biotic homogenization.

**O-2031**

## **Using species indicator values to characterize late-glacial and early Holocene environments and biomes at Kråkenes, western Norway**

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### **Abstract**

Environment and climate control plant distributions. Each species has a tolerance range, which can be characterised by species indicator-values. Several species indicator-values exist for many plants and they have been extensively used in ecological studies to assess environmental changes and ecosystem quality along gradients. However, these values are also valuable tools for reconstructing environment from palaeoecological data.

We used species indicator-values to reconstruct environment and past biomes from detailed plant-macrofossil data from Kråkenes, Norway, covering the late-glacial and the rapid warming into the early Holocene (ca. 14-9.0 ka). We use the well-known Ellenberg values and a newer set of attributes for species geographical distribution along north to south and east to west gradients. This offers a new and simple approach to reconstructing past biomes.

The results show that a stable arctic-montane biome during the late-glacial shifted at the start of the Holocene around 11.5 ka successively into a wide temperate biome ca. 9.0 ka (approximately 2500 years). At the same time, eastern and circumboreal elements characteristic of the late glacial decreased consistently indicating a change from Eurosiberian to European and towards Suboceanic environments.

Mean July and January temperatures are inferred from the modern distributions of the macrofossil species. They show similar patterns to the chironomid-inferred mean July temperature trends at Kråkenes, but these have larger fluctuations and interesting differences in timing. This may be due to different aquatic and terrestrial conditions. Air and lake-water warm quickly, whereas terrestrial substrates warm more slowly as ice melts and species' colonisation lags the temperature development.

Changes in light demand (L), soil moisture (F), productivity (N) and soil reaction (R) show different, but complementary responses. Light demand decreased in time. Soil moisture was relatively stable until it increased during organic soil development during the Early Holocene. Soil nitrogen (a proxy for productivity) also increased during the early Holocene. Soil reaction (pH) increased during the Younger Dryas due to soil disturbance by frost activity. It decreased markedly at the start of the Holocene, reaching low but stable values in the Early Holocene.

Results of our study support earlier interpretations of the vegetational and environmental history at Kråkenes. However, they represent a new and simple way to summarise complex palaeoecological data using similar metrics to those used in modern ecological studies. The responses to past climate warming may help predict what can be expected under present and future climate warming in arctic and alpine regions.

O-2032

## Using palaeoecology to guide conservation in protected areas of central Spain: A tale of ancient land-use and ungulate management legacies

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### Abstract

In the Mediterranean Basin, long-lasting human activities have largely resulted in forest degradation. Consequently, conservation efforts aimed at preserving and restoring Mediterranean forests often lack well-defined targets when using current forest composition as a reference. In the mountainous areas of central Iberia, land-use has heavily affected woodlands for centuries and even millennia. To assess future developments and as a baseline for planning, environmental managers are interested in understanding the origins of today's landscapes, what were the composition and structure of the 'original' ecosystems and their range of variability. With this main goal, we have been conducting palaeoecological research activities in the Sierra de Guadarrama ('Guadarrama') and Cabañeros ('Cabañeros') National Parks of central Spain during the last years, with a strong focus on conservation and restoration. We have relied on a multi-site (three sites in Guadarrama, two in Cabañeros) and multi-proxy (pollen, stomata, macrofossils, dung fungal spores, charcoal) approach supported by robust chronologies based on the radiocarbon dating of terrestrial plant macrofossils and peat.

Our results show that management history has a strong legacy in current woodland composition and structure. For instance, *Pinus sylvestris* forests have been very stable in Guadarrama for millennia because of the high value of its timber in the past, only declining for short intervals following enhanced grazing and fire occurrence. Contrarily, *Quercus pyrenaica* woodlands appear rather degraded nowadays after centuries of intense coppicing to produce firewood and charcoal, and heavy grazing. In Cabañeros, our data also show a remarkable ecological and engineering resilience of the dominant tree species, deciduous and evergreen *Quercus*, to changing disturbance regimes (e.g. fire, farming), but also a significant decline in the rear-edge populations of *Betula* as a consequence of enhanced grazing activities during the Middle Ages. Our dung fungal spore records indicate that herbivore densities during the last decades are truly unprecedented in Guadarrama and Cabañeros in the context of the last millennia and this may compromise the future persistence of *Quercus pyrenaica* and *Betula*, given the sensitivity to grazing they have shown in the long term.

In summary, our palaeoecological data have allowed: (i) to assure the natural status of pine forests at mid-elevations in Guadarrama; (ii) to prove that birches were more abundant in the past in Cabañeros; (iii) to disclose the existence of significant legacies on the structure of oak woodlands; and (iv) to highlight the sensitivity of birches and deciduous oaks to overgrazing, and the subsequent need for controlling ungulate densities in protected areas and for protecting relict birch populations from browsing by wild ungulates. Finally, we would like to stress the importance of the close and direct contact with the staff of the National Parks to ensure the use of the palaeoecological data in practice.

**O-2033**

**An analysis of what ecological shortfalls paleoecological data is most suited to address: the case of ancient DNA of plants**

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**Abstract**

Ecological shortfalls beset all modern ecological studies: we have incomplete information about species identities, distributions, evolutionary history, functional roles, population dynamics, abiotic tolerances, and ecological interactions. A limiting aspect of many ecological studies to properly address these gaps in our knowledge is the short timeframe, they are rarely longer than a decade, and often inferences are made from only a few years-worth of data. Paleoecological proxies, including pollen, DNA and macrofossils, can remedy this lack of temporal breadth, providing information about distributions, population dynamics, abiotic tolerances and evolutionary history back in time. Functional roles and ecological interactions of plants in the past can be inferred based on our knowledge from today, along with the assumption of the principle of uniformity of nature. Yet, addressing shortfalls, particularly population dynamics, depends on reliable abundance information, while others are dependent on relevant spatiotemporal and taxonomic resolutions which can be challenging to acquire with paleoecological data.

In this study, we look into which ecological shortfalls paleoecological studies are most suited to resolve, exemplified by ancient DNA of plants. Detection of plants from ancient DNA (aDNA) is a proxy that can provide good taxonomic depth and breadth, particularly as databases and laboratory procedures improve. We address the typical spatiotemporal and taxonomic resolutions of both plant community aDNA research and modern ecological vegetation research, with emphasis on study design, and discuss the implications in the context of addressing ecological shortfalls. A careful consideration of these knowledge gaps opens up opportunities for integration between paleo- and modern ecology.

O-2034

## Environmental controls on pollen chemistry variation and implications for palaeoecological research.

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### Abstract

Quaternary palynologists are heavily reliant on the use of morphological analysis of sub-fossilised pollen grains to document compositional assemblage changes through time. However, traditional methods for pollen identification based on morphology are time consuming and limited by taxonomic precision. Predictions of future ecosystem dynamics rely on our knowledge to identify ecosystems and the species they are comprised of. The ecological information obtained from fossil records is constrained by taxonomic difficulties for some taxa, preventing identification to species level. Infrared spectroscopy has been proposed as a promising alternative approach, which uses the information on chemical composition of pollen by characteristic spectral bands and features, using specific signals from lipids, carbohydrates, sporopollenin and other cell-wall biopolymers that can be used to fingerprint species. Exploring the chemical variation of pollen in modern samples is an important step to apply these methods in palaeoecological research.

This study aims to apply two IR pollen-chemistry methods on *Quercus* and *Eucalyptus* pollen sampled from wild populations in Australia and Portugal, and environmental gradients. *Quercus* and *Eucalyptus* are useful models to test this method, because of large numbers of species in both taxa, which are hard to identify using traditional light microscopy methods. Both genera are interesting objects of study: *Quercus* inhabits a large ecological range and is an integral part of woodlands all over the world, while *Eucalyptus* and its unique fire dynamics through time remain unclear.

Fourier Transformed Infrared Spectroscopy (FTIR) is used to explore the variation in lipid, carbohydrate and protein content, while the composition of sporopollenin is investigated using Raman Infrared Spectroscopy. Here, we present work which investigates whether: (i) taxonomic signals in chemical spectra of *Quercus* and *Eucalyptus* groups can be identified down to species level, (ii) environmental signals are stored in chemical spectra of *Quercus*, (iii) variation in pollen chemistry on population level. These results represent an important stepping-stone for applying pollen-chemistry techniques to fossil samples. Improved taxonomic resolution would improve our understanding of *Quercus* expansions and contractions in response to climate changes during the Quaternary, as well as fire-vegetation dynamics in *Eucalyptus* dominated systems. These methods could be applied to other genera as well and in combination with traditional light microscopy improve the information we can obtain from fossil samples. In addition to increased taxonomic resolution compared to light microscopy, these methods have the potential to uncover differences in chemical composition based on environmental influences or population differences in sporopollenin chemistry. Environmental and population information obtained from fossil records could improve our ability to explain current and future ecological dynamics with palaeoecological research.

O-2035

## Understanding forest responses to climate change in sub-arctic Canada: integrated palaeoecological and ecological records from the Northwest Territories

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### Abstract

High boreal environments are particularly susceptible to predicted temperature increases, where ecosystem interactions are both spatially variable and driven by episodic natural disturbances. Palaeolimnological studies from sites above the modern treeline in the Northwest Territories have revealed the dynamic nature of the response of the boreal ecozone to inferred climate warming during the mid-Holocene. However, knowledge of the character and timing of landscape evolution in the first few millennia after deglaciation remain poorly understood. This period was characterised by complex environmental changes as glacial meltwaters drained from the region and boreal forest communities migrated northwards in response to climate amelioration. This paper will draw upon peatland and lake sediment records from a transect of sites (n=9) that extends from the central Great Slave Lowlands to the tundra ecozone ca. 200 km to the northeast to (i) provide new insights into rates of peatland initiation, vegetation colonisation and treeline mobility in the early to mid Holocene; and (ii) appraise the utility of a range of proxies (pollen, stomata, chironomids, diatoms and charcoal) for understanding climate-environment interactions during this interval. Such insights have the potential to provide important context for understanding the impacts of future climate change in the region. Quantitative temperature reconstructions will be presented that are derived from fossil chironomid assemblages from three lakes (Matthews Lake, Horseshoe Lake and Frame Lake). These show that during the early Holocene (prior to ca. 8000 cal yr BP) temperatures exceeded present conditions by ca. 1-2 °C, whilst palynological data, particularly evidence from fossil stomata, reveal a more dynamic treeline in the mid-Holocene than previously documented. Pollen data from a transect of modern lakes (n=57) from the same region helps to better contextualise some of the inferred changes in Holocene forest dynamics, but also highlights some of the difficulties of using arboreal pollen data to reconstruct treeline position. Together the records provide a basis for further re-assessment of the character, timing and impacts of regional climate fluctuations in this sensitive northern region, and underline the benefits of integrating long-term palaeoecological data with an understanding of modern ecological processes.

**O-2036**

## **Simulations of Quaternary glacial cycles with complex and simple models**

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### **Abstract**

Significant progress has been achieved in recent decades in the understanding of Quaternary climate dynamics. A number of complex and conceptual models which can reproduce the major features of glacial cycles have been proposed. In particular, using the Earth system model of intermediate complexity CLIMBER-2, we were able to simulate the entire sequence of Quaternary glacial cycles. The CLIMBER-2 model incorporates all major components of the Earth system – atmosphere, ocean, land surface, northern hemisphere ice sheets, terrestrial biota and soil carbon, aeolian dust and marine biogeochemistry. Using this model we performed a set of simulations covering the last 3 million years using as the only forcing variations in the Earth's orbital parameters and gradually evolving in time land-ocean distribution and terrestrial sediment cover. We found that gradual removal of the terrestrial sediments from the Northern Hemisphere continent by glacial processes is sufficient to explain the transition from 40-kyr to 100-kyr worlds. Using the result of CLIMBER-2 simulations we also developed a simple model which is able to reproduce the behaviour of the complex model. Results of simulations with both complex and simple models shed light on the fundamentals of Quaternary climate dynamics and strongly support the notion that Quaternary glacial cycles are externally forced and deterministic.

O-2037

## A low-latitude driver for Northern Hemispheric ice-sheet build up during the Mid-Pleistocene Transition

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### Abstract

The Mid-Pleistocene Transition (MPT, 1.2–0.6 Ma), characterized by the still elusive switch from a 41 kyr to 100 kyr glacial-interglacial cyclicity, constitutes one of the most prominent changes of climate modes throughout the Cenozoic<sup>1,2</sup>. The massive expansion of glacial ice sheets commencing between Marine Isotope Stages (MIS) 24–22 is thought to be instrumental for this switch, as it prolonged the response time of the climate system to orbital forcing. This ice-sheet expansion also coincides with the so-called “900 kyr event”, a time when the Atlantic Meridional Overturning Circulation (AMOC) critically weakened resulting in prolonged cold sea-surface temperature (SST) conditions in the North Atlantic<sup>3,4</sup>. Although these cold background conditions favor the sustainability of large ice sheets, they also decrease the atmospheric moisture saturation level, raising a question about the pathways of moisture that would have fed extensive glacier growth in the Northern Hemisphere during that time. Here, we use Mg/Ca-derived mid-latitude Atlantic deep-thermocline temperatures, covering the MPT, to show that decreased thermocline stratification between 40 °N and 60 °N allowed accumulated subsurface heat to reach the surface of the subpolar North Atlantic, particularly during MIS 22. These relatively warm high-latitude SST would have provided a potent moisture source for glacier growth. Our data further indicate that mid-latitude stratification in the North Atlantic is predominantly driven by low-latitude processes, and might therefore act as a mediator for imposing low-latitude climate pacing onto high-latitude glacial ice-sheet dynamics. The combination of this precession-paced low-latitude mechanism for subsurface heat transport into the North Atlantic with the pre-existing obliquity modulation of ice-sheets may have contributed to the emergence of the 100 kyr beat during the MPT<sup>5,6</sup>.

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O-2038

## Ocean circulation during the last nine interglacials inferred from carbon 13 isotopes

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### Abstract

Interglacials before the Mid-Bruhnes Event (around 430 kyrs BP) were characterized by colder temperature in Antarctica, lower sea level and lower atmospheric CO<sub>2</sub> compared to the more recent interglacials. Climate simulations have shown that the climate of the interglacials before and after the MBE can only be reproduced when taking into account changes in orbital parameters and atmospheric CO<sub>2</sub> concentrations (Yin and Berger, 2010; Yin and Berger, 2012). Indeed, interglacial atmospheric CO<sub>2</sub> concentrations were ~250 ppm and ~280 ppm prior and after the MBE, respectively. Yet, the cause for this change in atmospheric CO<sub>2</sub> remains mainly unknown. Climate simulations suggest that oceanic circulation was different during the interglacials due to the different background climate states (Yin, 2013). The changes of oceanic circulation could have modified the carbon cycle: a more sluggish circulation would lead to greater carbon sequestration in the deep ocean and, subsequently, a decrease of atmospheric CO<sub>2</sub>. However, the possibility of changes of ocean circulation during the pre-MBE interglacials compared to post-MBE interglacials has not yet been assessed using proxy data.

Here we present a new global compilation of benthic foraminifera carbon isotopic ( $\delta^{13}\text{C}$ ) records from 31 marine sediment cores covering the last 800 ka to evaluate possible changes on interglacial circulation across the MBE. We show that the Atlantic  $\delta^{13}\text{C}$  distributions obtained from marine sediment cores vary among interglacials, but that all of them differ largely from a glacial state. A small systematic difference between pre and post MBE interglacial  $\delta^{13}\text{C}$  is observed, which could be linked to small changes of oceanic circulation. We also use the intermediate complexity model iLOVECLIM (Goosse et al., 2010 ; Bouttes et al., 2015), which simulates carbon isotopes, to evaluate the  $\delta^{13}\text{C}$  changes than can be obtained with different circulation changes.

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O-2039

## $\delta^{18}\text{O}_{\text{atm}}$ variations at orbital scale and comparison with coupled climate model equipped with oxygen isotopes

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### Abstract

Glacial-interglacial cycles are recorded in various climatic archives from high to low latitudes over the Quaternary. The EPICA Dome C (EDC) ice core provides a high-resolution record of  $\delta^{18}\text{O}_{\text{atm}}$  (i.e.  $\delta^{18}\text{O}$  of atmospheric  $\text{O}_2$ ) which combines past variations of the low latitude water cycle and of the biosphere productivity. Over the last 800 ka, the  $\delta^{18}\text{O}_{\text{atm}}$  presents similar orbital variability to the summer insolation at  $65^\circ\text{N}$ . However, the uncertainty associated with the  $\delta^{18}\text{O}_{\text{atm}}$  / insolation relationship for building ice core chronology is high (6 ka) and limits the interpretation of ice core records in terms of past climate dynamics. Based on comparisons between the  $\delta^{18}\text{O}_{\text{atm}}$ ,  $\delta\text{O}_2/\text{N}_2$  and their respective orbital targets as well as with the  $\delta^{18}\text{O}_{\text{calcite}}$  from low latitude speleothems, we propose a new EDC chronology with reduced uncertainties using a new dating strategy based on the synchronism between  $\delta^{18}\text{O}_{\text{atm}}$  and  $\delta^{18}\text{O}_{\text{calcite}}$ .

To address the lack of quantitative interpretation of the  $\delta^{18}\text{O}_{\text{atm}}$  and check our assumption of synchronicity between  $\delta^{18}\text{O}_{\text{atm}}$  and  $\delta^{18}\text{O}_{\text{calcite}}$ , we use a modelling approach to simulate precise estimates of past oxygen fluxes over several glacial-interglacial cycles. This approach combines (1) the coupling between the intermediate complexity climate model iLOVECLIM and the vegetation model CARAIB, (2) an estimation of the oxygen fluxes associated with photosynthesis and respiration processes, (3) an estimation of the isotopic composition of the oxygen in leaf water ( $\delta^{18}\text{O}_{\text{leaf}}$ ) and (4) an estimation of the oxygen fractionation during oxygen uptake. This method associates the climatic parameters and water isotopes simulated by iLOVECLIM with the changes in vegetation distribution and terrestrial biosphere productivity obtained by CARAIB for 26 PFTs (Plant Functional Types) instead of the 2 PFTs previously used in iLOVECLIM.

We present here the results of this new coupled model over several glacial-interglacial cycles. We discuss the spatial distribution of the  $\delta^{18}\text{O}_{\text{leaf}}$  as well as the oxygen fluxes linked to the continental biosphere productivity. The  $\delta^{18}\text{O}_{\text{leaf}}$  corresponding to the terrestrial contribution of the  $\delta^{18}\text{O}_{\text{atm}}$ , our results can be compared, as a first approximation, to the isotopic  $\delta^{18}\text{O}_{\text{atm}}$  data measured in EDC ice core and to the simulated  $\delta^{18}\text{O}_{\text{calcite}}$  of low latitudes speleothems.

**O-2040**

## **Modeling the evolution of the Northern Hemisphere ice sheets around Marine Isotope Stage 19**

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### **Abstract**

The Marine Isotope Stage 19c (MIS19c) interglacial period (~777,000 years ago) is a good orbital analog to the Holocene and thus it can be contemplated as the current climate system in the absence of any anthropogenic influence. We here run an ice-sheet model forced by the simulated climate of MIS19 from a recent realisation of a general circulation climate model. We show that different ice sheets likely existed at this period. The most extended and thick of this ice masses develops west of Greenland, gathering Baffin and Ellesmere Islands together with the Canadian Archipelago, at the same time as smaller ice sheets are found in Alaska, Northeastern Siberia and the Barents-Kara region. Transient simulations are also carried out in which, by perturbing the former MIS19 climate, we investigate the following glacial inception. Particularly, we focus on the effects that the recorded abrupt changes in humidity advection in Southwest Europe may have had on the evolution of the Eurasian ice sheets.

O-2041

## Climate-driven vegetation changes during MIS 12 and MIS 16 in southwestern Europe

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### Abstract

Understanding the dynamics of the climate system during past climatic extremes under diverse boundary conditions is one of the major challenges in paleoclimate research. Only few direct sea-land comparison records exist for past glacials, and none is available for the most severe glacials occurring after the middle Pleistocene transition such as the Marine Isotopic Stages (MIS) 16 (621–676 ka) and MIS 12 (424–478 ka). Both glacials are characterised by increasing ice volume since the glacial onset until the beginning of deglaciations and are marked by major instabilities of Northern Hemisphere ice sheets during the glaciation onset, before the peak glacials and during deglaciation. Those Northern Hemisphere ice sheets instabilities are however stronger after the peak glacial as revealed by maxima of ice-rafted detritus deposition in the North Atlantic. The major difference between the two interglacials is associated with the meridional SST patterns in the North Atlantic region which has been attributed to a more northern position of the Arctic front during MIS 16 when compared to MIS 12.

We present the first high-resolution direct sea-land comparison (including pollen, alkenone derived SST, % C37:4 and benthic  $d^{18}O$ ) of IODP site U1385 from the SW Iberian margin, encompassing the MIS 16 and MIS 12. Our data show that dry conditions over western Iberian Peninsula are synchronous with major freshwater pulses in the North Atlantic during both glacial periods. However, the driest conditions were attained during the onset of MIS 16 and prior to MIS 12 peak glacial rather than during episodes of maxima IRD deposition (deglaciations) in the North Atlantic region. Here we will discuss about the possible drivers of such unexpected signal within each glacial period.

**O-2042**

## **Last Interglacial $\delta^{13}\text{C}$ variability in the North Atlantic - a model study**

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### **Abstract**

The variability of  $\delta^{13}\text{C}$  in watermass can be used to infer changes in ocean circulation, watermass ventilation and changes in biological carbon pump, among others. New high resolution proxy reconstructions reveal that during the Last Interglacial (125-115ka) the variation of  $\delta^{13}\text{C}$  in the North Atlantic is not homogeneous both in space and time. Previous studies revealed that during this period the reconstructed  $\delta^{13}\text{C}$  trend was different from one sediment core site to the other (Gardar Drift IODP site U1304 vs Eirik's drift MD03-2664) highlighting the sensitivity of the watermass in these locations to modifications in the ocean circulation, ventilation, or biogeochemistry. In addition, abrupt changes of  $\delta^{13}\text{C}$  have also been clearly shown, suggesting deep and fast changes of these watermass properties over short time window. In this study, using an Earth System Model of intermediate complexity (iLOVECLIM), we analyze the changes in  $\delta^{13}\text{C}$  at these two sediment core sites by performing a set of transient simulations, with varying external forcings that could contribute to watermass property changes in the region. Under the preindustrial climate, the model reproduces fairly well the observed  $\delta^{13}\text{C}$  distribution. In our last interglacial simulations, we vary the fresh water input, which is presumed to impact the ocean circulation and ventilation, and therefore the  $\delta^{13}\text{C}$ . The fresh water is introduced in different regions for each experiment: (1) the Labrador Sea and (2) at the Ruddiman belt over the Eemian period (125ka-115ka). In addition, abrupt and fast change of fresh water input will also be tested by performing an 8.2 event scenario.

O-2043

## Human-environment dynamics in Jordan's eastern desert from 400,000-30,000 years ago: modelling the Azraq wetlands palaeolandscape and regional settlement patterns

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### Abstract

Located in the eastern desert of Jordan, the resource-rich ecosystem of the Azraq wetland has been a magnet for humans and human ancestors for at least the past 400,000 years. Lower, Middle, Upper, and Epipaleolithic occupations have been discovered throughout the endorheic Azraq basin, and recent work in the central wetland indicates that, at particular times in the past, the spring-fed Azraq oasis area functioned as a desert refugium for inhabitants of the basin during dry regional conditions. These dry period occupations were separated by extended wet periods—spanning tens of thousands of years—when the central Azraq basin filled with a large, shallow lake. Such fluctuations in the extent and distribution of freshwater resources played an important role in the lives of Azraq's Pleistocene inhabitants, and we argue that regional settlement patterns between 400,000-30,000 years ago reflect hunter-gatherer mobility and adaptation to regional palaeoclimatic conditions.

Here we present the results of stratigraphic and site formation analysis at the 270,000-year-old Shishan Marsh 1 (SM1) excavation site, combined with a deposit model of the surrounding Shishan Marsh landscape using sedimentological data from ten additional stratigraphic sections. Drawing on a series of optically stimulated luminescence, uranium-series, and radiocarbon dates, the newly developed deposit model for the Shishan Marsh is integrated with previous work in the area to reconstruct the late Middle and Late Pleistocene palaeolandscape of the greater Azraq oasis area. Together with geomorphic and stratigraphic data from outside the central Azraq basin, the palaeolandscape model indicates a complex pattern of settlement dynamics that is intertwined with fluctuations in the extent and distribution of freshwater resources over the past 400,000 years. These palaeoenvironmental fluctuations had dramatic effects on Pleistocene vegetation and faunal variability, which in addition to geomorphic changes have impacted the modern visibility and distribution of archaeological remains. Deciphering this complex settlement history and identifying specific hunter-gatherer adaptations to fluctuating freshwater resources in the Azraq basin has important implications for early human dispersal across arid southwest Asia.

O-2044

## A high-resolution Late Quaternary palaeoenvironmental and archaeological chronostratigraphy for North Eastern Libya

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### Abstract

A significant issue for palaeoecologists and archaeologists working with long sequences is the degree to which they retain a complete reflection of past environments, climates and human activity. This is particularly the case in caves, where sedimentation is sometimes discontinuous. Here we reassess the chronology and present a first detailed assessment of the upper part of the Haa Fteah Cave in the Gebel Akhdar in Northeast Libya; an important biogeographic refugium where continuity of human settlement was perhaps possible during the last glacial period.

In the 1950s, excavations of the Haa Fteah uncovered a lengthy Late Quaternary sequence of human activity with an iconic lithic sequence. Subsequent research on the prehistory of North Africa has used these discoveries as a yardstick. However, the chronology of the cave stratigraphy and archaeological sequence was based on a small number of age determinations made very early in the history of radiocarbon dating. Modern chronostratigraphic techniques were used in a recent reassessment of the age of the sequence, but considerable uncertainties have remained.

This paper presents the high resolution chronostratigraphy for the last ~50ka years of the Haa Fteah cave-fill using 241 AMS radiocarbon dates on charcoal, seeds and shells along with tephrochronology and OSL dating which have been integrated with climatic patterns deduced from molluscan assemblages and  $\delta^{18}\text{O}$  stable isotopes. Integral to this has been the ability to reliably radiocarbon date the stratigraphically ubiquitous terrestrial gastropod *Helix melanostoma*, which has a consistent  $^{14}\text{C}$  shell reservoir offset of  $476 \pm 48$   $^{14}\text{C}$  yr.

The very high resolution of the dating of the Haa stratigraphy reveals a complex sedimentary sequence with multiple short depositional hiatuses; significantly improving our understanding of the chronology of the archaeological sequence and the processes underlying sedimentation in long-sequence cave sedimentary deposits of this type. It also shows the difficulties in developing age-depth chronologies in caves without very high-resolution dating. The ability to reliably  $^{14}\text{C}$  date terrestrial shells throughout the sequence also means we can now tie climatic and stratigraphic information to evidence for anthropogenic activity reliably throughout the studied sequence.

This tightly linked framework of fine-scale geomorphology and fine scale dating, has enabled us to demonstrate with sufficient clarity that the atypical climate of the Gebel Akhdar during the Late Quaternary was a clear factor in the ability of early people to occupy the region continually; thus remaining a refugium when much of the rest of Northeast Africa was uninhabitable through extreme aridity. The success of this approach, on a sequence as complex as the Haa Fteah, emphasises the need for high resolution multiple dating allied with sophisticated geoarchaeology in we are to use humanly occupied caves in addressing these 'big questions' about humans and climate change.

**O-2045**

## **Human-environment interaction in the Upper Palaeolithic of the Southern Levant**

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### **Abstract**

Human adaptation to the environment and the resulting settlement patterns are a major point in the understanding of hunter-gatherer economy and subsistence, and rarely more so, than in environments including different ecotones as the Southern Levant. For the timeframe of the Upper Palaeolithic the results of a geoarchaeological study are presented investigating these processes on two different scale levels. A dataset of 129 inventories of published Upper Palaeolithic sites from the Southern Levant is used to model the settlement patterns. As an essential source-critical step an evaluation of the preservational conditions for Late Pleistocene sites is conducted through the analysis of geomorphological maps. Geomorphological and climatic results are used to reconstruct the Late Pleistocene Levantine environment, which presents itself as dominated by rising water tables and abundant fluvial sedimentation. The spatial distribution of the sites is mapped in relation to the major resources (water and raw material) to understand guiding factors in site locality choice. The Late Pleistocene Levantine environment is thus argued to be characterised by a mosaic landscape of patches with high resource availability and areas with resource depletion. Multivariate statistical evaluation is used to test the explanatory value of different environmental factors on the variability in the archaeological dataset. Particularities in site locality choice for the different cultural units are highlighted. The settlement patterns of Pleistocene hunter-gatherers are reconstructed and evaluated through an assessment of the different inventories in terms of the representation of the operational chains, the diversity of the tool assemblages, the working time invested in the production of the lithic assemblages, the caloric yield of the faunal inventories and tool curation. In general, the Upper Palaeolithic of the Levant is characterised by a stable residential mobility system adapted to the patchy but abundant distribution of resources.

O-2046

## Holocene paleoclimatic changes, land use and landscape dynamics in the central Mediterranean. A comparison of archaeological and natural soils

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### Abstract

A wide literature exists on paleoclimatic and paleoenvironmental reconstructions in Mediterranean sites using traditional continental and marine proxies (sedimentary successions, fossils, stable isotopes, pollens, plant macroremains, dendrochronology, archaeological findings, historical documents). Paleosols are also used as paleoclimatic archives, but papers focused on the Mediterranean mostly investigate pre-Holocene times. An overview on the response of soils and paleosols from archaeological and natural sites of central and southern Italy to Holocene paleoclimate, land use changes and geomorphic dynamics is proposed here. An emphasis is given to different methods and ancillary techniques applied to interpret the pedostratigraphic record, trying to disentangle the role of natural versus anthropogenic factors on paleoenvironmental changes.

A number of soils/paleosols from coastal and inland areas showed a varying volcanic ash input, sourced as proximal or distal products of Pleistocene and Holocene eruptions, often hidden as micrometric cryptotephra. The volcanic material allowed the development of andic features which contributed to make them fertile. The development to different extent of andic properties, related to short-range order minerals derived from the weathering of volcanic glass, versus dominant phyllosilicate clay minerals, is successfully used as an indicator of prolonged soil moisture availability against a pronounced seasonal contrast, which marked major climate shifts from the post-glacial amelioration to the Holocene climatic optimum and the late Holocene. Varying moisture conditions during soil formation during the Holocene are confirmed by other pedogenic features (illuvial clay coatings and iron oxyhydroxides), developed in soil profiles from several Italian volcanic and non-volcanic environments. At some sites, soil charcoal data evidence a major phase of geomorphological stability with a paleovegetation dominated by deciduous oak forest during Neolithic times, coupled with abundant humus accumulation in the paleosols. A sharp environmental change is widely recorded at the macro- and microscale around 5-3 ka BP in many sites. Paleosol truncation, colluvial processes or burial by younger aeolian, alluvial and slope deposits (and associated soils) indicate stages of landscape instability with increased erosion/sedimentation processes. This important paleoenvironmental change can be a consequence of one or more aridity phases (in places marked by stable isotopes in pedogenic carbonates), possibly superimposed (or alternatively controlled) by increased anthropogenic activities since the late Neolithic to the Bronze age and Roman times. Settlement remains, pole pits, ceramic artefacts, charcoals, bone fragments, plow furrows etc. document human occupation. Forest clearance and a drastic transformation of the vegetation cover from oak woodland to pine forest is recorded by soil charcoal data in some inland mountain sites, where agricultural practices increased over historical times. Recent erosion during the last 50-60 years as a response to deforestation, agricultural exploitation/abandonment and land degradation is documented in some soils by fallout radionuclide tracers ( $^{137}\text{Cs}$  and  $^{239+240}\text{Pu}$ ) derived from nuclear weapon tests.

O-2047

## Holocene environmental evolution and human-environment relationship in the Mu Us Desert, China

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### Abstract

The research of interaction between humans and surrounding environments during Holocene becomes one of the hot research problems in recent years. Here we presented a synthesis evolutionary series based on available information from stratigraphic profiles and prehistoric archaeological discoveries in the Mu Us Desert, China. Results showed that the earliest Human appearance commenced in Mu Us Desert region during Holocene when the Yangshao Culture began to expand and reached this remote area of northwestern China around 7.0ka BP. In the eyes of number and magnitude of available 541 archaeological sites, the culture exhibited a status of prosperity at Late Yangshao (5.5-5.0ka BP) and Longshan Culture (4.6-3.9ka BP) period, while it showed depression in the latter Bronze Age. Actually, the rise and fall of cultures was also determined by subsistence strategies, which reflected in the different types of artifact stone implements and indicated the possible subsistence behaviors including agriculture, animal husbandry, hunting, fishing and so on. In addition, combined with the soil micromorphological features of palaeosol layers, we considered that 5.5-3.9ka BP was the highly possible veritable Climate Optimum period in the Mu Us Desert, based on the comprehensive evidence derived from natural and human records. The above study may offer insights in comprehending how climate change could have affected human societies and the potential feedbacks from prehistoric humans in long-term scale.

O-2048

## Early to Middle Holocene human-environment interactions: a multi-scalar geoarchaeological investigation of continental aeolian deposits in SE Iberia.

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### Abstract

Early to Middle Holocene archaeological sites located in sand deposits are crucial for our understanding of subsistence strategies and palaeoclimates of late prehistoric hunter-gatherer and the first farming groups in Europe.

Geoarchaeology, especially if applied at a multi-scalar level, has the potential to contribute relevant new data on anthropic behavior and how climatic fluctuations during the Last Glacial-Early Holocene transition may have shaped cultural responses during this period.

In this context the evidence gathered by our investigations at the sites of El Arenal de la Virgen and Casa Corona (Upper Vinalopó Basin, Alicante, SE Iberia) sheds new light on this issue by providing new geoarchaeological data supported by field and laboratory works.

These two Mesolithic campsites formed in a continental dune system developed at the margins of the Villena paleolake. The archaeological deposits together with their geomorphological setting are currently subject to multi-scalar analyses at intra- and off-site level (stratigraphy, micromorphology, texture and soil chemistry) within the frame of the project PALEODEM -Late Glacial and Postglacial Population History and Cultural Transmission in Iberia (ERC-CoG 2015-ref 683018).

Our investigations at the sites focus on:

1. The sedimentary contextualisation of human occupation events to establish the origin and formation of the continental dune system and associated soils where the sites are located and determine the extension of the settlement area.
2. The identification of traits of anthropic behaviour to allow assessment of its impact in the sediments, characterize occupation surfaces at intra-site level and determine the integrity of the archaeological record.
3. The construction of a reliable chronological framework for the dune system, associated soils and the Mesolithic settlement combining C14 dating of domestic structures and OSL dating of sand deposits. Our aim is to improve our knowledge of the palaeoenvironmental contexts before during and after the Mesolithic occupation and assess the impact of climatic shifts on the settlement pattern of the area of study.

Our results indicate a correlation between soil development and environmental stability and human occupation at the sites during the Mesolithic. This soil formation is embedded between two aeolian sand formations indicating that human occupation was preceded and followed by two climatic periods of increased aridification. They also suggest



that the aeolian sediments overlying the Mesolithic occupation are most likely a local manifestation of the 8.2 cal BP event, which in turn can be directly related to the gap detected in the occupation of the study area.

We found evidence of run-off and colluvial events embedded between the aeolian deposits, indicating that both wind and water-related processes were involved in the formation of the dune system, attesting to environmental fluctuations that framed human activities in the area of study during the transition to the Holocene.

**O-2049**

## **Human-environment interactions during the past 4000 years in Sagalassos and South-Western Turkey**

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### **Abstract**

South-Western Anatolia has been an area of intense human occupation since the early Neolithic. However, human pressure on the landscape did not follow a linear trajectory from the Neolithic to the present but is rather characterized by cycles of land cover expansion and contraction, contrary to many temperate environments in NW Europe. Here, we provide a synthesis of human-environment interactions in the region of the antique city of Sagalassos in the Taurus mountain in South-Western Turkey during the past 4000 years. Multivariate statistical analysis of pollen data (cluster analysis and non-metric multidimensional scaling) was used to semi-quantify human impact on the vegetation dynamics. This palynological data in combination with archaeological and geomorphological data and spatial modelling techniques, enabled to reconstruct the relative importance of human disturbance and natural variation on the environment. The sensitivity of the landscape towards anthropogenic disturbance is strongly controlled by the geomorphic setting and feedback mechanisms in the soil system. The first major clearing of the landscape in the Iron Age led to a peak in soil erosion, but also to soil exhaustion limiting erosion rates in subsequent periods. This soil exhausting led in turn to a decrease in crop yield at the hillslopes and to changes in the settlement patterns. Soil erosion and sediment delivery is more limited during the main occupation phases of the Roman Imperial Period. Periods with more favorable climate in the Roman and Mid-Byzantine periods resulted in the occupation of more isolated parts of the territory (i.e. higher altitudes), whilst a decrease in human pressure can be observed during the Early Byzantine and Ottoman periods related to less favorable climate conditions. Such smaller and short-lasting bursts of human occupation did not significantly impact the environment. Only in the last two hundred years, human pressure reached similar high values as those encountered in the classical period.

O-2050

## Vulnerability of the global peatland carbon sink: past, present, and future tipping points

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### Abstract

The importance of peatland ecosystems has been mostly unrecognized and there is a pressing need for improved management strategies worldwide. Peatland soils are non-renewable, vulnerable to human disturbances, and their capacity to provide Earth System Services needs a comprehensive, informed strategy for their conservation and protection. Peatland ecosystems provide and balance water resources, regulate climate via long-term carbon (C) sequestration and exchange with the atmosphere, mediate nutrient and sediment supply to the oceans, and maintain biodiversity integrity. Peatlands also support human health by providing food, fiber, and fuel to our growing world population, in addition to providing natural barriers against wildfires and floods. From a paleoclimate perspective, it is well known that peatlands play a key role in the global C cycle at the millennial timescale. Likewise, hydrological and biogeochemical analyses have highlighted the importance of peatlands in regulating the quantity and quality of water flow across the land surface across the annual to decadal timescale. Despite the fundamental connections between peatlands, near-surface land processes, the global climate system, and our society, these ecosystems are still omitted from all CMIP5 Earth System Models.

This contribution challenges the current modeling approach in which peatlands are not considered. We identify and locate the drivers of change that can provoke non-linear responses in peatland carbon cycling; tropical and high-latitude peatlands are examined separately. The level of past, present, and future risk (vulnerability vs. likelihood) of rapid peatland carbon loss or gain from natural and anthropogenic disturbance is also explored. Lastly, order-of-magnitude estimates of the change in C stocks and fluxes over time are provided on the basis of expert assessment.

O-2051

## Recent changes in peatland testate amoeba functional traits, palaeohydrology and carbon accumulation within a replicated site network, subarctic Québec, Canada

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### Abstract

Northern peatlands are a globally important carbon (C) store that are predicted to remain a C sink under future warming scenarios. Understanding the drivers and predicting the future trajectory of the peatland C store requires upscaling from cores and sites to regions and continents, alongside a detailed understanding of the mechanisms governing peatland C sequestration. However, recent studies have shown that both within- and between-site variability in individual peatland C accumulation histories is high, driven by factors such as climate, hydrology, (micro)topography and vegetation, creating highly heterogeneous ecosystems. Studies incorporating replication are therefore important to quantify how this variability may affect upscaling from local-scale dynamics to models. In addition, we need to better understand the processes driving observed variability but the interplay between plants, microbes and C cycling in peatlands remains poorly understood. One approach to address both issues is to examine replicated microbiological functional traits within a multi-proxy framework to provide an ecosystem-level perspective on ecological and biogeochemical processes. Peatland testate amoebae (TA) are a functionally important group of protists well-suited to such an approach.

Here, we compare four key TA functional traits (mixotrophy, aperture size and position, biovolume) to C accumulation, palaeohydrological and vegetation changes in 12 post-Little Ice Age peat cores from high-boreal and low-subarctic regions in northwestern Québec, Canada in an experimental design that includes internal and external replication at both site and regional scales. Correspondence between C accumulation, palaeohydrology and functional traits varies, but recent changes mixotrophy and aperture size, which may effect peatland C sequestration potential and microbial food web structure respectively, show tentative links to recent C accumulation increases. Analysing TA functional traits provides an opportunity to examine processes that may effect key peatland ecosystem services. Detailed replication, coupled with future spatial classification, should allow the effect of ecosystem and landscape heterogeneity on upscaling to be quantified.

O-2052

## Global peatlands and the carbon cycle during the last millennium

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### Abstract

Coupled climate carbon cycle models point to a positive climate-carbon feedback, whereby climate change results in a larger fraction of anthropogenic CO<sub>2</sub> emissions remaining in the atmosphere, further warming the climate. However, the strength of this feedback is highly uncertain and the terrestrial carbon cycle feedback is the least well quantified. Furthermore, models have completely ignored the potential contribution of peatlands, even though they contain 530-694 GtC, i.e. almost as much as the total amount of carbon in the atmosphere. Even the sign of the contribution of peatlands to the global carbon cycle feedback is poorly known. The assessment of this feedback is limited by the available the spatial coverage of carbon accumulation data from peatlands, especially away from northern latitudes.

Efforts have been made to widen our understanding of the potential of different peatlands to accumulate carbon. This synthesis effort has led to a compilation of a dataset of carbon accumulation rates for most latitudes and regions during the last millennium (850-1850 AD).

Benefiting from this data, this study takes into account a range of peatland types and novel regions (tropics, China, etc), where carbon accumulation can be very high. The aim of this study is to assess the contribution of peatlands to the global carbon cycle over the last millennium, in order to provide a basis for projections of future peatland-climate feedbacks and to enable inclusion of these effects in climate models. First, the spatial extent and the carbon fluxes of peatlands simulated with the LPX model are evaluated against the newly available dataset. Second, the simulated carbon fluxes are used to assess the sign and magnitude of the feedback of peatlands on climate.

It is expected that the feedback effects included in LPX, e.g. between peatlands and hydrology or nitrogen availability, play an important role in the response of the model to changes in climate.

O-2053

## Investigating the evolution of peatland area and peat carbon accumulation since the LGM using a dynamic global vegetation model

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### Abstract

Results from process based models offer an independent perspective on the transient evolution of global peatlands and peat carbon stocks, complementing data-based reconstructions of global peatland expansion and carbon accumulation (Loisel et al. 2017). Our goal is to investigate the global dynamics of peatland area change and carbon accumulation since the Last Glacial Maximum (LGM) using the LPX-Bern Dynamic Global Vegetation Model. The model includes formulations for peatland establishment and expansion based on a TOPMODEL approach (Stocker et al. 2014) and simulates vegetation, acro- and catotelm dynamics, and carbon, nitrogen, and greenhouse gas fluxes (Spahni et al., 2013). Model parameters are calibrated towards modern data (Lienert and Joos, 2018) and climate forcing fields are constructed by combining a modern observation-based climatology with anomalies from climate model simulations.

First, we assess uncertainties stemming from the choice of climatic boundary conditions. Precipitation and temperature anomalies for LGM conditions are taken from eight different climate models used in the Paleo Model Intercomparison Project. Simulated peatland area is then in the range of 3 to 5 Mkm<sup>2</sup> for LGM conditions. This demonstrates a high uncertainty in modelled past peatland extent due to uncertain past climate forcing.

Next, we quantify peatland area change and carbon accumulation since LGM and identify the dominant climatic and environmental drivers. Transient simulations over the past 22,000 years are performed in standard and factorial model setups. The model simulates a 40% increase in global peat area from LGM until today, resulting from a combination of the expansion of new peatlands, mostly in the north, and the loss of old peatlands mostly in the tropics and North-American subtropics. These changes are driven by rising sea level, flooding peatlands on continental shelves, and the retreat of the ice shields, exposing new land for peatland establishment, as well as by nonlinear and local interactions between temperature precipitation and atmospheric CO<sub>2</sub>. The results suggest that all these different physical and environmental drivers contributed significantly to the overall peat evolution. Here we present the model results, compare to proxy-based reconstructions, and discuss strenghts and shortcomings.

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O-2054

## Wetland Assessment and Monitoring Tool: establishing baseline conditions for New Zealand's wetlands

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### Abstract

Peatlands have been heavily exploited for human activities across the globe. It is estimated that 10% of the New Zealand mainland was covered by wetlands before human arrival around 750 cal. yr BP. Today over 90% of New Zealand's wetlands have been lost. Although the early indigenous Māori settlers caused extensive deforestation of dryland forests by burning, wetland extent was minimally affected until after European arrival (1800s), when loss accelerated rapidly for development and agriculture. Remaining wetlands are therefore of high conservation priority; restoration of degraded wetlands is also a priority.

Little is known about the microorganism communities in New Zealand and recent evidence from European peatlands suggests that testate amoebae (a polyphyletic assemblage of free-living single-celled shelled eukaryotes) can provide more accurate information on environmental change than vegetation. However, most of the work on peatland testate amoebae has been undertaken on Northern Hemisphere *Sphagnum*. In New Zealand, the main peat formers are the restiads *Empodisma minus* and *E. robustum* in the North Island; and graminoids, *E. minus*, and *Sphagnum* spp. in the South Island. Little is known about testate amoebae communities in these peatlands as they remain less studied in the Southern Hemisphere.

In this study, we evaluate if testate amoebae can be used as reliable indicators for determining wetland conditions through time in New Zealand. Eighteen wetlands were selected for this study from the West Coast and Southland regions of New Zealand, including six bog systems that were highly impacted, six bogs that were moderately impacted, and six that were relatively non-impacted. Vegetation surveys were carried out at each site using four randomly located 5 x 5 m plots. Environmental variables were measured at each sampling site and the surface testate amoeba community patterns and community-environment relationships compared. Our preliminary data support the potential use of testate amoebae as indicators of ecological integrity of New Zealand bogs.

O-2055

## Contrasting carbon sink and source activities in Amazonian and Arctic peatlands under a changing climate

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### Abstract

We use a process-based peatland biogeochemistry model to quantify the carbon accumulation in the Pastaza-Marañon foreland basin (PMFB) in the Peruvian Amazon from 12,000 years before present to 2100 AD. We found that, under warmer and presumably wetter conditions over the 21<sup>st</sup> century, SOC accumulation rate in the PMFB slows down to 7.9 (4.3~12.2) from the current rate of 16.1 (9.1~23.7) and the region may turn into a carbon source to the atmosphere at -53.3 (-66.8~-41.2) (negative indicates source), depending on the level of warming. Soils in the PMFB may lose up to 0.4 (0.32~0.52) Pg C by 2100 AD with the largest loss from palm swamp. The carbon-dense Amazonian peatland may switch from a current carbon sink into a source in the 21<sup>st</sup> century. We also simulate the SOC accumulation in Alaskan terrestrial ecosystems over the last 15,000 years using the model. The simulated average rate of peat C accumulation was 2.3 Tg C with a peak value of 5.1 Tg C during the Holocene Thermal Maximum (HTM) in the early Holocene, four folds higher than the average rate of 1.4 Tg C over the rest of the Holocene. The SOC accumulation slowed down, or even ceased, during the neoglacial climate cooling after the mid-Holocene, but increased again in the 20<sup>th</sup> century. We found that warmer summer temperature and stronger radiation seasonality, along with higher precipitation in the HTM and the 20<sup>th</sup> century might have resulted in the extensive peatland expansion and carbon accumulation. Currently, we are evaluating the fate of Arctic peatland carbon during this century.

O-2057

## Exploring lake ecosystem resilience in a warming (sub)arctic through ecosystem structural changes

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### Abstract

Ecosystem resilience is the ability of a system to absorb disturbance and is fundamental for the continuation of ecosystem productivity, functionality and diversity. But understanding how resilience is affected by environmental stress is a major research challenge. This study aims to investigate how changes in ecosystem structure, used as a proxy for resilience, are related to increased temperature stress in (sub)arctic lake ecosystems. These ecosystems are at risk from rising global temperatures, with warmer temperatures already recorded and predicted to continue rising in high latitude areas. Increased temperatures create stress on ecologically sensitive environments where many organisms are adapted to cold temperatures. Temperature-sensitive organisms, such as chironomids (non-biting midge), provide useful datasets for investigating ecosystem structures in relation to climate change.

Three sets of analyses - beta diversity, compositional disorder, and network skewness - are applied to near-modern chironomid communities along temperature gradients in arctic and subarctic North America, Norway and Russia. Breakpoint analyses indicate significant shifts in the Norwegian chironomid communities between the Svalbard and Mainland Norwegian lakes, and between the arctic and subarctic lakes in the North American and Russian community compositions. Comparable results for beta diversity, compositional disorder and network skewness analyses suggest a strong temperature control on community composition in all three regions.

Community structural response to warming in the three regions is also assessed through time, from the beginning of the 20<sup>th</sup> century. Results indicate that the majority of the lakes have undergone warming since 1901-1950, both within arctic and subarctic zones. Associations between relative temperature change and the beta diversity, compositional disorder and network skewness results are less clear. This suggests that the chironomid response to warming, and hence the climate resilience of high latitude lake ecosystems, is mediated by local conditions, but also raises questions about the measurement of ecosystem structures.

O-2058

## Quantifying climate-induced changes in ecosystem resilience using remote sensing and modelling

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### Abstract

Anthropogenic climate change is expected to impact heavily on global ecosystems, for example by triggering range shifts, food web disruptions, and changes in water availability. Greater climate variability is also expected on top of these trends, which may in turn be integrated by ecosystems and lead to an increase in ecosystem variability. Together, these changes could degrade ecosystem resilience – the rate at which ecosystems recover from perturbations – leading to a greater risk of triggering large-scale ecological regime shifts. Various ecosystems are hypothesised to feature tipping points beyond which regime shifts would occur, especially if they are characterised by bistability. Dynamical systems theory suggests these tipping points are often preceded by indicators such as critical slowing down (indicated by e.g. increasing autocorrelation) and greater variability. These indicators can be used as resilience metrics, with increases indicating reduced resilience due to a weakening of stabilising negative feedbacks. However, despite recent advances in quantifying ecosystem resilience, many studies remain spatially or temporally limited.

Here we present preliminary results from two different approaches to quantify climate-induced changes in ecosystem resilience on a global scale. Firstly, we utilise remote sensing data available for recent decades via integrated online platforms, such as Google Earth Engine, to perform a comprehensive scan of short-term changes in spatiotemporal autocorrelation and variance in proxies of ecosystem productivity. Secondly, we simulate the decadal-to-centennial timescale impact of climate change and climate variability on global ecosystem structure and resilience over historical-to-future scenarios using the Madingley general ecosystem model, and compare how the spatiotemporal variability of the simulated ecosystems corresponds to increasing variability of the climate.

O-2059

## Spatial and temporal indicators of resilience loss in networks of paleoecological records

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### Abstract

Many ecosystems have abruptly changed in the past and may again in future, yet prediction and inference of causal mechanisms remains challenging. Critical transitions are one such mechanism, occurring when systems with alternative states cross a non-reversible threshold. These shifts between alternative states can be associated with a gradual loss of resilience, often signaled by increasing variance over time and space. Paleoecological time series have potential to reveal changes in resilience at broad scales by documenting past critical transitions, measuring whether variance increases before abrupt changes, and linking driver and state variables to reveal underlying processes. However, a key challenge is the transformation of resilience signals by sedimentological time-averaging and subsampling. The prairie-forest ecotone in midcontinental North America is considered an example of a system with alternative states, capable of critical transitions between prairie and forest when water availability crosses thresholds. Prior work has shown that the prairie-forest ecotone was highly mobile during the Holocene, shifting in response to changes in precipitation and fire frequency. We explore indicators of resilience loss in sites that remain prairie throughout the mid- to late Holocene, versus sites that transition from prairie to forest.

Using high-resolution, well-dated pollen records from midcontinental North America from the Neotoma database, we first investigated whether temporal variance was higher for sites that transitioned from prairie to forest, compared to sites that remained prairie. For each site, we created a Generalized Additive Model for Location and Scale (GAMLS), which models both mean and variance through time, and compared modeled variance through time for sites that remained prairie to sites that transitioned from prairie to forest. We incorporated estimates of temporal uncertainty by creating Bayesian age models for each site, then resampling the model posteriors and creating a new GAMLS for each iteration. Preliminary results indicate no significant differences in temporal variance between groups. Second, we investigated whether spatial variance was higher for clusters of sites that transitioned from prairie to forest than for clusters that remained prairie. Because spatial heterogeneity influences how vegetation at a site responds to a climatic driver, the susceptibility of an individual site to a critical transition can vary even among nearby sites. Increasing differences among sites during the transient phase between vegetation states are indicative of resilience loss, which is measured as variance across sites, through time. We measured spatial variance in 250-year time bins for two clusters of sites, finding that the cluster that transitioned from prairie to forest had higher spatial variance than the cluster that remained prairie. These initial findings suggest that shifts in the prairie-forest ecotone were caused by climatic drivers that changed too quickly for resilience loss to occur, or that the system is not characterized by alternative states.

O-2060

## Identifying lake ecological resilience across the tropical Andes

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### Abstract

Climate change has been identified as a main driver of ecological change in Andean lakes. However, evidence linking environmental variation to regime shifts is often restricted to small spatio-temporal scales. Here we test the hypothesis that if climate variability controls lake ecosystem transitions, historical climate fluctuations should have already induced shifts in the past; and should have done so in a synchronized manner across large geographic areas (Moran effect). We analyzed four lake records spanning the last 2,000 years across the tropical Andes (Yahuarcocha and Llaviucu in Ecuador, Umayo and Titicaca in Peru), and we modeled diatom community variance as an indicator of critical transitions via Generalized Additive Models (GAMs). In addition, we tested for potential spatial synchrony in regime shifts and in historical floristic trajectories by plotting fossil diatom samples passively, against a contemporary database of tropical South American diatoms (8°N–30°S and 58–79°W). Our results suggest that Andean lakes have undergone different states, as indicated by diatom community clusters or ‘basins of attraction’. Shifts in diatom community composition showed spatial synchrony in the two Ecuadorean lakes at 60-80 and 1000-1100 cal yr BP. However, the investigated lakes showed distinct floristic trajectories over time, with different environmental drivers influencing their dynamics. GAMs showed marked and cumulative increase in compositional variance in a variable fashion across the four Andean lakes, suggesting the existence of external and internal drivers following latitude-related controls. Our research will provide a better understanding of long-term ecological resilience by connecting paleoecological and contemporary data across a large spatial scale. This improved understanding may help inform sustainable management of lake ecosystems that provide critical water resources to the Andean and Amazonian nations.

O-2061

## Estimating continuous measures of ecological resilience from palaeoecological time series

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### Abstract

Ecosystems are highly variable across time and space and the consequences of this variation have been widely studied. Interest in ecological resilience has recently increased as we now appreciate the role environmental variability plays in maintaining biodiversity and in the identification and early detection of regime shifts. Frustratingly, quantifying resilience from palaeoecological time series is difficult because samples are irregularly spaced in time, sample ages are uncertainty, and older samples are compacted and represent greater amounts of time. One of the most widely-used methods for estimating resilience time series involves calculating indicators over moving windows. Critically, statistical evaluation of resilience time series is complicated for four reasons. First, the resilience indicator time series violates the independence assumption of Kendall's  $\tau$ . Second, using surrogate time series to assess the significance of  $\tau$  requires fitting a time series model to the original data, which is problematic given the irregular observations. Thirdly, moving windows yield truncated resilience indicator time series; up to half the number of observations in the original series may be lost. Fourth, the moving window approach involves several *ad hoc* decisions; the size of window, how the original data are detrended, and the detail of the time series model fitted for the surrogate time series all affect the results.

We present a novel approach to the estimation of resilience indicators based on generalized additive models (GAMs), which resolves the problems described above. GAMs have previously been used to model trends in palaeoecological time series, assuming that other properties of the series are constant. Distributional GAMs relax this and allow the simultaneous estimation of mean, variance, and other parameters of the data, whilst maintaining the flexibility and simplicity of GAMs. We illustrate our approach by generating continuous estimates of key resilience indicators for time series of algal pigments from a sediment core from Lake 227 (Ontario, Canada), which has been experimentally manipulated to induce eutrophication. We show that our distributional GAM approach is capable of reproducing previous results (Cottingham et al 2000, *Ecology Letters*) that identified an increase in the variance of phytoplankton populations in the lake post disturbance whilst also providing a continuous estimate of the variance for the entire time series where previously only a single estimate was available for periods before and after manipulation. Furthermore, skewness, another key resilience indicator, can also be estimated, uncertainty is fully quantified, and we can accommodate age uncertainty, effects due to sediment compaction, and censored observations that are below detection limits. Our results show that distributional GAMs provide robust, continuous estimation of time series of ecological resilience, which may be used to reliably identify patterns of stability and resilience and to test key predictions of resilience theory using long-term ecological records.

O-2062

## Using species distribution modelling and palaeoecology to understand what determines resilience to fire in a critically endangered rain forest community

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### Abstract

Recent catastrophic wildfires in the Tasmanian highlands herald a significant threat to the future endangered fire-sensitive ecosystems. One such ecosystem is the montane rain forest community dominated by *Athrotaxis* spp. (Cupressaceae) and *Nothofagus gunnii* (syn *Fuscospora gunnii*; Nothofagaceae) in Tasmania, Australia. This endemic and hyper fire sensitive rain forest community has floral affinities with the temperate rain forests that dominated the super-continent Gondwana. Today, it is restricted to upper-montane areas of this topographically complex island. Wildfires following the British invasion of Tasmania in the late 1700s have reduced the distribution of montane rain forest by around 50%, and there is little evidence for post-fire recovery of these systems. Here, we use palaeoecology, species distribution modelling and remote sensing to unpack the various factors governing the resilience of this community to fire. We contend that both landscape heterogeneity in complex topographic landscapes and flammable species invasion can over-ride the effects of regional climate on ecosystem resilience to fire in this region. We provide evidence that long-term climatic change acts to decrease the rate of recovery of rain forest from disturbance by fire, thus, bringing these ecosystems closer to points of critical transition (so-called tipping points of collapse) - i.e. a critical slowing down. Whether a critical transition occurs is, at least in part, dependent on the presence or absence of species that can initiate a positive feedback switch that can shift the ecosystem to an alternate state. We conclude with a provocation: should we say goodbye to Gondwana in Australia or should we use this data to focus our efforts in areas of greatest reward for effort?

O-2064

## Spatial distribution of Palaeolithic sites in relation to raw material sources in the central Narmada valley, India

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### Abstract

The spatial distribution of archaeological sites in a particular area represents the land use patterns of hominin population adaptations in accordance to raw material and water resources. Understanding these distribution patterns also suggests their adaptations to different conditions which provide insights on understanding their behaviour. Landscape adaptation in central India is quite exceptional as more than 300 Lower Palaeolithic sites/occurrences have been reported in different contexts. The present work specifically deals with these assemblages and associated raw material sources in the central Narmada valley. The central Narmada valley is rich in various rock types (sedimentary, metamorphic, igneous and volcanic) which also served as raw material for various Pleistocene hominin populations. The Narmada River divides the region into northern and southern parts. In the northern part of Narmada Valley, there are mainly the Vindhyan Supergroup (sedimentary and metamorphic rocks) and Deccan Trap (volcanic rocks), whereas in the southern part of Narmada Valley, there are mainly the Gondwana Supergroup (sedimentary rocks), Deccan Trap and the Mahakoshal Group. Along the river, there are a few exposures of the Vindhyan Supergroup and thick deposits of Quaternary alluvium. Due to this varied geology, the quartzite and sandstone from the Vindhyan Supergroup are prominently utilized, whereas, in the south of Narmada, the main raw materials came from quartzite of the Mahakoshal Group in the form of pebbles, cobbles and boulders, and chert from Gondwana Supergroup in the form of *in situ* exposures. Acheulean sites are mostly found along the foothills of Vindhyans as well as along the banks of the Narmada River and its tributaries. As pebbles and cobbles dominate the southern parts of the valley, the majority of the Palaeolithic assemblages there comprise flake and chopper industries, which makes it difficult to assign them to a particular lithic cultural phase. For now, no sites have been reported or found on basalt (Deccan Trap) although stray artefacts have been observed. In this paper, the author has tried to link these raw material sources with the occurrences of Palaeolithic sites to have a better understanding of past hominin land use patterns and ecological adaptations.

O-2065

## **Absence does not mean absence: Modern day land-use and the visibility of the archaeological record (Kibbanahalli Palaeolithic Complex, southern India)**

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### **Abstract**

Kibbanahalli is an important Lower Palaeolithic site-complex in southern Karnataka, a state in the southern region of Peninsular India. This region is important as it is somewhat centrally located between regions to the north, east and south, where decades of systematic Palaeolithic research has led to the establishment of firm cultural stratigraphy(s), and even, in cases, of chronology(s). However, in stark contrast to these regions, southern Karnataka is often ignored in prehistoric research. Over 90 years of (intermittent) Palaeolithic investigations at this site-complex have set the foundation of our understanding of the Palaeolithic occupation of this vital region. It is of utmost importance to continue Palaeolithic research in this area as it is one of the fastest industrialising and urbanising zones of the world, with large population centres such as Bangalore (Bengaluru), Mysore (Mysuru) and others located here. Documenting the rich Palaeolithic heritage in this region, before its eventual surrender to the forces of 'development' is thus a priority. Further, it is also necessary, if possible, to qualify and quantify the impact of these developmental processes on the visibility and preservation of the archaeological record, in general, and the Palaeolithic record, in particular, which might serve as a model for future research in other similar regions. It is with this objective that the present author has initiated field investigations into the rich Palaeolithic record of this region. These recent investigations have led to a secure identification of the technological attribution of the lithic assemblages here, as well as the identification of many new Palaeolithic localities. The presence of a uniform stratigraphical association of the archaeological horizon and similarities in the lithic assemblages have led to the reclassification of the many sites/localities at Kibbanahalli and its vicinity, into a site-complex. This paper reports on a series of field observations and remotely-sensed data collected to understand the distribution pattern of the various Palaeolithic localities of this site-complex. Results of this study highlight the important role played by modern day land-use patterns in the region on the observed distribution of the archaeological record as well as on the visibility of the archaeological record itself. This challenges previous interpretations regarding the settlement patterns and strategies suggested for the Palaeolithic occupation of this region. Further, this study draws attention to the need and necessity to understand the role of various site formation processes, especially modern day land-use activities, on the observed and observable patterns in the archaeological record as well as the visibility, or lack thereof, of the archaeological record.

O-2066

## **Stretching Boundaries: A geo-archaeological re-examination of District Damoh and adjacent areas of Madhya Pradesh, from river channels to peripheral landforms.**

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### **Abstract**

Since the publication of R.V. Joshi's work over half a century ago on the Palaeolithic record of Damoh, this area of Madhya Pradesh in central India has received little interest compared to its neighbours, the Narmada Basin in the south and the Son Valley to the northeast. This is not surprising since a well-developed Quaternary stratigraphy is preserved along the Narmada and Son. Though R.V. Joshi speaks about two tool-bearing gravel horizons and Sali (1990) puts forth a general stratigraphy for the area, in comparison, the Sonar and Bearma, and their tributaries, flowing through the district of Damoh and adjacent areas have far less extensive river sections with Quaternary deposits, with the underlying Vindhyan bedrock exposed at regular intervals. However this Vindhyan geology, made up primarily of shale and sandstone with quartzite outcrops, and dominating the lithology of these basins, offers an opportunity to understand the development of cultural surfaces/horizons, not limited to the outcome of fluvial processes. A recent pilot survey in the area was undertaken with the objective to better understand the landscape by expanding the focus to include the pediments and escarpments on the northwest and east of the district while also surveying the various river and stream channels. Several geomorphic processes including deposition by river action but also erosion, in-situ weathering of bedrock and mass wasting seemed to have contributed uniquely to the distribution and exposure of Palaeolithic sites across the region. The variety of available raw materials which was seen to increase towards the fringes of the Sonar-Bearma basins warranted widening the survey area to include parts of districts Panna and Satna, and the breccia formations of Chhatarpur and understand any corresponding variability in lithic assemblages. By stretching boundaries beyond fluvial environments, the most commonly worked upon archaeological context in South Asian Palaeolithic studies, the present work aims to fill a lacuna in our understanding of this potentially interesting study area straddled by some of the richest prehistoric sites in the Indian subcontinent. Owing to the preliminary nature of the research currently undertaken, no cultural or chronological categorisation of Palaeolithic sites from the area has been attempted. However by revisiting localities mentioned in the published literature and several previously unexplored ones, the various geomorphological processes and proximity to a range of different fine quality raw material sources seem to have resulted in a rich archaeological record spanning much of the Palaeolithic.

O-2067

## Late Pleistocene palaeoenvironments in South Asia and associated palaeoanthropological implications

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### Abstract

Climate change is prominently considered as a causal mechanism for hominin dispersals, expansions and technological innovations/transitions in the Old World. Being in the centre of the Old World and ecologically diverse, the Indian subcontinent must have played a prominent role in hominin dispersals and adaptations across Asia during the Late Pleistocene. Despite available palaeoenvironmental proxies and ample archaeological evidence, very few detailed multidisciplinary studies have been carried out to investigate environment-human interactions in prehistoric South Asia. This presentation focuses on the status of younger palaeoenvironmental studies in South Asia and associated debates regarding hominin behaviour and faunal extinctions. It synthesises current palaeoclimatic data and prehistoric evidence at regional levels and proposes testable hypotheses regarding dispersal routes, technological diversity (especially after ~100Ka) and associated adaptive strategies (e.g. Toba issue, seasonal monsoon). Broad inferences are drawn from ~ 100 studies, carried out on individual proxies including carbonates (7), sediments (34), pollen (16), ostrich eggshell fragments (2), fossil enamel/wood/seed (4), speleothem (1) and multi-proxies (30). The records show that the period from 125 – 80 ka is predominantly characterised by humid environments. It was followed by varied results/changes in climatic conditions at 79-70 ka and arid environments at 69-60 ka. Between 59-30 ka, South Asia's environment was again generally humid. The period from 29-20 (LGM) again represent varied results which were later followed by the arid conditions from 19-11 ka. Typo-technological transitions from the Middle Palaeolithic to the early Mesolithic are also addressed, including interpretative issues with the Upper Palaeolithic. Palaeoenvironmental reconstructions carried out thus far have lacunae regarding geographical, temporal and methodological aspects. Finally, this paper highlights the importance of investigating unexplored regions and focused time periods and attempts to link the South Asian palaeoenvironmental records with regional Asian counterparts about hominin adaptations and population movements.

O-2068

## New techno-chronological data on select terminal Pleistocene-late Holocene microlithic occurrences in the central Narmada basin, Madhya Pradesh, India

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### Abstract

The earliest occurrences of microliths in South Asia date back to the Late Pleistocene at Mehtakheri in central India (48-45ka), Jwalapuram in southern India (38ka), Batadomba-Lena in Sri Lanka (35-36 ka) and Kana and Mahadebbara in northeastern India (38-35 ka). Microlithic technology is distributed almost across the entire Indian Subcontinent and chronologically continues up to the Iron Age. This paper discusses new data acquired from the author's ongoing doctoral research in the two districts of central Narmada Basin, Madhya Pradesh (Hoshangabad and Sehore) in central India.

The surveys were carried out in the Vindhyan and Gondwana foothills and in the surrounding Narmada floodplains. Over 30 microlithic occurrences were identified and documented through the four seasons of fieldwork (2015-2018). The assemblages were collected to study the technological aspects of the microliths and locational data was recorded to understand land use patterns. Few sites with abundant lithic assemblages in exposed sediments were selected for optical dating, samples for which were processed between 2016-2018. We present here the preliminary dates from key sites namely Pilikarar, Morpani, and Gurla-Sukkarwada. The dates range between 12.4 ka and 2.2 ka. The luminescence measurements were carried out using Risoe TL/OSL Reader at the Birbal Sahni Institute of Palaeosciences, Lucknow. The SAR (single aliquot regeneration) protocol was applied to all the samples. The samples were processed with basic chemical treatments to remove any substantial organic material and carbonates. The fine-grained (4-11 mm) methodology was used to process the samples by preparing fifty aliquots per sample. The ages were calculated from the DRAC using the central age model.

Technology during the terminal Pleistocene and early Holocene transitions from non-geometrical to geometrical shapes, however, the assemblages are still being analysed for a more comprehensive picture. The dates are varied between terminal Pleistocene to Holocene, which can propose a change in the technology of the microlithic production. However, major factors such as continuation of hunter-gatherer populations co-existing with the other technologically developed populations by the proto-Historic and Historical periods cannot be ruled out. This research confirms the existence of hunter-gatherer populations over a prolonged time in the central Narmada basin since at least the late Pleistocene and possibly much earlier, based on published data.

O-2069

## Understanding Geo-archaeology in Trans-Himalaya: A Case study based on Lithic assemblages from Dzamathang, Spiti Valley, Himachal Pradesh, India

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### Abstract

The Trans- Himalayan region is generally seen as a barrier during prehistoric times due to its topographic and intense climatic features. Spiti Valley is located in the trans-Himalayan terrain of India, from where non-geometric microliths, were recently discovered in this part of Himalaya. While the Siwalik Hills have been subject to extensive prehistoric surveys, this is the first evidence of lithic tools discovered in the trans-Himalayan region of Himachal Pradesh, India. This suggests that this Himalayan zone may have also acted as a corridor instead of a barrier during human migration. In fact, in the adjoining area of western Tibet, other researchers have reported lithics from several sites and assigned to the Middle Palaeolithic. This paper is based on artefacts which were collected from surface contexts. Large numbers of lithics and debitage were found in the Dzamathang area of Spiti Valley. These assemblages consist of assorted artefacts including a unifacial chopper, microlithic core, blade flakes, backed blades, burins and a large amount of debitage. The majority of artefacts are on quartzite or quartzarenite. The quartzite is the most common rock in the Spiti valley, from Neoproterozoic to Permian age. The quartzite is mainly found in the Chandpur, Nagthat, Batal, Katarigali, Chambaghat, Kauriyala formations (Neoproterozoic); Koti, Kunzam La formations (Cambrian); Thango Formation (Ordovician); Muth quartzite Formation (Devonian) and Po Formation (Carboniferous) in Spiti valley. The future surveys will be targeted at recovering primary context sites for excavations and absolute dating.

O-2070

## A geo-archaeological study on mounds using multi proxy to reconstruct past climate and drainage affecting Harappan population near Rakhigarhi, India.

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### Abstract

The age old of problem of the demise of Harappan Civilization, is conflicted because of uncertainty related to the existence of a perennial river, also known as the Saraswati River. On the basis of zircon dating, Clift et al. (2012), has suggested that the flow to the river was perennial before 30ka and the river became ephemeral sometimes between around 30 and 15ka. Giosan (2012) observed that the absence of late Painted Grey Ware Harappan sites in the lower reaches of the present day Ghagghar River (former Saraswati River), suggests that Harappans moved out of the area due to lack of perennial source of water or due to weakening of monsoon. However the migration of population, and the drainage disorganization of the river (Clift et al. 2012) do not coincide. Few archaeological sites in Rakhigarhi, when observed from the present proposed course of the river, lie very far away from any perennial river channel (Singh et al. 2010), for any early civilization, hence Mehdi et al. (2016), on the basis of remote sensing, identified two more tributaries which supported the presence of archaeological sites away from the river.

Singh et al., 2010 and 2011, suggested the migration and expansion of Harappan population on the basis of distribution of archaeological sites during different phases of Harappan timeline, whereas Giosan et al. 2012, highlighted the role of climate and rainfall on the societal evolution of the civilization. Numerous studies suggests that earlier river was perennial which turned ephemeral before onset of Harappan Civilization (Singh et al.

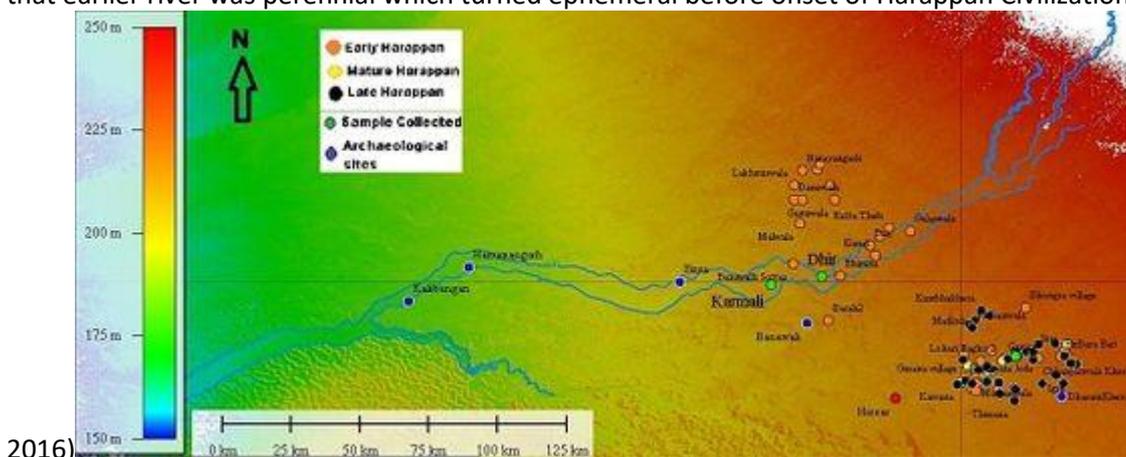


Fig: Distribution of archaeological sites representing different phases of Harappan period.

However, our preliminary studies on sediments obtained from multiple archaeological mounds near Rakhigarhi suggests a new story. Presence of burnt charcoal and ash collected from different sedimentary layers within mounds suggests a series of occupation and abandonment of these sites. C-14 ages of charcoal have helped in constraining these activities from early to Mature Harappan phase. The presence of thick massive deposits of mud interlayered with ash deposits suggests that during Harappan period, Rakhigarhi was in the vicinity of an active river which frequently flooded the entire region forcing people to migrate. Similar studies have been conducted on geological



cum archaeological mound in the main paleochannel which also represents age between early and late Harappan phases. At least three events of flood has been recorded and have been analyzed. In this amalgamation of geology and archaeology, we have attempted to create a relatively high resolution climate record and fluvial activities in the region based on multiple proxies which affected the Harappan population to the extent that it forced them to abandon these sites.

O-2071

## Multi-proxy records from Plio-Quaternary cave sediments in Slovenia

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### Abstract

In karst terrains caves often preserve the only sedimentary record of the latest stages of landscape evolution. Caves trap and accumulate various clastic, chemical and organic sediments brought into caves by sinking rivers, vertical percolation of precipitation or collapse. The dynamics of sedimentation is mainly controlled by climate and hydrology (*e. g.* glaciations, floods, precipitation), by changes in river catchment and by evolution of cave network. Protected in caves sediments are generally well preserved and reveal exceptionally good, multi-proxy record of surface environmental conditions at the time of their deposition. They can cover time span from several million years up to the present.

Systematic research of cave sediments sampled over the last 20 years used different dating methods shows that sediments in Slovenian karst are up to 5 Ma old. Previously it was believed that the cave sediments deposited mostly during Pleistocene and that caves are not much older. The majority of sediments studies has been carried out in SW Slovenia (*i.e.* in the NW part of Dinaric Karst), and at some sites of Alpine karst. More than 4,000 samples were taken and analysed in 42 different sections from active, relict and unroofed caves and surface sediments. Standard paleomagnetic analyses were used (thermal /TD/ and alternating field /AF/ demagnetization, magnetic susceptibility measurements, etc.). All field hand specimens were oriented *in situ* and on some profiles magnetic susceptibility was directly measured. Procedures were selected to allow the separation of the respective components of the RM and the determination of their geological origin. The systematic acquisition of paleomagnetic data within a studied section allowed the construction of a detailed magnetostratigraphic profile with a high resolution. In intervals with polarity change, the frequency of sampling was so high that an almost continuous record of the magnetic and paleomagnetic parameters was obtained. Results from paleomagnetism and magnetostratigraphy were calibrated by U-series, paleontological and geomorphological dating if possible. Age sequences were made of composition of sections with different ages within Cenozoic era. A robust chronology in the spatially and temporally highly discontinuous sediment record preserved in karst was set up. Calibrated data contributed to the reconstruction of speleogenesis, deposition in caves, and indirectly to the evolution of karst surfaces and succession of tectonic movements. The oldest sediments, about 5 Ma, are now situated in relict caves close to the surface or in unroofed caves, which were exposed to surface by karst denudation. Sedimentation in caves has also reflected the evolution of the surrounding landscape; *i.e.* climatic changes with flood events or/and changes of the tectonic regimes during Neogene and Quaternary. Paleomagnetic data obtained from cave sediments were also used to document neotectonic (<5Ma) vertical-axis rotations in the NE corner of the Adria-Eurasia collision zone.

O-2072

## Pliocene-Quaternary landscape evolution based on cave geomorphology: Picos de Europa mountains (Spain)

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### Abstract

Karst caves preserve morphologies and records, which study reveals data about regional landscape evolution. In the Northern Iberian Peninsula, Picos de Europa mountains are formed by Carboniferous limestone that occupies the majority of their topographic surface. These mountains with more than 420 km of cave conduits represent one of the most important karst areas of the World, including 14% of the deepest caves explored today. This work aims to reconstruct the Pliocene-Quaternary evolution of these high mountains at regional scale, based on geomorphological and geochronological research (U/Th and Al/Be) carried out in four alpine caves. Cave geomorphological mapping showed 12 km of studied caves formed by 47 % vadose canyons and shafts, 45 % phreatic/epiphreatic conduits organised in six cave levels, and 7 % breakdown-modified passages. Cave deposits include perched flowstones that represent ancient pavements, fluvial terrace deposits with allochthonous clasts, slackwater deposits related to cave floods, and debris deposits produced by breakdown. One Al/Be burial age indicated a minimum age of  $2.1 \pm 0.5$  Ma for the caves development, allowing estimation of the mountain uplift at  $0.15-0.25$  mm·a<sup>-1</sup> since the late Pliocene. Thirty-four U/Th ages allow us to define main sedimentary and erosive periods from MIS 8 to 1. This data provided a landscape evolution model with 6 phases at regional scale. Phase 1: development of cave in the Pliocene, in limestone partially or totally covered by the detrital Permian-Mesozoic cover. Phase 2: river incision, erosion of this cover and occurrence of fluvial captures. Phase 3: cave infill during 220-145 ka, probably caused by the erosion of Stephanian detrital outcrops. Phase 4: erosion of cave infill during 125-45 ka. Phase 5: apparent pause in the speleothem formation during 45-25 ka related to dry and cold regional conditions. Phase 6: reactivation of the speleothem precipitation since 25 ka. Fluvial incision, regional climate, and the ancient presence of detrital rocks that covered limestone would be the main factors that controlled the regional geomorphological evolution since the Pliocene.

O-2073

## Speleothems as recorders of centennial- to millennial-scale climate events during the Last Glacial

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### Abstract

Caves are unique environments that offer physical protection for speleothems and other climate-sensitive archives, particularly during glacials when surficial deposits may be removed or reworked by erosion. Speleothems (calcitic or aragonitic stalagmites, stalactites and flowstones) are ideal materials for U-series dating, permitting the construction of exquisitely detailed chronologies for depositional phases, well beyond the c. 50ka limit of radiocarbon dating. Crucially, speleothem deposition requires that liquid water is available to percolate downwards through soils and bedrocks, and so during glacials, intervals of speleothem deposition indicate episodic absences of permanently frozen ground and the availability of biogenic CO<sub>2</sub>. Results of 1-D thermal modelling of heat conduction through soils and bedrock will be presented, along with a discussion of new and published U-series dates from selected European caves, with specific examples from Ireland, the Alps and Georgia to constrain the duration of the onset of climate amelioration during the Dansgaard-Oeschger (DO events). Previously published U-series dates from Crag Cave, SW Ireland (Fankhauser et al., 2016), augmented by additional dates for key speleothems from this site provide evidence for short-lived climate-driven centennial to millennial scale episodes of deposition. These occur during Marine Isotope Stage 5 (MIS-5) through to the Last Glacial Maximum (LGM), into the Late Glacial. New U-series dates will also be presented for stalagmites collected from Solkota Cave in western Georgia during 2016. Stalagmite SKK 16-3 from Solkota Cave exhibits intense but short-lived depositional phases that are contemporaneous with DO events in the Greenland ice cores. In detail, SKK 16-3 shows rapid but intermittent growth around 84 ka, coinciding with climatic amelioration during Marine Isotope Stage (MIS) 5a, and specifically during the short-lived Greenland Interstadial 21.1e (GI-21.1e). Following a long-lived hiatus, a short interval of deposition resumed at 57 ka, coinciding with a warm interval in MIS3, Interstadial GI 16.1, indicating a strong climatic control. Coeval episodes of speleothem deposition are seen at Crag Cave and in the published results from caves in the European Alps. Finally, the new results permit snapshot comparisons of elevation-corrected Last Glacial speleothem longitudinal  $\delta^{18}\text{O}$  gradients during selected DO events across Europe, from the Irish Atlantic margin in the west to the Black Sea in the east, with those of the Holocene.

Fankhauser, A., McDermott, F. and Fleitmann, D. (2016) Episodic speleothem deposition tracks the terrestrial impact of millennial-scale last glacial climate variability in SW Ireland. *Quat. Sci. Rev.* 152, 104-117.

**O-2074**

## **Millennial-scale glacial climate variability from a cave record in Southeastern Alaska follows Dansgaard-Oeschger cyclicity**

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### **Abstract**

Speleothems have the potential to preserve long terrestrial records, with the added benefit of precise dating with U-series dating. These records are therefore sought after for reconstructing climate histories in different parts of the world. However, this approach has seldom been applied in Alaska, with no long, continuous record available. Here, we fill-in this gap and provide the first precisely dated terrestrial paleoclimate record from Alaska covering large parts of the last glacial period. A stalagmite from Prince of Wales Island grew between ~75,000 and ~11,100 yr BP, interrupted by seven hiatuses. Hiatuses correspond to permafrost development and a temperature drop of up to 5°C from modern. Intervals of calcite deposition place tight constraints on the timing of mild climatic episodes in Alaska during the last glacial period, when no permafrost was present, allowing water infiltration into the karst system. These periods of calcite deposition are synchronous, within dating uncertainties, with Greenland Interstadials 1, 10, 11, 12c, 14b-14e, 16.1a, 17.2, and 20c. This speleothem record is the first chronologically well constrained evidence of the impact of Dansgaard-Oeschger events on climate and vegetation in the northeast Pacific realm.

O-2075

## Chronology of a Pleistocene cave ventilation event that impacted speleothem records and their geochemistry

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### Abstract

Speleothems rarely grow continuously for more than some thousand years. However, the composite speleothem record based on multiple samples from the same cave can have tens or even hundred of thousands years in duration. The geological evolution of the cave systems (e.g., re-routing of drip flow, opening/colmatation of conduits affecting ventilation, etc) is often a common cause for changes in speleothem growth. These non-climate change related cave processes can also be recorded in the geochemical and petrological speleothem proxies, causing problems when interpreting paleoclimate from speleothem records. Identification of hydrological or inside-cave climate events unrelated to climate changes in speleothem records is difficult, although the study of the erosive and/or depositional record of caves often provide valuable information.

Here we present a study of an extreme case of condensation corrosion in Eagle Cave (central Spain). Large speleothems were formed in this cave, although a sudden ceiling collapse caused a drastic change in cave ventilation that resulted in a net dissolution of speleothems over the main hall of the cave due to the condensation corrosion process. Speleothems affected by dissolution show blunt morphologies and their internal structure (i.e., layers) is visible on their surface. Cyclic thermal changes related to the new ventilation dynamics, forced the condensation of water droplets on the cave walls and the speleothems. The droplets had an acidic pH as a result of cave atmosphere CO<sub>2</sub> diffusion in the solution, causing the corrosion of carbonates where the drops were standing or flowing. The dissolution of speleothems by this event is recorded through the cave, although the magnitude of the process varies locally. Based on the morphology of speleothems, the thickness of carbonate lost by dissolution was in the order of tens of centimetres for most speleothems.

Progressively, the collapse sinkhole that enabled the large thermal variability in the cave was filled with gravitational sediments and the ventilation regime became once more stable enough for speleothems to have net accumulation. Thus, a distinctive series of speleothems overgrew the dissolved speleothems. Dating of several speleothems before and after the dissolution event framed the condensation corrosion event between 60 and 55 ka BP, suggesting that dissolution rates might have been as high as 100 µm/yr. Petrology and geochemistry of speleothems differed before and after the dissolution event as the result of ventilation dynamic differing from the previous stage of speleothem formation. This research highlights the potential of speleothem proxies to record non-climate change related processes.

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O-2076

## Speleothem rubble as a new low-impact tool for Quaternary palaeoclimate studies: insights from a cave model

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### Abstract

As speleothems become increasingly valued for their scientific importance and aesthetics, the pressure on cave environments grows. Several recent scientific studies have stressed the necessity of low-impact sampling strategies such as pre-screening, mini-coring and re-installation of samples after use to reduce unnecessary damage. The great abundance of speleothem 'rubble' in caves, however, suggests another highly-promising tool for low-impact scientific study. Here this concept is first explored in a model, and then applied to the World Heritage Naracoorte caves in South Australia.

To construct the model, we assume that the age frequency distribution of randomly sampled rubble from a family of caves will reflect periods of enhanced and reduced effective precipitation. Speleothem U-Th age frequency distributions were then synthetically generated based on an assumed climatic forcing; Monte-Carlo simulations then help us to understand any potential biases when using the rubble approach. Since any interpretation from an age frequency distribution is strongly dependent on the precision and accuracy of the timing of peaks and troughs within it, we also studied factors that affect the curve shape, such as the type of probability density function, sampling method and sample size. To produce the frequency distribution, a Kernel Density Estimator (KDE) was used rather than the typically employed Probability Density Function (PDF), because the latter rewards ages with small uncertainties producing spiky peaks. In addition, absolute age-uncertainties vary with age for the U-Th method which also introduces bias into a PDF. Our model shows that peaks in the KDE can be reliably identified up to 300-350 ka. After 350 ka, the intensity and timing of the peaks become more difficult to interpret and should be treated with care. The model also confirms the ideal minimum sample size of 120 – 150 mentioned in previous studies.

In our real-world example 137 individual rubble samples (stalagmites, stalactites and flowstones) were collected from thirteen caves in the Naracoorte region, and dated with U-Th techniques. We observe no correlation between sample size (diameter of stalagmites and stalactites) and age, suggesting that there is little if any bias related to rubble form/preservation. The exponential relationship in the natural decay of speleothem material (i.e. a decrease in the number of old stalagmites) reported in recent work was not observed for the Naracoorte region. Based on our model, we suggest that under-sampling and non-random sampling may cause spurious trends in speleothem age frequency distributions, and that their influence should be thoroughly assessed before interrogation of the proxy record. The rubble sampling method offers great promise for palaeoprecipitation studies but can also provide valuable information on the timescales of karst processes and, when combined with other proxy methods (e.g. speleothem palynology), offers a novel, low impact method of palaeo-environmental reconstruction.

**O-2077**

## **The view from the cave: vertebrate responses to abrupt climate change over the last 60ka in Britain**

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### **Abstract**

The rapid climatic fluctuations of the Last Cold Stage and particularly the Last Glacial-Interglacial transition produced a major re-ordering of the vertebrate (chiefly mammalian and avian) faunas of northwestern Europe, resulting in aggregations of extinct and extant taxa that have often been referred to as 'disharmonious', by comparison to their present day biogeography. Previously, the combined problems of poor resolution and chronology have made it hard to establish whether the apparent patterns of vertebrate turnover observed are really synchronous with the climate changes recorded in long terrestrial records such as the Greenland ice cores and whether the apparent co-existence of species that are not sympatric today is genuine, or a taphonomic artefact of a low-resolution record. This has hampered our understanding of (i) the mode and tempo of faunal movement, (ii) regional extinction chronologies in this complex period and (iii) baseline evidence for establishing what is a native species. Cave sequences, especially those from Britain - at the margins of the North Atlantic - offer some of the best archives for addressing these questions, where extensive vertebrate assemblages can be extracted from (semi)continuous sequences. Using new evidence from British cave assemblages, this presentation will examine the different responses of mammalian and avian taxa to withstand abrupt climate change during this period and evaluate the role of cryptic northern (micro)refugia at the very margins of the North Atlantic.

O-2078

## Chironomid inferred temperature reconstructions from the Northern Isles of Scotland during the Last Glacial - Interglacial Transition.

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### Abstract

The Northern Isles of Scotland extend northward into the North Atlantic (~59°N) and are ideally located to reconstruct the interactions between the ocean-atmosphere-terrestrial systems during the Last Glacial-Interglacial Transition (LGIT). The climate of this region is strongly influenced by the North Polar Front and the North Atlantic thermohaline circulation (Barker et al., 2009). Currently, the INTIMATE Greenland stratotype sequence is the best highly resolved archive for understanding climate changes across the North Atlantic region (Rasmussen et al., 2014). However, this assumes that climate and environmental changes are synchronous across the North Atlantic. Presently, temperature oscillations for the wider North Atlantic region are not well understood and have been largely inferred through computer modelling.

Outwith the Greenland ice sheet, environmental changes in the ocean-atmosphere system can be reconstructed from a range of proxies, for example pollen, diatoms and speleothems. However, each proxy is not without its problems and few are directly sensitive to single climate variables, particularly temperature. Palaeo-temperature records have been inferred from coleopteran beetle assemblages but these tend to lack sufficient temporal resolution. Chironomids, on the other hand are found in large concentrations, within small quantities of sediment and provide high resolution records of climate change - within sub-centennial scales (Brooks et al., 2016).

Here, we present the first high-resolution chironomid inferred mean July summer temperature record from the Northern Isles of Scotland. Three continuous cores were sampled from lake basins in Caithness (Northern mainland Scotland), the Isle of Orkney and the Isle of Shetland. The cores are constrained by a robust age-depth model based on AMS dating and supported by tephrochronology. While the three chironomid inferred temperature records show broadly similar climatic shifts to the Greenland Ice Core records they differ in magnitude. Also, based on the bayesian age-depth models, there appears to be significant differences between the timing of temperature changes in the Northern Isles of Scotland and the Greenland Ice Core records during the LGIT.

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O-2079

## Prolonged heavy snowfall during the Younger Dryas

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### Abstract

Snowfall is an important component of Earth's climate system; however, long, continuous high-resolution records of global snowfall are lacking because of the absence of suitable proxies. In this study, diatom record from the sediments of Yunlong Lake, in the southeastern Tibetan Plateau, was used to reconstruct snowfall during the Younger Dryas. Variations in the abundance of low-light-tolerant diatoms and diatom flux indicate that the duration of lake ice-cover during the YD was significantly longer than during the colder Heinrich event 1; this suggests that heavy snowfall, rather than temperatures, was responsible for the greater duration of lake ice-cover during the YD. Thus, we conclude that prolonged, heavy snowfall occurred in the southeastern Tibetan Plateau during the YD. In addition, this conclusion is supported by the results of a climate model simulation that also suggest that heavy snowfall occurred at high latitude in the Northern Hemisphere during the YD. We propose that the heavy snowfall intensified cooling in Northern Hemisphere by increasing the albedo; and that it increased hydrological variability at low latitudes by increasing the duration of the southward migration of the Intertropical Convergence Zone, and by delaying the onset of the Asian summer monsoon. The snowfall would have been a source of continuous freshwater that acted as a positive feedback and resulted in a prolonged weakened state of the Atlantic meridional overturning circulation which lasted for more than 1000 years. Overall, our results emphasize the amplification and positive feedback function of heavy snowfall in triggering abrupt climate change.

O-2080

## The sensitivity of decadal resolved *n*-alkane hydrogen isotope records of two adjacent lakes in northern Poland during the Younger Dryas

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### Abstract

Lipid biomarkers, preserved in sedimentary archives, have become important tools to reconstruct past climate change. Particularly *n*-alkanes, produced by aquatic and terrestrial organisms, are employed due to their ubiquity and stability. Compound specific hydrogen isotope ratios ( $\delta^2\text{H}$ ) are used to reconstruct hydrological changes on local and regional scales. With increasing analytical sensitivity and automated extraction techniques it is now possible to work on a sub-decadal sample resolution in annually laminated lacustrine archives, potentially reconstructing changes related to weather rather than climate. Here we test the sensitivity of *n*-alkane concentrations, compound distributions and  $\delta^2\text{H}$  values by comparing two adjacent paleoclimate records in northern Poland (Trezchowski Paleolake TRZ, Czechowskie Lake JC) that shared the same catchment (TRZ is included in the larger JC catchment), were exposed to the same climate and were surrounded by the same vegetation. The precise age models for both lakes, based on varve counting and tephrochronology made it possible to compare them at a resolution of exactly the same ten year steps in a varved section shared by both lakes between 13,000 and 12,679 yrs BP and in high temporal resolution ( $\sim 10$  years/sample) between 12,679 to 10,500 yrs BP which includes the abrupt onset and the termination of the Younger Dryas (YD) cold period. Within the varved section we observed significant differences in the response of the individual biomarkers. Average offsets in  $\delta^2\text{H}$  values of *n*-alkanes between both lakes for the  $n\text{C}_{23}$ ,  $n\text{C}_{25}$ ,  $n\text{C}_{27}$ ,  $n\text{C}_{29}$  and  $n\text{C}_{31}$  were 14‰, 8‰, 4‰, 5‰ and 4‰ respectively. At the transition into the YD similar responses showed in both lakes, with lower *n*-alkane concentrations and a coeval decrease of *n*-alkane  $\delta^2\text{H}$  values (19-15‰TRZ and 10-5‰JC). Offsets in  $\delta^2\text{H}$  values between both lakes for the mainly aquatic derived  $n\text{C}_{23}$  and mixed aquatic-terrestrially  $n\text{C}_{25}$  were larger than the average analytical uncertainty of 1-2‰, implying differences in the source of  $n\text{C}_{23}$  and  $n\text{C}_{25}$ . During the YD JC showed a significantly lower Average Chain Length (ACL) index, also suggesting increased aquatic macrophyte derived  $n\text{C}_{23}$  and  $n\text{C}_{25}$  input compared to TRZ. As such we suggest, that  $n\text{C}_{23}$  and  $n\text{C}_{25}$  in JC were more of aquatic origin during the YD compared to TRZ. The smaller TRZ showed a significantly higher variance (15‰-25‰) of  $\delta^2\text{H}$  values compared to JC (6‰-13‰), except for  $n\text{C}_{23}$  (47‰JC, 34‰TRZ). These results suggest that in smaller lakes the mainly aquatic sourced  $n\text{C}_{23}$  and the mixed aquatic/terrestrially sourced  $n\text{C}_{25}$  concentration and  $\delta^2\text{H}$  values are prone to be affected by changes in the aquatic ecosystem, such as available aquatic growth area. Terrestrial long-chain *n*-alkanes showed smaller offsets (4-5‰) and less dissimilarity between both lakes, probably due to concurrent change in the common catchment, indicating a more robust representation of local hydrological change.

**O-2081**

## **Holocene temperatures from the Mutual Ostracod Temperature Range method in Northern Estonia**

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### **Abstract**

Continental archives like lakes help to understand and test climate models for the Quaternary. Reconstructions using fossils, e.g. calcareous ostracod shells, pollen or chironomids, express quantitative palaeotemperature excursions for interglacials. The Mutual Ostracod Temperature Range (MOTR) method (Horne 2007) reconstructs the mean monthly air temperature ranges for January and July and MOTR based annual mean temperatures range.

Here is offered a MOTR example from Estonia, northern Baltic, where the method is used for Holocene continental sequence from Lake Äntu Sinijärv. The lake is unique due to its continuous calcareous sedimentation throughout the Holocene and the lake marl gives opportunity to study and test different approaches (fossils, chemical composition of lake sediments etc) to detect any abrupt changes. Ostracod-based study relies on a new age model for the lake (Street-Perrott et al 2018).

Ostracods occupied the lake at ca 10500 yrs BP and their fossil data covers the entire Holocene period and expresses different freshwater ostracod assemblages. This gives a good background for applying MOTR method. Results suggest temperature around +18° to +19°C for July and -2° to 0 C for January and the mean annual temperature (MAT) range from +7° to +9° C in the Early-Holocene (10 500-9200 yrs BP). This is a little higher than modern temperatures. MOTR method suggest an abrupt cooling around 10 000 yrs BP when MAT was ca +3.5° C.

At 9200-3900 yrs BP the MOTR July temperatures varied around +17° C and January temperatures were ca -3° C, MAT values ca +5° C. Sudden MAT drops occurred at ca 9000 yrs BP and 8500 yrs BP where the MATs were around +3° C, and at 6550 yrs BP when MAT values dropped lower than -6° C.

The MOTR suggest for the Late-Holocene rather cool period. July temperature range was from +15° to +17° C and MAT was ca -4° to -2° C. Temperatures started to increase at ca 1500 yrs BP, where temperature for July was ca +18°C and for January ca 0°C, MAT values around + 9° C.

In perspective, the Holocene temperatures derived from ostracod assemblage structure can be tested in combination with different proxy methods and refine any regional reconstructions.

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O-2082

## The groundwater recharge lake evolution in arid region, a case from Badain Jaran Desert, Northwestern China

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### Abstract

Vertical water transport plays an important role in the development and maintenance of lakes in arid zones. However, previous study of this phenomenon has focused mainly on the effects of regional precipitation, rather than effects of groundwater recharge, on arid-zone environmental change. We selected a core from a seasonal lake basin located in the hinterland of the Badain Jaran Desert, northwestern China, to assess the Holocene environmental evolution of this region and its response to climate change.

Our results show that peat deposition from 11 to 10ka indicates humidification after YD, the lake sediment, lower EM2 and lower PCA-1 scores indicates relative more humid environment from 10 to 7.8ka, the lake sediment and higher EM2 and higher PCA-1 scores indicates most humid environment from 7.8 to 5.8ka, the transition from lacustrine facies to limnetic facies and increasing salinity indicates drying trend from 5.8 to 2.5ka, and the aeolian sand sediment, lowest EM2 and lowest PCA-1 scores indicates driest environment from 2.5 to 0.8ka, lacustrine facies and finest grain size indicates relative humid environment during the Little Ice Age period. The environment was relative humid in early Holocene, most Humid in mid-Holocene and dry in mid-late Holocene. The moisture pattern in the hinterland of the Badain Jaran Desert was synchronous with that in the northeastern of Tibetan Plateau, imply that the groundwater recharge lake was dominated by the intensity of groundwater recharge from monsoon margin area, especially the northeastern of Tibetan Plateau. As a record from groundwater recharge lake without runoff, our study provides the groundwater output quantity record from northeastern of Tibetan Plateau and would benefit the environment change research and regional water resources allocation around the Tibetan Plateau.

By analyzing the peak of the short term (non - millennial scale) of the main proxy of sedimentary profile, ten environmental events were identified including the wet events of 10.3 ka, 7.4 ka, 6.3 ka, 4.2 ka, and 0.4 ka and drought events of 9.4 ka, 8.2 ka, 5.4 ka, 2.8 ka and 1.4 ka. And these events, except for events of 6.3 ka and 5.4 ka, are consistent with the North Atlantic cold event as a response to global climate change. It is a perfect record about the North Atlantic cold event in the groundwater recharge lake from arid land of China.

O-2083

## Millennial and centennial climatic influences on productivity and sediment composition in two boreal lakes

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### Abstract

In arctic and high alpine lake ecosystems climate often has a direct influence on the lakes, through changes in mixing regime, lake depth and ionic concentration, while in boreal and temperate systems climate often has a more indirect, catchment-mediated influence. The latter includes complex processes linked to catchment size, geology, soils, vegetation and elevation, and can effectively filter and distort climatic signals, as well as introduce lags in response. One particularly important filter in the cool and humid boreal region is catchment and near-shore wetland dynamics, because of the influence that the extent and configuration of wetlands have on hydrological flow paths, the production of dissolved organic carbon and aquatic habitat availability. Our paired boreal headwater lakes in central Sweden are governed by strong lake-wetland dynamics and provide the opportunity to examine how climate forcing over millennial and centennial timescales are registered in the paleolimnological records of these systems. In addition to paleoecological data (pollen, diatoms), we apply principal component analysis to Fourier-transform infrared spectroscopy and inorganic and organic geochemistry data from two 10,400 cal. y BP sediment records with the aim to link climatic forcing with long-term and short-term excursions in lake productivity and sediment composition. Our results indicate that solar irradiance is important for millennial-scale trends in lake productivity, but that indirect, catchment-mediated processes through lake-wetland interactions dominate sediment dynamics in these boreal lakes. Near-shore wetlands effectively both mute and reinforce climatic signals, but over different timescales. One example is the wetland expansion at ~2000 cal. y BP, which substantially altered the organic matter composition and the diatom community assemblages in both lakes. Additionally, human land use, also linked to the presence of wetlands, may have had important influence on sediment composition over the last 1000 years. For these lakes, wetland dynamics emerge as key to understanding the effects of future climatic changes on these lake ecosystems.

O-2084

## The 4.2 ka BP event: multi-proxy records from Hulun Lake in the northern margin of the East Asian summer monsoon

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### Abstract

The 4.2 ka BP event has been widely investigated since it was suggested to be a possible cause for the collapse of ancient civilizations. With the growth of proxy records for decades, however, both its nature and its spatial pattern have become controversial. Here we examined multi-proxy data of the grain-size distribution, ostracode assemblage, pollen assemblage and the pollen-reconstructed mean annual precipitation from a sediment core at Hulun Lake in northeastern Inner Mongolia spanning the period between 5000 and 3000 cal. yr BP to identify the nature and the associated mechanism of the 4.2 ka BP event occurring in the monsoonal region of eastern Asia. Higher sand fraction contents, littoral ostracode abundances and Chenopodiaceae pollen percentages together with lower mean annual precipitation reveal a significant dry event at the interval of 4210–3840 cal. yr BP that could be a regional manifestation of the 4.2 ka BP event in the northern margin of the East Asian summer monsoon (EASM). We suggest that the drought would be caused by a decline in the intensity of the EASM on millennial-to-centennial scales that could be physically related to persistent cooling of surface waters in the western tropical Pacific and the North Atlantic. The cooling of western tropical Pacific surface waters could reduce moisture production over the source area of the EASM, while the cooling of North Atlantic surface waters could suppress northward migrations of the EASM rainbelt, both leading to a weakened EASM and thus decreased rainfall in the northern margin of the EASM.

O-2085

## Application of seismic geomorphology in reconstructing the Quaternary evolution of Australia's Northwest Shelf

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### Abstract

An ongoing acoustic seabed mapping program by Geoscience Australia has revealed extensive palaeoshorelines features and drowned reefs along the West Australian continental margin. These features constitute one of the most detailed and unique palaeoclimate archives documenting reef and coastline evolution in response to climate and sea level change during the Quaternary.

Acoustic multibeam mapping of the seabed has been effective in defining the geomorphology of submerged shorelines and other coastal sedimentary environments where the primary morphology has been preserved. However, a more typical scenario is the significant reworking or burial of palaeoshorelines particularly during sea level transgression, masking or eroding the original landform and limiting palaeoenvironmental reconstructions.

Over the last decades, the petroleum industry has been collecting extensive 3D seismic data over Australia's Northwest Shelf. Here we investigate their utility for imaging the paleoshorelines of the Quaternary by processing the first few milliseconds of return data (~upper 50 m of seabed) with *PalaeoScan*<sup>TM</sup> software. This type of data analysis not only reveals the internal architecture of submerged landforms but captures a temporal and spatial record of the shoreline evolution in response to stable and oscillating sea levels.

A total of ~15,000 km<sup>2</sup> of 3D seismic data sets located in the Barrow Sub-basin to the west of Barrow Island were analysed, revealing an extremely detailed and complex relic submerged coastal landscape encompassing a range of landforms including channels, coastal barriers, barrier spits and islands, tombolo's and coral patch reefs. These mature landforms are uniformly located in water depths of around -70 m which would suggest a significant sea level still stand at this elevation.

3D seismic data provide the opportunity to create multiple DEM's each representing a single seismic reflector thus enabling for the analysis of coastal landform evolution under a variety of climate and sea level scenarios. These results might provide useful analogues for understanding future coastline response under changing sea levels and climates.

O-2086

## Sea-Level Change and Preservation of Submerged Terrestrial Landscapes in the Western Gulf of Maine

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### Abstract

For more than 30 years I have mapped the seafloor from the western Gulf of Maine (USA) out to 60 m depth, collecting approximately 6,000 km of boomer and 3.5 kHz seismic reflection as well as side scan sonar observations and about 1000 km of multibeam bathymetric records. With students and colleagues, I have more than 50 vibracores and many hours of submersible and ROV observations to groundtruth remotely sensed records. In all of this effort, we have found terrestrial landscapes in only a few locations that depend on local temporal and spatial conditions. Sea-level change offers a strong constraint on landscape preservation. Following a late glacial highstand in Maine around 15 ka, sl fell rapidly to a lowstand at 60 m depth by 12.5 ka. It then rose rapidly until 7.5 ka and entered what we have termed a "slowstand" when sl rose only a few meters between 11 ka and 8 ka. Since then sl rose quickly and then ever-more slowly to the present. The early sl regression was rapid and few traces remain offshore. The lowstand was a time of uncertain length during which isostatic and eustatic sl changes were in equilibrium. Exposed sandy paleodeltas graded to 60 m depth were places of sediment accumulation, but the subsequent transgression wiped out most early traces. Off muddy paleodeltas natural gas obscures the sediment from acoustic tools. Landward from the lowstand, the regressive unconformity was mostly eroded by the subsequent transgression. The transgressive unconformity is widely seen offshore from the lowstand to the coast. Immediately above it one commonly finds *in situ* shellfish and wood fragments that have provided many dates for the local sl record. Sea level rose rapidly from lowstand, passing over glacial landforms with minimal erosion since there was little time or sediment freed up to construct new coastal landforms. The slowstand interval between 11 and 8 ka and 15-25 m depth, is where most paleo-landscapes are found. The slow rise of sl eroded glacial landforms but provided time for large amounts of sediment to accumulate. We have cored an intact salt marsh from 22 m depth and recognized lake basins, terrestrial wetlands and intertidal shellfish *in situ* with associated human artifacts between 15-22 m. Potential lakes were recognized as basins with a connection to the sea, but all cores in these locations lacked lake sediment presumably due to erosion as they drowned. A rapid rise in sl after this preserved this record well. Since 5 ka, slow sl rise has allowed marshes and barrier beaches to grow, and excellent marsh peats are cored off all large beaches, but no artifacts were recovered.

O-2087

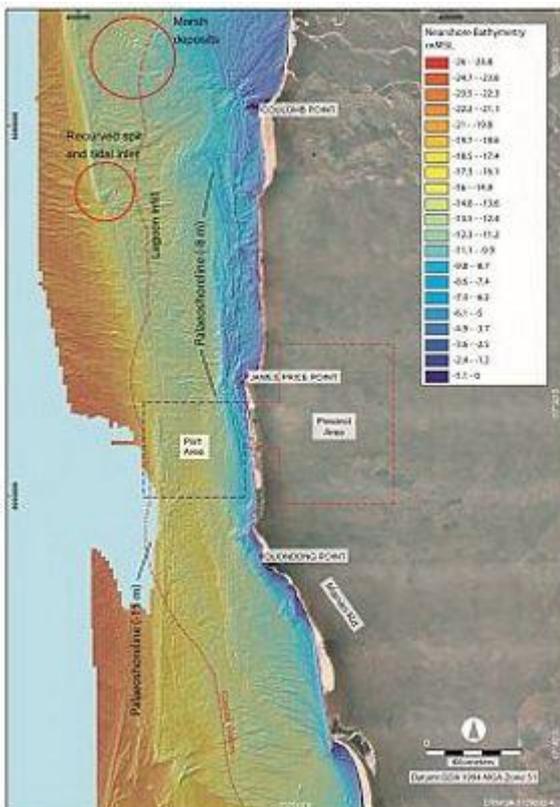
## Visualising a unique marine cultural '*terra incognita*', James Price Point, southern Kimberley

Ingrid Ward<sup>1</sup>, Piers Larcombe<sup>2,1</sup>, Thomas Whitley<sup>3</sup>

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### Abstract

The ancient landscapes of Australia's NW shelf that were drowned by Post-Glacial sea-level rise represent an unexplored frontier – an archaeological *terra incognita* – home to thousands of years of past Australian lives, culture and memory. At James Price Point, in the southern Kimberley region, high-resolution bathymetric imagery reveals a series of astonishingly well-preserved drowned shoreline sequences at depths of ~15 m and ~8 m, with relief of up to 5 m above the surrounding seabed (Figure 1). These linear palaeoshorelines likely date to the early Holocene (last ~9000 years) and border a now-infilled palaeo-lagoon and associated fossil intertidal flats, and are rich in material able to inform reconstructions of past sea level, salinity, temperature and other environmental information. Further, these geological units have high archaeological potential (Ward et al. 2016), which, coupled with many well-documented archaeological sites at the coast, mean that they probably constitute Australia's best prospect of finding its first fully marine archaeological sites. Supported by oceanographic measurements, we use the 3D visualization tools of Terragen 4.0 (Planetside Software, 2017) to develop experimental simulations of shoreline morphology (e.g. <https://www.youtube.com/watch?v=lKqzahMOBrA>) and archaeological site preservation potential through the Holocene, which can be tested through ground-truthing.





*Figure 1. Surface topography and nearshore bathymetric image off James Price Point, showing series of parallel N-S lineations of the -15 m and -8 m shorelines (sourced from DSD 2010, Fig.1–8).*

**References:**

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Ward, I., Larcombe, P., Carson, A., Lane, A. 2016. Archaeological assessment of coastal and marine development sites: case study from James Price Point, WA. *J. Roy. Soc. WA*, 99(2), 31–46.

O-2088

## Late Quaternary sea-level change and evolution of Belfast Lough, Northern Ireland: new offshore evidence and implications for regional sea-level models.

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### Abstract

The Irish Sea region has one of the most complex deglacial sea-level histories on earth, with glacio-isostatic adjustment (GIA) models displaying great variability across the region. Field data needed to calibrate these GIA models are often sparse for areas across Britain and Ireland where past sea level was lower than present and where sea-level indicators are now buried in offshore sediments.

This contribution presents the analysis of marine geophysical data, 39 vibrocores and 24 radiocarbon dates acquired in the marine embayment of Belfast Lough (east coast Northern Ireland). Results show a typical sequence of till, glacial marine and Holocene sediments, as well as a distinct Younger Dryas deposit. All data were used to evaluate existing models as well as to develop a new relative sea-level (RSL) model for the region. Our data provide constraints on the direction and timing of RSL change since c. 15ka cal BP. Furthermore, by applying the concept of a 'Depth of Closure', a sea-level position with associated error term has been calculated.

The proposed RSL reconstruction shows two lowstands (max. -40m) at c.13.5 and 11.5ka cal BP. These are both preceded by rapid transgression, in turn followed by a period of RSL stability. This first transgression can temporally be linked to the final stage of meltwater pulse 1A, with the stable sea level coinciding with the Younger Dryas period. The second stillstand is dated to 10.3-11.5ka cal BP. The timings of events and lowstand depths differ from the GIA models but validate some previously published data.

Whilst marine limiting data, such as obtained through this project, are often disregarded by GIA modellers, this presentation will highlight their importance for the construction of ground-truthed RSL reconstructions and the re-evaluation of the eustatic and/or isostatic components used in the regional models.

O-2089

## **Drowned barriers, gravel spits and beaches from the southern Namibian shelf: a story of antecedent controls on shoreline preservation**

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### **Abstract**

Multiple drowned gravel spits and beaches are preserved along the southern Namibian coastline. A dense grid of seismic profiles reveals an ~ 300 km long, buried set of ridge features at elevations of -70 to -50 m. Ridges may be compound or simple, with internal geometries that vary from bimodal, onshore-offshore dipping planar strata, to steeply seaward dipping strata. These are identical to the gravel barrier spits and beaches of the contemporary coast. The submerged shoreline features vary in along-strike character, with barrier spits prevalent to the south in a palaeo-embayment, merging into beaches outside of the sheltered zone. With increasing drift alignment, the shorelines increase in volume. The largest barriers are found in the antecedent shelter of old embayments and low points formed by incised valleys. These form large (> 15 m thick) features with complex internal structures and evidence of partial cementation in the form of dislocated blocks. The formation of these features is ascribed to the development of planform equilibrium shorelines during a still stand, fed by strong littoral sediment supply. Given their depth co-occurrence with similar features on the SE African margin, we consider these to have formed during a still stand at the same time. Their preservation is linked to antecedent conditioning, together with rapid increases in the rate of sea level rise associated with melt water pulse 1B.

O-2090

## Successive stack of lowstand sequence at shelf slope of active marginal zone, off the Yufutsu Plain, Hokkaido, Japan

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### Abstract

Stratigraphic records provided by offshore surveys have greatly improved understanding about dynamic evolution of sedimentary system associated with the Quaternary sea-level changes. There are many studies about sediments on coastal shelves especially those of the Late Pleistocene to the Holocene based on high-resolution seismic surveys, whereas fewer studies about succession on shelf slopes. At active marginal zones, shelves tend to be narrow and sediments should be efficiently delivered to offshore through the narrow shelves during the lowstand stages. Therefore, sediments of the lowstand stages could be archived as shelf slope sediment at active marginal zones. As a part of offshore active-fault survey, we conducted multi-channel seismic survey with a small watergun (15 in<sup>3</sup>) source to obtain high-resolution profiles including shelf slopes at off the Yufutsu Plain, Hokkaido, Japan. The study area develops narrow shelf of 25 km wide and 130 m depth. The shelf slope is 500 m height and basin floor is > 600 m depth. The seismic profiles figured out sedimentary structure up to 500 m under sea-bottom surface. At the shelf slope and basin floor, we can recognize at least 4 sedimentary packages based on seismic facies. The sedimentary packages are bounded by downlap surfaces, and downlap structures are clearly formed at the toes of shelf slopes. Repetition of downlapping sedimentation suggest cyclic change of sedimentary flux on the shelf slope and basin floor. Sea-level changes in the late Quaternary should have strongly controlled coast-line migration and sedimentary budget stored on the shelf. Therefore, the regression of coast line would increase sedimentary flux outside of the shelf and the transgression would starve the sedimentary flux. Consequently, downlapping sedimentary bodies should be sediments of falling and lowstand stages, and downlap surfaces should be formed during transgressive and highstand stages. Based on the assumption, the sedimentary packages are correlated with sequence of MIS 5-2, MIS 7-6 MIS 9-8, MIS 11-10, in descending order. This interpretation is concordant with chronology of existing marine geological map (Tuzino and Inoue, 2012). Our result demonstrated that lowstand sequences since the Middle Pleistocene were successively stacked on shelf slope of active marginal zone. Sequence boundaries recognized in high-resolution seismic profiles can be used as chronological scale of 100 ka order and are also useful especially for evaluations of active-fault activities. Comparison among the lowstand sequences would contribute to verify magnitude and duration of the lowstands since the Middle Pleistocene.

Reference: Tuzino and Inoue (2012) Geological map of Hidaka Trough.

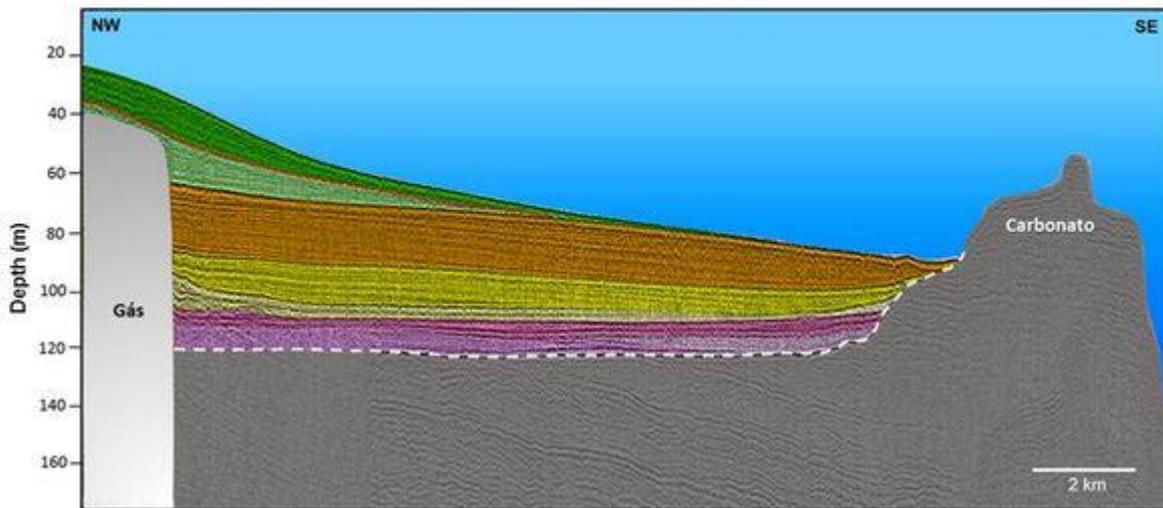
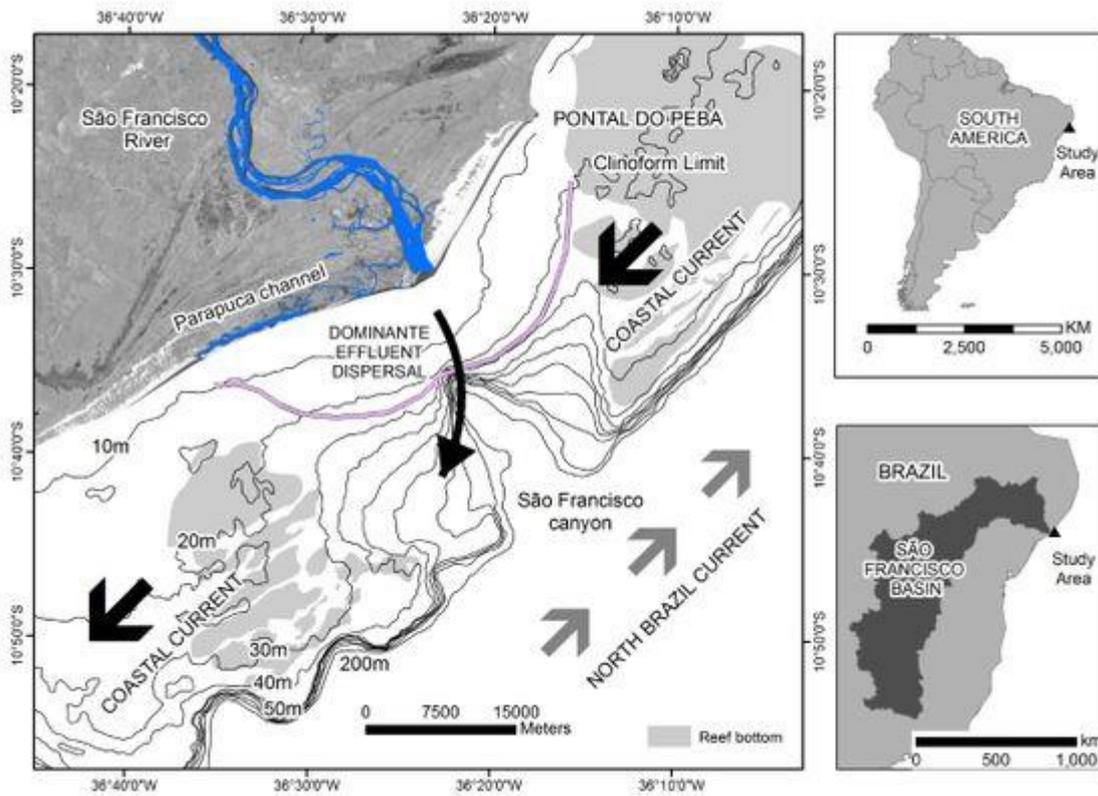
O-2091

## Antecedent topography controls preservation of late Quaternary transgression record and Cliniform geometry: the São Francisco delta (Eastern Brazil)

Adriane Rangel, José Dominguez  
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### Abstract

The shallow (<60m) and narrow (<40km) shelf off east-northeast Brazil makes it difficult to investigate the effects of the last eustatic sea-level rise in the development of the Brazilian deltas. In addition, high wave energy results in greater shear stress at the bottom, precluding the development of deltaic cliniforms exhibiting a classical sigmoidal geometry. Notwithstanding, because of very peculiar characteristics, a complete record of the last sea-level rise is present at the wave-dominated São Francisco delta. This delta was built in a topographically low region of the shelf, associated with the head of the homonymous canyon. This resulted in the creation of an additional accommodation space of several tens of meters. This peculiarity, in addition to favoring the development of a thick muddy cliniform, allowed us to investigate the influence of sea level rise on the architecture and stratigraphic evolution of the delta since the LGM. Five isostratigraphic units were identified in shallow seismic records. The lowermost units (U1, U2 and U3) accumulated around the canyon head in an estuarine environment. U1 was possibly drowned by Meltwater Pulse 1A. U2 and U3 accumulated in the subsequent period characterized by decreasing rates in sea-level rise, which culminated in the Younger Dryas period. The top of U3 passes laterally (along strike) to a wave-cut terrace sculpted in the side walls of the bathymetric depression. This terrace is located approximately 60m below present sea level, and marks the shoreline position at the YD. U3 was drowned by MWP1B as indicated by a wedge of sediments that buries its lateral terminations. U4 deposition began after the MWP1B, from 8.8 to 8.3 ka, based on lateral correlation and radiocarbon dating of samples recovered from boreholes drilled at the deltaic plain. U4 was also drowned after the 8.2 ka event, after which the modern day cliniform (U5) started prograding over U4. U5 muddy cliniform has a typical sigmoidal geometry that dips gently ( $0.4^\circ$ ) towards the ocean. Its thickness does not exceed 40 meters in the most proximal portion of the delta, decreasing progressively offshore, where it reaches just 2 meters. Currently, the cliniform has prograded over half of the shelf, reaching the canyon head. Muddy sigmoidal cliniforms usually develop on extensive low wave-energy shelves. The development of the São Francisco sigmoidal cliniform in a narrow shelf with high wave-energy was favored by the existence of an antecedent bathymetric low, where the modern delta prograded. The present work shows how variations in sea-level rise rates coupled with local antecedent morphology helped in creating a continuous sedimentary record of the Holocene transgression, also allowing the development of the modern sigmoidal deltaic cliniform of the São Francisco river.



LEGEND	
<span style="color: green;">■</span> UNIT 5 (HIGHSTAND SYSTEM TRACT)	--- UNCONFORMITY SURFACE
<span style="color: cyan;">■</span> UNIT 4 (TRANSGRESSIVE SYSTEM TRACT)	- - - MAXIMUM FLOODING SURFACE
<span style="color: orange;">■</span> UNIT 3 (TRANSGRESSIVE SYSTEM TRACT)	<span style="color: lightblue;">■</span> COLUMN OF WATER
<span style="color: yellow;">■</span> UNIT 2 (TRANSGRESSIVE SYSTEM TRACT)	<span style="color: grey;">■</span> ACOUSTIC MASK (GAS)
<span style="color: magenta;">■</span> UNIT 1 (LOWSTAND SYSTEM TRACT)	<span style="color: darkgrey;">■</span> PRE-QUATERNARY SURFACE

O-2092

## Dating Younger Dryas icefield retreat in Scotland using glaciolacustrine varves and tephrochronology.

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### Abstract

A major debate has developed concerning the timing of Loch Lomond Readvance (LLR) ice cap retreat in the Scottish Highlands and the forcing mechanisms responsible. Bromley *et al.* (2014) dated organic remains that accumulated in small basins within one of the main centres of ice dispersal (the Rannoch plateau) and proposed a minimum date for deglaciation of this area by ~12.2 ka BP. However, Small and Fabel (2016) argue on the basis of CRN dates obtained from boulders located in the same sector of the ice cap that deglaciation was not initiated until ~11.5 +/-0.6 ka. The latter view supports the findings of MacLeod *et al.* (2011) and Palmer *et al.* (2010), based on radiocarbon, tephra and varve chronologies obtained from deposits in ice-dammed lake systems at the terminal zones of two ice lobes fed by the icefield, in the Loch Lomond and Glen Roy/Glen Spean catchments. Consequently, for these opposing views to be resolved additional and more stringent chronological information is required.

A key location for establishing the timing and nature of ice cap demise lies north of the Rannoch plateau, within the Glen Spean-Glen Roy catchment. Glaciers fed from mountains at the plateau margins contributed to the ice barrier that dammed the lakes, which temporarily occupied these valleys. Varved deposits accumulated in the lakes and episodes of ice advance and retreat, which led to changes in the lake levels, are reflected in variations in the thickness of the varve layers. Analysis of the varve records provided an initial estimate of the overall duration of the lakes of 515 years, termed the Lochaber Master Varve Chronology (LMVC), the first robust quantification of this time period for the UK (Palmer *et al.*, 2010). Here we will present new data obtained from a network of sites within the Glen Roy basin that, when combined with recent tephrochronological studies, allow the LMVC to be refined and estimates of the precise timing of initial ice retreat in this valley to be revised on an absolute timescale.

These new data provide more robust age estimates supporting the timing of the deglaciation onset in Glen Spean-Glen Roy catchment close to the end of the GS-1 interval, although glacial ice probably persisted into the early Holocene. They also provide insight into the challenges to be met when developing varve chronologies and integrating results with tephrochronology to generate robust absolute chronologies for dating glacier advance and retreat. The evidence, nevertheless, casts doubt on the Bromley *et al.* (2014) hypothesis and provides insight into the response of the LLR ice cap to climatic forcing, which may have been triggered by enhanced atmospheric warming driven by oceanic changes during the latter stages of the GS-1.

O-2093

## Timing the Little Ice Age Advance and Fluctuations of a Glacier in the Eastern Alps - a multi-proxy Lake Sediment Study

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<sup>1</sup>University of Innsbruck, Innsbruck, Austria. <sup>2</sup>eurac research, Bozen, Italy

### Abstract

In order to investigate the variation of glacier extent during the Little Ice Age (LIA) and Holocene in the Eastern Alps, we studied a multi-proxy sediment record from a small high alpine lake spanning over 10 kyr. The lake is located at 2790 m a.s.l. in Southern Tyrol, Italy, in a terrain with active glaciers. Proxies include organic carbon and nitrogen content, dry-weight and wet-density; sediment geochemistry at 1 cm resolution measured on ground dry samples with ED-XRFA, and at 1 mm resolution on core halves with ITRAX-XRF core-scanner; P-wave velocity, gamma density, and magnetic susceptibility measured at 1 mm resolution with a GEOTEK Multi-Sensor Core Logger; biological microfossils. With the Bayesian age-depth modelling software Bacon, we established an age-depth model based on 15 radiocarbon dates using plant macrofossils, and <sup>210</sup>Pb and <sup>137</sup>Cs dating of the top sediment layers. Due to turbidites and visible changes in sediment accumulation rate, establishing a robust chronology remained challenging. In the age-depth model we considered turbidites >1 cm thickness and a boundary layer caused by the shift in sediment properties due to glacier reconnection.

While the lake has currently lost its fluvial connection to the local glaciers, the periods of glacier meltwater input are evident in the sediment record. Before 10 000 cal. yr BP the lake first lost its connection to the glaciers; around 9500 ± 500 cal. yrs BP the lake shifted from a turbid to a clear water lake, and sediment layers became very homogenous and dominated by organic sedimentation for the major part of the Holocene. After 1100 ± 220 cal. AD, we observed another clear system shift; distinct changes in sediment organic content, density, turbidites, and geochemical composition separated several periods with glacier meltwater input of variable intensity and frequency and thus marked the onset of the LIA in this region, and the subsequent fluctuations in glacier extent. Around 1880 ± 20 cal. AD the glaciers started to retreat, and by 1950 ± 7 cal. AD the lake again became a clear water lake without direct glacier meltwater inflow, thus indicating a major retreat of the glacier that is currently still ongoing.

Despite highly variable meltwater input and connectivity to the local glaciers, the lake's sediment record itself was not disturbed or repositioned by glacier movements during the LIA. However, during LIA glacial maxima, the catchment area increased almost eightfold. The resulting vast water volume caused lake outbursts recorded in chronicles from a village in the lower valley which was affected by floodings and landslides. The unique position of the lake at the fringe of a glacier during LIA maximum glacier extent makes this lake's sediment a sentinel for glacier fluctuations and climate variations, especially during the Little Ice Age.

O-2094

## High-resolution fjord sediment record of a retreating glacier with growing intermediate proglacial lake (Steffen Fjord, Chile)

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<sup>4</sup>Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

### Abstract

Steffen Glacier (47°S) is the southernmost outlet glacier of the Northern Patagonian Icefield. Although it has been retreating since the Little Ice Age (LIA), the first aerial images of the glacier in 1944 show a frontal retreat of only 200 m between 1945 and its most likely LIA position approximately 70 years earlier. Since then the glacier has retreated over 5 km, of which 3 km during the last two decades. The ice front retreat resulted in the formation of proglacial Steffen Lake between the glacier and the LIA moraine, through which most of the water and sediment flow before reaching Steffen Fjord via Huemules River. Proglacial lakes are well known to have a filtering (coarse sediments are filtered out) and trapping (decreased downstream sediment yield) effect on the sediment output. Here, we aim to investigate the sedimentary signature of the recent retreat of Steffen Glacier in downstream fjord sediments at exceptionally high temporal resolution. During a field expedition in 2017, four gravity sediment cores were collected along a proximal-to-distal transect in Steffen Fjord. An age-depth model was constructed for the most distal core based on varve thickness and <sup>137</sup>Cs concentrations, which reveals very high sediment accumulation rates during the last 60 years (2–4 cm/yr). Lithostratigraphic correlations between the four fjord sediment cores based on magnetic susceptibility (MS) and grain-size results indicate that sediment accumulation rates decrease by a factor of two over a distance of 10 km. Results from the different sediment cores demonstrate that sediment accumulation in the fjord increases through time with accelerating glacier retreat, in contrast with the many studies that indicate that the formation of a proglacial lake generally results in a decrease in sediment yield. This implies that, in the case of Steffen Fjord, the increase in sediment delivery due to accelerating loss in ice volume exceeds the sediment trapping effect of the growing proglacial lake. The fjord sediments also show a slight fining-upward accompanied by a decrease of the flood-induced MS, grain-size, and to a lesser extent Zr peaks, most likely due to the increasing filtering effect of the developing proglacial lake. However, our findings show that the filtering effect of the proglacial lake reached a maximum when the lake attained a length of approximately 2 km in 1998. The last 3 km of the glacier retreat during the last 20 years does not seem to have had any additional impact on downstream sedimentation. This study confirms that proglacial lakes do have a sediment filtering and trapping effect but that (1) the trapping effect can be outpaced by the accelerating glacier retreat and (2) the filtering effect becomes stable once the lake attains a certain critical size.

O-2095

## A multi-method approach to constrain glacier geometry changes between the Gran Campo Nevado and Pacific Ocean during last glacial-deglacial phase

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### Abstract

Presently a strong correlation exists between southern westerly wind (SWW) strength and precipitation west of the Patagonian Andes ( $r=0.8$ ; Garreaud *et al.*, 2013). As a result glacier chronologies west of the Andean divide are capable of recording local to hemispheric palaeoclimatic shifts during the late Quaternary better than their eastern counterparts. The aim of the #ChileFjords18 project is to develop a detailed understanding of glacier expansion and manner of recession of intermittently marine terminating outlet glaciers to unravel the interplay between glaciological, climatic and oceanographic forcing during the last glacial-deglacial phase in south-western Patagonia. To reach this aim, we conducted a field-expedition in November 2018, where we combined geomorphic mapping techniques (terrestrial and marine) and geochronological methods to constrain glacier geometry changes of two major outlet glaciers (Icy and Xaltegua) between the Gran Campo Nevado and Pacific Ocean (52°S, 72-74°W). High-resolution terrestrial and marine geomorphic mapping is integrated to understand sub- and marginal glacier dynamics. Cosmogenic surface exposure dating of bedrock and erratics is used to establish vertical and horizontal retreat rates of the former Icy and Xaltegua outlet glaciers. Given the hyper-humid setting in the south-western fjords of Chile (Kilian & Lamy, 2012), we also apply a novel approach to determine sample-specific weathering rates by combining cosmogenic and optically stimulated luminescence techniques (Sohbati *et al.*, 2012; Lehmann *et al.*, 2018). The latter is relevant to assess impact of weathering rates on final cosmogenic surface exposure ages. By using a multi-method approach we hope to provide high-resolution empirical data for integration and testing of regional to global glacier-climate models spanning the last glacier termination.

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O-2096

## **<sup>36</sup>Cl exposure-age chronology of Late Pleistocene glaciations on Mount Tymphi, Pindus Mountains, northwest Greece**

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### **Abstract**

The mountains of Greece and the wider Balkans were glaciated during the Pleistocene. The most extensive glaciations occurred during the Middle Pleistocene when large ice caps and glaciers formed in several ranges including the Dinaric Alps and the Pindus Mountains. The Late Pleistocene in the Balkans, however, was characterised by smaller ice masses with glaciers restricted to the highest mountains. Nevertheless, these glaciers were important in shaping much of the high mountain landscapes that we see today and they supplied many rivers with outwash sediments. Here we present preliminary results from <sup>36</sup>Cl terrestrial cosmogenic nuclide analyses. From samples collected in summer 2017, we have calculated exposure ages from moraine boulders and glaciated bedrock in the uppermost valleys and cirques of Mount Tymphi massif (2497 m) in northwest Greece. We address both a significant geographical gap in Mediterranean glacial chronologies and the temporal gap in the glacial history of this region by targeting the previously undated Late Pleistocene glacial record. Coupled with published U-series ages from lower elevation moraines, this is the first glacial chronology in the east-central Mediterranean based on multiple dating methods.

On the southwest side of the massif, 18 exposure ages obtained from 3 moraines in the cirque and mouth of the Laccos Megalon Litharion valley and the mouth of the western cirque of Tsioumako (2155 m), indicate moraine formation between 1700 m and 2050 m a.s.l. during the Late Pleistocene. This complements previous U-series ages obtained from secondary calcites in glacial sediments below 1700 m (and elsewhere in the Balkans), which demonstrate more extensive glaciations dating to the Middle Pleistocene. At ~1430 m a.s.l. in the Laccos cirque on the northeast side of the massif, 6 exposure ages (5 boulders, 1 bedrock) from a pair of end moraines represent the first dates from this side of Mount Tymphi. They suggest small cirque glaciers persisted until at least the end of the Late Pleistocene, facilitated by avalanching snow and shading from the cliffs of Goura (2467 m). Understanding where, when and why glaciers reached their maxima during the last glacial cycle is not only important for understanding the dynamics of the glacial climate in this region, but also for the timing of sediment and meltwater delivery to river systems; the dynamics of Mediterranean refugia; and has implications for understanding the environmental context of nearby Middle and Upper Palaeolithic archaeological records.

O-2097

## Rapid retreat of the western Laurentide Ice Sheet driven by Bølling-Allerød warming

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### Abstract

The last deglaciation of the Laurentide Ice Sheet (LIS) dominated Late Pleistocene sea level rise and its retreat serves as an analogue for understanding the dynamics of modern ice sheet change. Accurate reconstruction of the timing and mechanisms of LIS retreat are important to our understanding of the sensitivity of ice sheets to climate forcings. Within western Canada, knowledge of Laurentide Ice Sheet deglaciation is also an important constraint on the migration of flora and fauna (including early humans) between Beringia and the region south of the North American ice sheets. Furthermore, ice sheet configuration also controls the evolution of large glacial lakes and the development of meltwater drainage routes to the Arctic Ocean. Despite its importance, much of the ice sheet retreat history of the southwestern LIS is still poorly constrained by minimum limiting <sup>14</sup>C data. Here, we present a database of <sup>10</sup>Be surface exposure ages from glacial erratics spanning southwestern Alberta to northwestern Saskatchewan. We combine these data with regional geomorphic mapping to provide an updated chronology for the retreat of the southwestern LIS. Our dataset suggests that the retreat of the southwestern LIS began at ~14.9 ka BP, concurrent with, or possibly somewhat before the abrupt warming at the onset of the Bølling-Allerød, and retreated >1200 km to its Younger Dryas position in ~2000 years or less. This new chronology implies the southwestern sector of the LIS was highly dynamic, retreating earlier and at an accelerated rate than portrayed in radiocarbon derived deglaciation models.

O-2098

## Modeling glacier extents and equilibrium line altitudes in the Rwenzori Mountains, Uganda, over the last 31,000 years

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### Abstract

Mountain glaciers and their moraine records are vital to interpreting the timing and magnitude of past climate changes. Equilibrium line altitude (ELA) reconstructions, however, typically relate to moraines with no or poor age control, and the interpreted changes in climate usually focus on temperature without accounting for precipitation. Here, we use a 2-D ice-flow and mass-balance model to simulate continuous glacier extents and ELAs in the Rwenzori Mountains in East Africa since 31,000 years ago (31 ka), including the Last Glacial Maximum (LGM), Late Glacial period, and the Holocene Epoch. The model uses branched glycerol dialkyl glycerol tetraether (brGDGT) temperature reconstructions from alpine lakes on Mt. Kenya, and the LGM precipitation change is set to -10 and +30% from modern conditions in separate runs. Our results show strong agreement between the brGDGT temperature reconstructions, the timing and magnitude of modeled glacier extents, and mapped and dated moraines in the Rwenzori. Rwenzori alpine regions require a  $>6^{\circ}\text{C}$  cooling with a -10% precipitation change to simulate glaciers that reach moraines dated to the LGM.

O-2099

## The earliest Acheulean-Middle Stone Age transition highland site in Kenya

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### Abstract

The human family tree likely dates back to ~7million years ago. With the exception of our own species *Homo sapiens*, many hominins have appeared and gone extinct. There is great interest in when *H. sapiens* first appeared, the manner of this speciation, and the diversity of behavioral and technological adaptations at the dawn of our species. The Middle Stone Age (MSA) period is widely acknowledged as the period that provides the behavioral context for *H. sapiens*, whose earliest fossils date to at least 200ka. The MSA is also a watershed of behavior that is considered modern. Few archaeological sites document this transition technologically or with fossil remains of early modern *H. sapiens*. Emerging research documents MSA technology sites, including Yiapan, that predate 300ka suggesting that the appearance of *H. sapiens* is earlier than known or that there existed contemporaneous MSA tools-making variants of archaic *H. sapiens* in the Mid- Pleistocene. The Yiapan site is newly discovered in Mau Narok, Kenya and is one of very few highland sites dating to the Mid- Pleistocene. The site documents archaeological remains that are associated with the appearance of our own species *Homo sapiens*. Preliminary investigations indicate that Yiapan site is stratified and has stone tool assemblages that range from Late Acheulean/Early Middle Stone Age (EMSA), Middle Stone Age (MSA) and the Neolithic. The site therefore potentially represents the first time that stone tools of such antiquity have been reported at such high altitude, and indicate previously undocumented hominin adaptation to highlands in Kenya. Rift Valley basinal sites comprise the bulk of archaeological assemblages known to researchers in Eastern Africa and consequently may result in a skewed understanding of hominin behavioral variability. This paper presents results of preliminary research conducted at this site that has the potential to contribute to the understanding of technological and environmental adaptations of hominins in East Africa at the dawn of our species *H. sapiens*.

O-2100

## Seasonal subsistence and seasonal land use adaptations in the Armenian volcanic highlands during the Middle Paleolithic: Excavations at Kalavan 2

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### Abstract

The Southern Caucasus is a rugged and environmentally diverse landscape characterized by a mosaic of distinct ecological niches and large temperature gradients with strong seasonal fluctuations across different elevations ranging from 400 to more than 5000 masl. This posed major challenges and opportunities for hunter-gatherer populations. Seasonally fluctuating environmental conditions and differential resource availability along topographic gradients most likely prompted Pleistocene hominin groups to adapt through adjusting their mobility strategies. However, the role that relatively higher elevation landscapes played in hunter-gatherer settlement systems during the Late Pleistocene (Middle Palaeolithic [MP]) remains poorly understood.

The MP site of Kalavan 2 (Armenia), on the northern slopes of the Areguni Mountains, is currently the only open-air locality in the Southern Caucasus with a stratified sequence that preserves faunal remains and lithic artifacts in association. The site is situated in the Kura River catchment on the northern slopes of the Areguni Mountains north of Lake Sevan. At 1640 masl on a parched river terrace near the confluence of the Barepat River and one of its tributaries, the site is ideally positioned for testing hypotheses on elevation-dependent seasonal mobility and subsistence strategies over repeated occupations of a single locale. Initial excavations exposed at least four meters of stratified fluvial-alluvial deposits with MP stone artifacts and animal bones. In 2017 – 2018, excavations were resumed at Kalavan 2 by our Armenian – Monrepos (Germany) research group. This lecture presents the initial results of the latest excavations, highlighting chronologically and environmentally contextualized archaeological data that shed light upon Pleistocene hunter-gatherer subsistence, mobility, and land-use behaviors in a higher elevation landscape of the Southern Caucasus.

O-2101

## Late Paleolithic vegetation and climate changes in Yunnan province, SW China

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### Abstract

During the past decade, many Late Paleolithic sites were excavated in Yunnan Province, SW China, which gives us opportunity to reconstruct vegetation and climate background for the early human beings before the occurrence of agriculture. Case studies are carried out at two sites, including Xiangbidong site and Naminan Site. The Xiangbidong site is located in Hengduan Mountains, the first cave relic found in Jianchuan County. The Naminan Site is located in the west of Luoguo Mountain, Xishuangbanna Dai Autonomous Prefecture.

Pollen study on seven archaeological layers with two different stages at the Xiangbidong Site recovers abundant palynomorphs, indicating a change process of vegetation and climate. It reveals that the Xiangbidong Site during 100-75 Ka BP was under a warm and humid climate condition represented by abundant *Nyssa* and *Pinus* at first, and followed with a short dry period indicated by a distinct occurrence of *Chenopodiaceae*. The warm and humid climate condition mostly recognizable by *Nyssa* and *Fagus* was then resumed again. It is consistent with the climate condition in the last interglacial period (MIS 5). At about 11 Ka BP, *Nyssa* and *Fagus* became the maximum which is accompanied by *Cyclobalanopsis*, representing a much warmer climate condition in the postglacial period.

The Naminan Site is located in a karst cave, and pollen are not well preserved. Instead, rich phytoliths were found from six archaeological layers with six recognizable phytolith zones. According to the warm index and humid index of the phytoliths, it infers that the Naminan Site experienced a process of climate changes with warm and humid at first, and followed by cold and dry, cool and humid, cool and dry, cold and dry, and warm and humid conditions during 23 Ka BP -10 Ka BP, which is more or less comparable with the global changes.

Taking into the account of high woody pollen value on the whole at the Xiangbidong Site, the signal for human activities during the two separated stages was still weak. Meanwhile, both sites show no evidence for cultivated plant in the fossil assemblages, gathering, hunting and fishing are considered as the human being's main approaches for living at that time. Palm-type phytoliths are very rich in most of the phytolith assemblages which might indicate an enhanced human activity at the Naminan Site.

A general exploration of other Late Paleolithic sites in the Yunnan Province is given for future study. This work was supported by National Science Foundation of China (No. 41771219) and the Strategic Priority Research Program of Chinese Academy of Sciences (No. XDB26000000).

O-2102

## Late Pleistocene hunter-gatherer occupation of the high-altitude afro-alpine ecosystem in the Bale Mountains, South Ethiopia

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### Abstract

Long-held views of high-altitudes as natural ecosystems characterized by late anthropogenic transformation processes have recently been challenged by studies carried out on the world's high plateaus. This is all the more relevant in light of the demanding question where prehistoric populations retreated to, especially during arid intervals, when lowlands may have become uninhabitable.

In this presentation we introduce an interdisciplinary approach for the reconstruction of Quaternary abiotic, biotic and cultural changes in African model highland environments of southern Ethiopia. The Bale Mountains represent the largest afro-alpine ecosystem of the continent. They are characterized by a very high biodiversity including a large number of endemic species and they host relevant archives to reconstruct the coupled landscape and human history. First results of a joint Ethio-European research unit ("The Mountain Exile Hypothesis", funded by the Deutsche Forschungsgemeinschaft) summarized here, comprise archeological, archeozoological, soil biogeochemical and glacial chronological studies and concentrate on the earliest human occupation and persistent use of the available resources.

The Bale Mountains feature the oldest evidence for humans in African high elevations. Late Pleistocene hunter-gatherers must have been very familiar with the then glaciated environment. In immediate vicinity to valley glaciers, high-quality obsidian was regularly and repeatedly extracted from primary outcrops located above 4200 m asl, the highest known occurrences in Ethiopia. Settlement and subsistence activities concentrated on the ice-free areas with access to melt-water. Prehistoric foragers were moreover capable of developing unique subsistence strategies for sustainable and continuous survival and to satisfy the higher caloric demands of living in these altitudes. The associated Middle Stone Age material culture shows the existence of networks to lowlands, but at the same time exhibit the development of distinctive and independent technological traditions.

O-2103

## Bone collagen stable isotope analysis of a Bronze-Age-Site of Liushugou in arid Northwest China and its implication for subsistence strategy

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### Abstract

Liushugou site is located at one of the southern mouths of Eastern Tianshan Mts., Xinjiang, China. Our investigation of Liushugou, a Bronze Age agropastoral community that consist of both semi-sedentary residential space and burial areas (3.5-2.9 cal ka BP), focused on bone carbon and nitrogen stable isotopic analysis of both the human and faunal assemblage. By virtue of macrobotanical result, attempting to understand how these people responded to the harsh environment and thus resource scarcity, and eventually overcame all and made a living in a valley for several centuries. Stable isotopic results revealed that the inhabitants of this site have high animal protein in diet with mean  $\delta^{13}\text{C}$  value of  $-18.1 \pm 0.4\text{‰}$  and mean  $\delta^{15}\text{N}$  value of  $13.1 \pm 1.5\text{‰}$  ( $n = 46$ ). Sheep/goats served as their dominating livestock and also the primary food source which produce a mean  $\delta^{13}\text{C}$  value of  $-17.8 \pm 1.2\text{‰}$  and a mean  $\delta^{15}\text{N}$  value of  $8.3 \pm 1.7\text{‰}$  ( $n = 37$ ). Cattle was the second favorite in number output a mean  $\delta^{13}\text{C}$  value of  $-19 \pm 0.6\text{‰}$  and mean  $\delta^{15}\text{N}$  value of  $8.9 \pm 1.8\text{‰}$  ( $n = 11$ ). Wild animals like boars, deer, antelope, goral and hare were also explored as protein sources (See left). Test flotation result demonstrated that if there was no other cereals, at least barley was grown there, implying they were no pure pastoralists. Comparing the isotopic composition of Liushugou with published data of other sites from this region with result showing right. It's revealed that the food structure can be divided into two clusters, with one likely consumed more C4 food and the other more C3 food, also the former group may have had more animal protein in their diet compared to the later one, besides, the isotopic signal were more diversified in the first cluster. It's highly likely that Liushugou people lived a life far away from their contemporary Tianshanbeilu occupants from Hami Basin, instead they were more like the later ones from north. Basically, the occupants of Liushugou site were pastoralists like their neighbors from north of Tianshan Mts., with high proportion of animal food mainly mutton and chevon intake, and barley as a nutritional supplementary, lived in a primitively structured society. May have been resulted from the harsh environment and consequently source shortage, except for animal breeding near the site and long-distance herding to maximize pasture, hunting to supplement food diversity, swapping goods to increase income, to survive this community could never have been a peace-loving population, drastic competition even killing and cannibalism should have been expected, which explains how the human thoracic vertebrae ended up on the residential floor.

O-2104

## Late Holocene subsistence change in North America's highest residential villages: Alpine archaeobotany in the White Mountains, California, USA

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### Abstract

The White Mountains of eastern California, USA, contain the highest-elevation prehistoric residential occupations known from North America, with villages composed of several house foundations and dense occupational middens ranging from ~3000 to as high as 3850 m. The White Mountains alpine archaeological record documents striking late Holocene shifts in settlement and subsistence patterns, predominantly focused on hunting mammals ranging from ground squirrels to marmots to mountain sheep. Equally striking are shifts in the use of plant foods, the subject of this report. Plant materials from 12 sites were retrieved from sediment samples from firehearths, storage pits and other features, and from more general contexts within the sites. These sites date to four main time periods designated by archaeological phase names: Little Lake (4450-3150 BP), Newberry (3150-1350 BP), Haiwee (1350-650 BP), and Marana (650-100 BP). During the Little Lake and Newberry phases, limited evidence of plant usage incorporated a mix of lowland, montane, and alpine resources, mainly seeds of subalpine pine (*Pinus flexilis*, *P. longaeva*) and goosefoot (*Chenopodium*). During the ensuing Haiwee phase, when residential village occupation began to intensify, the abundance of plant remains increased, and taxonomic diversity also increased substantially. Remains of root crops – bitterroot (*Lewisia pygmaea*), biscuitroot (*Lomatium*) and spikerush (*Eleocharis quinquefolia*) – as well as nuts from the montane pinyon pine (*Pinus monophylla*) and grass seeds became important resources. Montane and alpine plant foods dominate, while valley-based plants diminish in abundance. During the ensuing Marana phase, when residential village occupation became firmly established, plant food use increased once again, dominated almost exclusively by montane rather than alpine crops. The results suggest that when family-based residential village occupation commenced in the White Mountains alpine zone, inhabitants experimented widely with a variety of food-getting strategies, making use of plant foods from several habitats and exploiting both high-cost as well as high-value resources. Once the alpine residential mode became better established and better integrated with other seasonal food-gathering strategies, the roster of plant foods declined in variety, increased dramatically in abundance, and focused heavily on economically most valuable plant foods from nearby montane habitats, rather than from the alpine zone itself.

O-2105

## Late holocene glacier and archaeological history of the Miyar Basin, Lahaul Himalaya

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### Abstract

The glacial-archaeological history of the last millennium is not known in parts of the Himalayas. Various studies made attempt to reconstruct the glacier fluctuations of the period but have a number of limitations. Observation suggests that glacial chronology of the period in the region is largely dominated by relative dating and in areas where the absolute dating has been applied; it has a low frequency of dates. Areas (such as Gangotri and Mount Everest) which have been historically accessible dominate on part of the available glacial chronology of the region. Reconstruction based on the archaeological records in the glacier end moraine complex gives the direct guide to understand the climatic variation, glacier fluctuations and people's survival in the region. We report the glacier archaeological history of the Tharang glacier, Lahaul Himalaya, India which lasts for almost of a Millennium. Three high altitude villages (*Tharang*, *Phundang* and *Patam*) thrived in the end moraine complex of the glacier with around 100 settlements, associated agriculture fields and irrigations systems. Radiocarbon dating suggests that these villages survived in the glacier end moraine complex between 980-1840AD, encompassing the period of the Medieval Warm Period (800-1300) and the peak of the Little Ice Age (1300-1600), elsewhere. Inference based on the chronology of the ruins, geomorphology of the basin and available historical maps and dendrochronological of the region suggests that during the span of these ruins glaciers in the region were constrained even it was the period of the peak of LIA, elsewhere. Glacier could only advance by the late 18<sup>th</sup> or early 19<sup>th</sup> century in the region. The advance resulted in 1-2 kilometres length change in all the glaciers of the basin from their present terminus position.

O-2106

## Relevance of high-resolution records for understanding the past and future ecology of tropical ecosystems in a warmer world

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### Abstract

The history and diversification of tropical ecosystems result from complex interactions between climate, ecological succession and disturbance regimes on multiple time scales ranging from inter-annual to multi-millennial. Regional and global reconstructions of biomass burning suggest that large uncertainties still exist for tropical regions, due to the lack of continuous and spatially-representative records, but also due to the endemically complex nature of climate-vegetation-fire relationships (and relative feedbacks) in the tropical domain. Over the last few decades, multi-proxy and high-resolution, continuous records from extra-tropical regions greatly advanced our understanding of past ecosystem dynamics, the historical legacy of past human impact, and the relevance of past records for biodiversity conservation and ecosystem management under future climate and land use changes. This full potential is yet to be uncovered for most tropical regions. Continuous and well-dated palaeorecords, especially when located at key ecotonal positions or near biogeographical boundaries, can reveal how fire and associated ecological processes mediated climate control on the savanna/forest boundary, the legacy of prehistoric human impact on tropical ecosystems, and the extent to which tropical ecosystems may be adapted (or not) to future changes. Also, continuous records of tropical climate and environmental history at high temporal resolution can be integrated and compared with time series from other natural archives that display seasonal to multi-annual resolution. Recent advancements in stable-isotope research show that tree rings from tropical species may contribute to century-long reconstructions of rainfall variability, or provide spatially detailed disturbance histories and stand-scale dynamics, with annual resolution. Methodological approaches integrating these different temporal scales are relevant for tropical palaeoecology because they can improve existing regional-scale syntheses of climate and ecosystem history (vegetation and fire dynamics) at a greater temporal resolution and precision. Such framework may then inform landscape management aiming at the conservation of endangered tropical tree species, such as the African teak (*Pericopsis elata*) in the Congo Basin.

O-2107

## Coherence from complexity? Maya lowland records of hydroclimate and human impact.

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### Abstract

Syntheses of North American/Neotropical palaeoclimates have tended to include only a small fraction of published records from the lowland Maya area (modern Guatemala, Belize and Mexico) due to poor dating control, the relatively short periods covered by some records, or a lack of clarity about the primary driver of the signal contained. The interpretation of climatic records from the Maya lowlands is made more difficult by the complexity of the region's climatology lying between the main zones of influence of the ITCZ and the Mexican (North American) Monsoon, mediated by drivers from the Atlantic (AMO) and Pacific (ENSO). Interactions between climate and human activity have also long been of interest in this region, with ongoing debates about the impact of climate (especially drought) on the sustainability of human occupation and likewise the extent to which human activity caused significant changes in natural ecosystems, resulting in environmental degradation. Studies of different archives and different proxies have tended to provide insights into either hydroclimate (primarily based on  $\delta^{18}\text{O}$ ) or vegetation change (pollen, charcoal), with relatively few adopting a multi-proxy approach that might allow a more robust discrimination of these two elements. Here we present recent results from Lake Tuspan (Guatemala), beach ridges associated with the mouth of the Usmacinta River (Mexico), Cenote Yaal Chac and Laguna Esmeralda (Mexico) which provide continuous records covering up to 8,800 years. Today the sites experience very different rainfall amounts (from  $> 2000$  mm to  $< 1000$  mm yr<sup>-1</sup>) and represent different hydrological settings. They also cover a range of known intensities of Maya occupation, with Tuspan lying close to a number of major sites, while Esmeralda appears to have been in an area with rather sparse occupation during the Maya period. All sites have been analysed using a variety of proxies which record both regional and local signals. Sedimentological, geochemical, isotopic and diatom data provide records of changes in water balance and periods of catchment disturbance, while charcoal data can be related to both natural fires and deliberate vegetation clearance at different times. Results are broadly consistent with established patterns of NH tropical climate response to insolation forcing during the Holocene, but also reflect variability at shorter timescales (e.g. centennial) which must be related to other drivers. Factors such as sea level change and changes in seasonality also come in to play. Comparison with other records from the lowlands, primarily from other lakes and speleothems, highlight periods of coherence in behaviour, but also illustrate the complexity of individual system response. Different hydroclimatic settings also influence whether wetter or drier conditions are conducive to agricultural intensification and the potential vulnerability of Maya communities to drought.

O-2108

## Developing annual tree-ring chronologies and climate reconstructions from moisture sensitive *Araucariaceae* trees in tropical and subtropical Australia

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### Abstract

Many parts of tropical and subtropical Australia lack both annually-resolved long-term instrumental climate data and proxy climate records. This limits our understanding of past climate patterns and impacts. There are however, remnant forest stands where dendroclimatology could be applied to extend the climate record. Early studies into tropical Australian tree species suggested difficulty in dating these records due to the fact they are compromised by numerous ring anomalies. This has led to such species being understudied with little known about their tree growth to climate relationships and paleoclimate potential. Recent research of trees in the *Araucariaceae* family has attempted to address these issues in order to develop annual, chronologically precise, long-term climate reconstructions across tropical and subtropical Australia.

*Araucariaceae* trees are commonly found across northern and eastern Australia and are longer lived than many other local non-temperate species. They are known to produce growth rings that are mostly annual and their growth appears sensitive to climate, specifically to moisture conditions. Three *Araucariaceae* species, hoop pine (*Araucaria cunninghamii*), bunya pine (*Araucaria bidwillii*) and purple kauri pine (*Agathis atropurpurea*) have been studied at five locations within the rainforests of eastern Queensland. Ring anomalies including false, faint, locally absent, and pinching or wedging rings, were identified. This was done by applying bomb-pulse radiocarbon dating, radiographic analysis, and density pattern assessment to hoop pine trees from subtropical Lamington and D'Aguilar National Parks. Additionally, dendrometers were installed on trees of all three species so that the annual nature of growth could be proven and the climate variables influencing seasonal growth identified. This analysis verified annual growth for all three species and proved that dating can be confirmed using a multi-technique approach. This demonstrates the suitability for dendrochronology in tropical and subtropical Australia to be applied for high-resolution climate reconstruction. Examination of growth-climate relationships indicated that moisture conditions are driving tree growth in these species so long-term reconstructions of rainfall and drought can be established. Following this, a 164-year drought reconstruction for Southeast Queensland was developed using hoop pine trees from the subtropical rainforest of Lamington National Park and a record extending back to 1400 has been developed for tropical Queensland. Additional work is continuing using this approach to further develop a network of long-term Queensland, Australia tree-ring climate records.

O-2109

## DeepCHALLA – a 250,000 year record of hydroclimate from equatorial East Africa using diatom and organic isotope data

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### Abstract

Long-term variability of rainfall in equatorial East Africa is thought to be associated with Hominin evolution and ecology. At the millennial scale, rainfall patterns have been quite well constrained for the last 25,000 years but earlier records are more fragmentary hindering consideration of the role of climate in the evolution of our species. Here, we provide information on past hydrological changes using oxygen and carbon isotopes in fossil diatom frustules ( $\delta^{18}\text{O}_{\text{diatom}}$ ) and sedimentary organic matter ( $\delta^{13}\text{C}_{\text{org}}$ ) from the ~214-metre long ICDP DeepCHALLA sediment record retrieved from Lake Chala ( $3^{\circ} 19'S$ ,  $37 42'E$ ), a freshwater crater lake (92 m deep) situated on the lower eastern flank of Mt. Killimanjaro. Provisional chronologies suggest this record extends to MIS 8, and the consistent laminated structure imply few discontinuities. Lake Chala's hydrology is driven by evaporation exceeding local precipitation and surface inflows, and lake level being maintained by groundwater inflow and outflow. Precipitation and shallow groundwater inputs deliver water with low oxygen isotope ratios to Chala's surface water ( $\delta^{18}\text{O}_{\text{lake}}$ ) where it is subjected to evaporation. Sedimentary  $\delta^{18}\text{O}_{\text{diatom}}$  signatures are thus a measure of local insolation and relative humidity, skewed towards the diatom growth season (Southern Hemisphere winter when conditions are dry and windy) over inter-annual timescales. Sedimentary  $\delta^{13}\text{C}_{\text{org}}$  signatures are driven by variation in autochthonous productivity and terrestrial inwash. Seasonal and long-term variation in East African rainfall reflects shifts in the latitudinal position of the tropical rain belt linked to the Intertropical Convergence Zone (ITCZ), which migrates meridionally in response to changes in interhemispheric heat distribution. However, the intensity and movement of the ITCZ itself is driven largely by variation in Indian Ocean Sea Surface Temperatures (SSTs), which in turn determine the strength of monsoonal dynamics delivering rainfall to eastern Africa. The diatom-isotope data from Lake Chala reflect major hydroclimate variability in equatorial East Africa through the last glacial cycles, superimposed on a long-term hydrochemical evolution of the lake basin.

O-2110

## The contribution of Lynch's Crater to the history of local, regional and global environmental change

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### Abstract

It is 50 years since the iconic site of Lynch's Crater was 'discovered'. It has provided and continues to provide insights into patterns and causes of environmental change through the latter part of the Quaternary on the volcanic Atherton Tableland and the broader region of tropical north-eastern Australia with implications for the environmental history of the Australian continent and the globe as a whole. In relation to vegetation, the record demonstrated, contrary to a then widespread belief in the stability of tropical rainforest, that lowland tropical rainforest expanded to replace sclerophyll vegetation on the Tableland after the last glacial period and changed progressively in composition since that time. Further back in time the record revealed the importance of a moist rainforest type that was dominant during recent glacial periods but now largely confined to subtropical latitudes, as well as documenting several regional plant extirpations, and the total extinction of a species or even genus - an event rarely recorded during this late Quaternary period. Additionally, the last known record of a tropical swamp forest in Australia was detected in the early Holocene from a combination of pollen and plant macrofossil evidence. Climate variation, operating at various scales, from orbital to millennial, has been identified as exercising a major control over changes in vegetation and associated sediment stratigraphic features with the recognition of southern and northern hemisphere and tropical forcing, as well as some novel and significant interactions between them. However, the cause of the major and sustained transformation of the vegetation with the elimination of the moist rainforest around 40 ka, that was associated with an increase in charcoal, has been the source of continuous debate - was it climate or was it people? An initial explanation that burning by people, on arrival, directly caused the replacement of fire sensitive moist rainforest by fire-adapted sclerophyll vegetation, has been modified by suggesting that, based on recent evidence for a sharp decline in faunal dung fungi at this time, 'overkill' was primarily responsible for megafaunal decline and this resulted in a build up of fuel that led to the burning increase and vegetation change. Those advocating climate as the cause of environmental change at Lynch's Crater and at other sites have failed to demonstrate the unique nature or sustainable impact of this event although evidence for a general drying trend through much of Australia from the mid-Brunhes, may have resulted in an environmental tipping point. There has been a general avoidance of a multiple cause for the 40ka event but a recent examination of interannual variability in climate derived from Lynch's Crater in relation to the pattern of decline in moist rainforest opens the possibility of a dual human/climate explanation.

O-2111

## A revised age model and lake-level curve for Lake Naivasha's Late-Holocene sediment record

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### Abstract

One of the better-known Late-Holocene climate-proxy records in East Africa is the lake-level reconstruction from Lake Naivasha in Kenya, based on lithostratigraphic interpretation of its sediment record inside Crescent Island Crater (CIC; Verschuren 2001 *Journal of Paleolimnology*). Usually connected to the main basin of Lake Naivasha except during the driest periods, CIC preserved a unique continuous palaeo-environmental archive of a climate-sensitive amplifier lake in the East African Rift (EAR) region, because its deep and wind-sheltered bottom environment limited sediment disturbance and allowed persistence of a remnant salt lake during the most severe Late-Holocene droughts. Adding to this the relatively high sedimentation rates (on average 4 mm/year), the high-resolution CIC record has been favourably exploited for reconstructions of climate history (Verschuren et al. 2000 *Nature*) as well as terrestrial (Lamb et al. 2003 *The Holocene*, Colombaroli et al. 2014 *Global Change Biology*) and aquatic (Mergeay et al. 2011 *Ecology*) ecosystem dynamics in this semi-arid region of the EAR.

Continued interest in the potential of Lake Naivasha's CIC record for environmental reconstruction as well as advances in age modelling have prompted an update and partial revision of the information published almost two decades ago. Concerning core chronology, new computational techniques allow a more robust yet flexible chronological framework, with explicit consideration of changes in sedimentation rate constrained by lithostratigraphic evidence. Especially in the very dynamic depositional environments of fluctuating lakes, this facilitates the construction of age models which incorporate site-specific understanding of the sedimentological context; the CIC record provides a good case study to highlight the advantages of such Bayesian age-depth modeling. Secondly, extension of the diatom-inferred salinity reconstruction which was published by Verschuren et al. (2000) to the lower part of the 1600-yr sediment record created confidence in a more detailed lithostratigraphy-inferred lake-level reconstruction for the period before 1100 cal. yr BP (the part that had been presented originally).

Producing solid palaeoenvironmental reconstructions from tropical continental regions remains challenging, due to the scarcity of natural archives that are demonstrably continuous, can be properly dated, and contain robust climate or ecosystem proxies over sufficiently long time periods. Defects in these aspects are often not explicitly stated or documented in publications; and regional syntheses tend to include also the more ambiguous time series at face value, because stringent selection would leave large geographical data gaps. In this context, the Lake Naivasha record is now more amenable to inclusion in regional and larger-scale palaeodata syntheses, while at the same time our revised data do not substantially affect any major conclusions of previously published work. This study aims to highlight that with respect to future contributions to understanding tropical climate and ecological dynamics, "revisiting the past" may well start in our own drawers.

O-2112

## Savanna in equatorial Borneo during the late Pleistocene

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### Abstract

Equatorial Southeast Asia is a key region for global climate forcing. Here, the Indo-Pacific Warm Pool (IPWP) is a critical driver of atmospheric convection that plays a dominant role in global atmospheric circulation. However, fluctuating sea-levels during the Pleistocene produced the most drastic land-sea area changes on Earth, with the now-drowned continent of Sundaland being exposed as a contiguous landmass for most of the past 2 million years. How vegetation responded to changes in rainfall that resulted from changing shelf exposure and glacial boundary conditions in Sundaland remains poorly understood. Here we use the stable carbon isotope composition ( $\delta^{13}\text{C}$ ) of bat guano and High Molecular Weight *n*-alkanes, from Saleh Cave in southern Borneo to demonstrate that open vegetation existed during much the Last Glacial Period. This location is at the southern equatorial end of a hypothesized 'savanna corridor' and the results provide the strongest evidence yet for its existence. The corridor operated as a barrier to east-west dispersal of rainforest species, and a conduit for north-south dispersal of savanna species, at times of lowered sea level, explaining many modern biogeographic patterns. The Saleh Cave record also exhibits a strong correspondence with insolation and sea surface temperatures of the IPWP, suggesting a strong sensitivity of vegetation to tropical climate reorganization on glacial/interglacial timeframes.

O-2113

## Evolution of the Agulhas leakage to the Atlantic Ocean through the Pliocene and Pleistocene

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### Abstract

The Agulhas leakage is an important contributor to the global thermohaline conveyor system, adding warm and saline subtropical waters from the Indian Ocean to the South-east Atlantic Ocean. It has been demonstrated that during the late Pleistocene there were increases in heat and salt to the Southeast Atlantic Ocean during deglaciations, which have been interpreted as an indication of strengthening Agulhas leakage. In turn, it has been proposed that by reinvigorating the Atlantic Meridional Overturning Circulation, these increases in Agulhas leakage could have been important for the development of interglacial warmth.

However, little is known about the longer-term evolution of Agulhas leakage during the Pliocene and Pleistocene (the last 5.3 Ma). In the Pliocene, the continental ice sheets were smaller in size, and the position and strength of key ocean and atmosphere circulation systems in the South Atlantic region were different. The Pliocene is also characterised by a series of gateway changes which are argued to have affected North Atlantic climate, but the response of the Agulhas leakage system remains unclear. It is also unclear whether the 'early deglaciation' signal is a specific component of the late Pleistocene 100 kyr cycles. Identifying how and when this signal developed could have important implications for understanding the impact of ocean circulation changes on the development of the mid-Pleistocene climate transition (MPT) ~1.2-0.6 Ma, when the period of the glacial-interglacial cycles shifted from ~41 kyr to ~100 kyr.

Here we present initial results from a new Cape Basin site (Site U1479, 35°03.53'S; 17°24.06'E), which was recovered by IODP Expedition 361 in 2016 from the western slope of the Agulhas Bank (Hall et al., 2016). We combine reconstructions of sea surface temperatures (using the alkenone-derived  $U_{37}^k$  index) and sea surface salinity (from alkenone  $\delta D$  analysis) with details of planktonic foraminifera assemblages, to identify and understand variability in Agulhas leakage operating across both orbital and longer timescales. There is an overall cooling of ~4°C since the Pliocene, but it is focussed around ~2 Ma and from 1.2 Ma. Orbital scale and longer-term variability in SST, sea surface salinity and Agulhas leakage fauna are also determined, demonstrating that the Agulhas leakage system has evolved across a range of timescales through the Plio-Pleistocene, especially in association with the MPT.

### References



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**O-2114**

## **Insolation-triggered millennial-scale glacial climate resonance**

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### **Abstract**

Millennial-scale glacial climate variability, known as Dansgaard-Oeschger events, is a ubiquitous feature during glacial periods of the Pleistocene epoch. To date, changes in the Atlantic Meridional Overturning Circulation (AMOC), especially its bistable behavior, has been commonly suggested to be the mechanism at the heart of the underlying dynamics of these events. However, a coherent triggering mechanism remains elusive. Here I show, by using a comprehensive fully coupled model, that insolation change alone can cause glacial climate resonance, of which simulated periodicity and global responses are in a good agreement with empirical evidence. My results demonstrate that interactions between insolation-induced changes in high-latitudes sea ice cover and low-latitudes hydrological cycle in the North Atlantic – two key processes modulating the AMOC strength – play a critical role on stimulating the millennial-scale oscillations. Specifically, the enhanced sea ice cover and weakened atmospheric moisture export from the subtropical North Atlantic to Pacific, associated with changes in obliquity and precession, respectively, can kick the oscillation from a strong AMOC state under intermediate glacial conditions. The oscillation can be maintained afterwards by the low- and high-latitudes atmosphere-ocean-sea ice feedbacks in the North Atlantic. Additional millennial-scale variability of atmospheric CO<sub>2</sub> (~ 20ppm) appears to modulate the oscillation periodicity – a higher CO<sub>2</sub> level leads to a longer cycle. Altogether, my results for the first time integrate millennial-scale glacial climate variability with Milankovitch theory, providing a coherent framework for systematically understanding the triggering mechanism of abrupt glacial climate changes.

O-2115

## Millennial scale variations in 100-year resolution NW Pacific sea surface temperature over the past four glacial-interglacial cycles

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### Abstract

To investigate millennial scale variations in sea surface temperature (SST), we reconstructed high-resolution records of alkenone unsaturation index and *Globigerinoides ruber* Mg/Ca ratio and  $\delta^{18}\text{O}$  from the northwestern Pacific margin (IODP Site U1429) over the last 400,000 years. Our proxy records have an average resolution of approximately 100 years, constituting the first northwestern Pacific high resolution, continuous SST record spanning the past 400 ka. On orbital scale, *G. ruber* Mg/Ca (summer-biased) and alkenone (annual mean) temperatures are coherent and in phase with one another at the eccentricity (100 ky), obliquity (41 ky), and precession (23 ky) bands; the significant difference between the two is that, compared to Mg/Ca temperature, alkenone temperatures show strong spectral response at the 100 kyr band, typically associated with changes in global ice volume and sea level. In addition, the alkenone temperatures well match the glacial age  $\text{CO}_2$  structure, while *G. ruber* Mg/Ca temperatures do not, indicating that  $\text{CO}_2$  change appears to be more associated with alkenone temperature than Mg/Ca temperature. The millennial scale variations in the northwestern Pacific SST were identified from both SST anomalies after filtering out the 100, 40, 23 and 19 ka cycles. In general, both SST anomalies tend to covary through the entire period on millennial scale, although Mg/Ca temperatures varied with larger amplitudes compared to alkenone temperatures. Comparison of alkenone SSTs between Site U1429 and the Iberian margin shows that both SSTs match well from a frequency perspective, meanwhile the amplitudes of Iberian margin SST variations were much larger. In addition, comparison to the synthetic record of Greenland climate variations shows that these two records are similar. These observations support that Dansgaard-Oeschger type variations in the surface temperature of the North Pacific, extended to MISs 6, 8 and 10, and they were linked to the Atlantic rapid climate changes.

O-2116

## Assessing the Pleistocene hemispheric climate links through correlating loess, marine and ice-core records

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### Abstract

Near continuous loess-soil records in China cover the past 22 million years. Here, we compare various independent climate proxies from the terrestrial, marine and ice-core domains to re-evaluate the regional and global significance of the China loess with special emphases to the Quaternary portion. The results confirm that the intensity of loess deposition in China is closely coupled with the northern high latitude climate from the over-orbital to millennial scales, and that loess accumulation rates (LAR) and loess particle-size reflect many features of the northern high latitude ice conditions. Consequently, correlating the loess and marine records could offer the possibility for addressing the hemispheric climate links. Our loess-marine correlations show that both records are broadly coupled during the Pleistocene. However, numerous decoupled features exist between the two records. Marine oxygen isotope record shows a general trend of increased ice-volume during the Pleistocene. This trend has no clear reflection in the loess LAR and grain-size data. A prominent change at  $\sim 430$  ka, referred to as the Mid-Brunhes Event (MBE), is clearly documented in both marine and EPICA ice records while its reflections in loess are rather ambiguous. Both marine and EPICA data show a cooler-than-average interglacial for the marine-oxygen isotope stage 13 (MIS-13) while a series of terrestrial records show a warm-extreme interglacial for the northern hemisphere. During a number of glacial intervals, such as MIS-16, MIS 14, MIS-12 and MIS-3, interglacial-level of loess grain-size are observed while they have no obvious reflections in the marine and EPICA ice records. Based on a multi-proxy approach, we argue that these decoupled features between the loess and marine records are attributable to the asymmetrical behaviors of the Pleistocene climates between the southern and northern hemispheres.

O-2117

## Increasing Pleistocene permafrost stability and carbon cycle conundrums

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### Abstract

Arctic permafrost sequesters a substantial stock of perennially frozen organic carbon that could be released to the atmosphere as methane and carbon dioxide upon thawing. This thaw vulnerability of permafrost organic carbon represents a potentially powerful amplifier of climate change, but little is known about permafrost sensitivity and associated carbon cycling during past intervals of persistent climate warming. Here we reconstruct permafrost history in northwestern Canada during Pleistocene interglacials from 131 uranium-thorium ages on 74 speleothems, cave deposits that only accumulate during intervals of deep ground thaw. We infer that interglacial permafrost thaw was widespread ~0.5-1.5 million years ago, but deep permafrost persisted in much of Arctic and sub-Arctic North America through warm interglacials of the last ~500,000 years, with deep thaw likely limited to sub-Arctic discontinuous permafrost during the Marine Isotope Stage 11 “super-interglacial”. On Pleistocene timescales, interglacial CO<sub>2</sub> concentrations remained within a narrow  $\sim 280 \pm 20$  ppm range and were insensitive to differences in the magnitude of interglacial permafrost thaw inferred here. This implies the existence of processes that attenuated the permafrost-carbon feedback during Pleistocene interglacials, including those when the magnitude of inferred permafrost thaw exceeded numerical model projections for extensive ground thaw over the next several centuries.

O-2118

## Gibraltar Outflow and Mediterranean overturning circulation during the last 500 ky

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### Abstract

In order to explore past changes in the Mediterranean Outflow Water (MOW) we analyzed the fine sand content in the sediments together with some geochemical proxies and planktic and benthic stable isotopes at IODP site U1389. This site was recovered in the vicinity of the Strait of Gibraltar along the path of the main core of the MOW. The content of fine sand together with Zr/Al ratios were used to investigate the MOW speed variability along the past 500 ky. The MOW speed variability at this site was mainly driven by changes in the density contrast between the Inflow and Outflow, which was, in turn, governed by changes in the Mediterranean heat and freshwater budgets. Events of enhanced freshwater input to the Mediterranean associated to northward shifts of the Intertropical convergence Zone reduced the density contrast at Gibraltar and weakened the MOW at Gibraltar. Weak MOW events were recorded at times of sapropel deposition in the eastern Mediterranean.

At millennial scale, the MOW intensified at times of Greenland stadials and weakened during interstadials. However, during Heinrich stadials typical three-phase events were observed, with a sandy contourite layer at the bottom and top and a phase of weak MOW in the middle of the stadial, coinciding with the arrival of icebergs to the Gulf of Cadiz. For Heinrich stadial 1 this weak MOW event occurred at the time of the massive release of icebergs from the Laurentian ice sheets. However, the inflow of less saline water to the Mediterranean should have increased not decreased the density contrast between the Inflow and Outflow, especially because freshwater discharge to the Mediterranean from the African monsoons was extremely low. We propose different scenarios to explain these weak MOW events in the middle of Heinrich stadials that were certainly triggered by prominent changes in the Mediterranean heat and freshwater budget.

**O-2119**

## **Climate impact of orbital forcing from deep times to Quaternary**

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### **Abstract**

Orbital parameters variations have been accurately computed from Quaternary to Cretaceous (Laskar et al., A&A 2004). For Quaternary, the climatic consequences of orbital forcing have been for long intensively studied using a large hierarchy of models (Berger and Loutre, EPSL, 1992; Paillard, Nature, 1998 and Ganopolski et al. Climate of the Past, 2010). The imprint of climatic consequences of astronomical variations has been documented for deep times in very different contexts than Quaternary. One of the oldest and most amazing illustrations of this imprint is the role of orbital forcing in explaining high resolution sediment records (Svalbard) depicting glacial/lacustrine oscillations occurring at the end of the Marinoan snowball episode (635Ma) in a context of very high CO<sub>2</sub> level (Benn et al., Nature Geoscience, 2015) .

The imprint of so-called Milankovic forcings has also been found for Paleozoic and Mesozoic, such as Devonian (De Vleeschouwer et al, EPSL, 2013) and mid-Cretaceous period (Herbert et al., Nature 1986; Giorgioni et al, Paleoceanography, 2012).

More recently, during the Tortonian period [11-7 Ma], the ultimate shrinkage of a huge epicontinental sea, that extended from Eastern Europe to Western Asia, has been shown to drastically enhance the climate response to orbital changes at the emergence of early hominins (Zhang et al., Nature, 2014).

The huge impact of astronomical forcing during Quaternary leading to glacial/interglacial cycles has been shown to be associated with the long decrease of pCO<sub>2</sub> since Eocene. A first threshold was achieved 34 million years ago corresponding to Antarctica Ice sheet onset (Deconto et al., Nature, 2008; Ladant et al., Paleoceanography, 2014). The second threshold was achieved more than 30Ma later and led to the Greenland glaciation, occurring at the late Pliocene when atmospheric CO<sub>2</sub> reached values low enough to produce first short lasting Greenland ice sheet (Tan et al., EPSL, 2017) before a perennial glaciation (Lunt et al., Nature 2008; Tan et al., Nature Comm. 2018). This permanent glaciation associated with low pCO<sub>2</sub> value favored the onset of Northern hemisphere glacial/interglacial cycles that punctuated Quaternary climate.

This presentation will depict how modeling with sophisticated coupled AOGCMs interacting with ice sheet models are able to simulate the climatic impacts of orbital forcing from deep time to the onset of Quaternary. We will emphasize the very peculiar geological and pCO<sub>2</sub> conditions that explained the periodic oscillations of the last million years.

O-2120

## Assessing anthropogenic impacts on the landscape configuration of coastal areas of Corsica (France) from Early Neolithic to Late Roman times

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### Abstract

We present the first reconstruction of the landscape evolution of the coastal lowlands of the Island of Corsica, in the western Mediterranean, together with the identification of the first human impacts on both vegetational and morphological changes in some of the island's major river mouths. We performed a bio-stratigraphic analysis of a new set of boreholes drilled in saltmarshes and lagoons located in the SE (Bonifacio-Piantarella and Porto Vecchio-San Ciprianu sites), NW (Saint Florent) and in the central-eastern (Aleria-Del Sale) coast of the Island. We reconstructed the paleoenvironmental history of the last eight millennia in these areas, which are amongst the earliest settled areas of Corsica. The laboratory analyses of the borehole cores comprised: i) ostracods, which support and refine facies characterization and the turnover of depositional environments; ii) pollen grains, which enable us to reconstruct the local vegetation history; iii) radiocarbon dating of 20 samples of organic matter, peat, marine and lagoonal shells which provides a robust chronostratigraphic framework for each site; and iv) XRF core scanning of the Saint-Florent core, drilled within a deltaic context, which provides a record of continental sediment detrital input. The principal results highlight the development of a Mediterranean maquis, together with a riparian forest, in the coastal plains of the island since at least early Neolithic times (ca. 5500 cal. BCE). The first signs of human influence appear in SE Corsica around 5450 cal. BCE (Early Neolithic) with the identification of *Cerealia*-type pollen and coprophilous fungi; while in the NW part of the island, the pollen data indicates human impacts on the vegetation since ca. 3300 cal. BC. Archaeological records from the Bonifacio area do not suggest any early agricultural activity. By contrast, in the Saint-Florent area, archaeological finds in the 1980s provided evidence of agricultural practices since ca. 3300 cal. BC (Mid Neolithic times), which is in good agreement with our pollen record. Surprisingly, at all sites there is minimal evidence of agricultural activity during the Roman period. From a paleogeographic perspective, the sedimentological analyses combined with the meiofaunal identifications (ostracods) indicate that major shifts in the shoreline position occurred during key archaeological periods: The first and most significant deltaic progradation occurred around 3500 cal. BC, and it can be related to the sudden decrease in the postglacial sea-level rising rates observed at the Mediterranean Sea. A second phase of major deltaic progradation occurred around 2200 cal. BC in the Aleria-Del Sale and Saint-Florent areas. This date corresponds to the well known 4.2 ka RCC event and also to the shift from the Chalcolithic to the Bronze Age in Corsica. By combining all the proxies, we try to disentangle the climatic and anthropogenic influences on major sediment discharge at the river mouths.

O-2121

## The impact of environmental changes during the second half of the Holocene on human subsistence strategies in the Ukrainian steppe

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### Abstract

The study of pollen and soil successions from 21 archaeological sites (from Chalcolithic to the Iron Age) in different provinces of the Ukrainian steppe has shown drastic environmental changes, which clearly affected material cultures. During the climatic optimum 6.0-5.5 ka BP, forbs dominate mesophytic steppe; broadleaf forests with mesophillous *Carpinus* occupied valleys and gullies, where forest pedogenic processes developed. The settlements occurred on plateaux and in the valleys; the cattle strongly dominated the herds; and *Cerealia* was cultivated in places. The aridification during 5.2-4.8 ka BP lead to a woods reduction (*Carpinus* disappeared), humus accumulation even in the gullies, settlements location mainly near rivers and gullies, and domination either sheep and goats, or horses in the herds of the Late Chalcolithic people. The end of Northgrippian (4.6-4.2 ka BP) was marked by an increase in humidity and a cooling. High floods, the spread of mesophytic steppe and valley woods, dominated by boreal trees, development of forest soils on slopes took place.

The Early Bronze Age settlements existed on plateaux and near rivers, cattle was abundant in the herds, *Cerealia* was cultivated in valleys, and woodworking appeared. The strongest drought occurred at the beginning of Meghalayan (4.2-3.8 ka BP). A dry steppe, dominated by *Artemisia*, spread north, kashtanozems formed in the place of the former chernozems, desiccation fissures and loess-like sediments occurred in the south. Only short-lasting settlements existed there. During the Late Bronze Age (3.5-3.0 ka BP), sedentary settlements existed under humid climate. Woods from broadleaf trees occupied the valleys. In the western and southern steppe, the Sabatynivka farming economy flourished, with dense net of settlements in the areas, which are now too dry for a farming. During the arid phase 2.9-2.7 ka BP, xeric steppe with weak humus accumulation occupied a large part of the modern grassland with well-developed chernozems. The Bilozirka farming culture (the Final Bronze Age) persisted in the lower reaches of rivers, but on steppe plateaux, only temporary camps of cattle breeders occurred.

At 2.6-2.2 ka BP, woods for the last time occupied large areas in valleys. The extensive spread of chernozems to the south also indicates the humid climate of the time, when Greek colonies appeared on the Black Sea shore, the Scythian tribes kept large herds of cattle in the southern steppe, and their tribes in the northern steppe cultivated crops. The very dry phase, with *Artemisia* steppe in the south, took place 2.2-1.6 ka BP, when Scythians were replaced by the successive waves of nomads from the Asiatic steppe. The sedentary Saltiv culture, which existed in the east under the wet climate 1.3-1.0 ka BP, was destroyed by the new waves of nomads during the Medieval Warm Period, which was arid on the steppe.

O-2122

## Ancient water reservoirs and cisterns in the Negev Highlands (Israel): Building a chronology

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### Abstract

Ancient open water reservoirs and subterranean cisterns are frequently occurring archaeological installations in drylands. The former type are round open water reservoirs, which were dug into impermeable layers. They may reach 10 m to 12 m in diameter and 4 m to 5 m in depth, and were lined internally with unhewn stones and clay or marl that served as an aquiclude. In comparison, subterranean cisterns are rock-cut, excavated into soft limestone or chalk formations with a capacity up to hundreds of cubic meters.

These installations collect and store water can sustain settlements, agriculture and nomadic pastoralism under dry conditions. Despite the large number of cisterns and reservoirs in the Negev Highlands, they have scarcely been studied systematically.

During precipitation events surface runoff from adjoining slopes erodes and transports sediments, which are then deposited in the reservoirs and cisterns. Therefore, these archaeological installations also serve as sediment traps, representing fluvial processes in their catchments.

Crucial for investigating water harvesting systems and their sediments is the establishment of robust chronologies. Due to the removal of sediments during construction and maintenance, optical stimulated luminescence (OSL) dating proves to be the preferred dating method of these installations, as it enables the determination of the time of construction, utilisation and abandonment of reservoirs and cisterns. Insights into the life cycles of the different installations provide a basis for discussions about their chronology, the circumstance of construction and their purpose.

O-2123

## The river culture relationship of the Harappan civilization

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### Abstract

The Bronze-Age Harappan civilization (5.8-3.5 ka) of the Indian sub-continent is probably the most enigmatic example of pre-historic human-nature connection. How the majority of Harappan settlements developed along the seasonal river Ghaggar at the arid margin of the Indian desert, is a topic of intense debate. The Ghaggar river has been often hypothesized to be the remnant of an ancient perennial channel and compared with the legendary river Saraswati of Indian mythology due to its matching geographical position with the later. However, lack of evidence for uninterrupted flow of the river during the peak of the civilization has made scholars wonder, whether the civilization was riverine to begin with. In the present work we have reconstructed the palaeo-fluvial landscape along the Ghaggar and provided evidence for the existence of a mighty river in the Harappan heartland by studying temporal changes of sediment provenance in the Ghaggar alluvium, along an ~300 km stretch of the basin in the north-western India. This is achieved using <sup>40</sup>Ar-<sup>39</sup>Ar ages of detrital muscovites and Sr-Nd isotopic ratios of sediments in fluvial sequences, dated by radiocarbon and luminescence methods. Our results establish that during 80 to 20ka and 9 to 4.5ka, much of the sediments, dominated by coarse-grained sands, originated from the glaciated regions of the Himalaya. In the intervening and subsequent periods, the river had lost its strength becoming seasonal, and deposited recycled finer sediments. The temporal changes in the Harappan settlement dynamics along the Ghaggar river also support the current observations. It is the rejuvenated phase of the river during mid-Holocene (9-4.5ka) that facilitated the development of early Harappan settlements along its banks. These findings endorse the theory of river-culture association.

O-2124

## The collapse of the Terramare culture (Northern Italy): a question of climate change or human overexploitation of natural resources?

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### Abstract

The Terramare civilization developed in the Po Plain of northern Italy between the Middle and the Recent Bronze Ages (XVI–XII cent. BCE). Settlements were banked and moated villages, located in the alluvial plain of the Po River of northern Italy, mostly in present-day Emilia Romagna. The Terramare economy was based upon cereal farming, herding, and metallurgy; moreover, Terramare settlements relied on a well-developed management of water and wood resources and established a wide network of commercial exchange between continental Europe and the Mediterranean region. This civilization lasted for over 500 years, suddenly collapsing at around 1150 years BCE, in a period marked by a great societal upheaval throughout the whole Mediterranean area. The timing and modalities of the collapse of this Bronze Age culture are widely debated, and a combined geoarchaeological and palaeoclimatic investigation – the SUCCESSO-TERRA Project – is shedding new light on this conundrum. We are investigating two main Bronze Age sites in Northern Italy: (i) the Terramara Santa Rosa di Poviglio, and (ii) the San Michele di Valestra site, which is a coeval settlement outside the Terramare territory, but in the adjoining Apennine range. Human occupation at San Michele di Valestra persisted after the Terramare crisis and the site was settled with continuity throughout the whole Bronze Ages, up to the Iron Age. The combined geoarchaeological, palaeoclimatic, and archaeobotanical investigation on different archaeological sites and on independent archives for climatic proxies (offsite cores and speleothems) highlights the existence of both climatic and anthropic critical factors triggering a dramatic shift of the land use of the Terramare civilization, which was mainly based on a radical deforestation and intensive, irrigation-supported agriculture. The overexploitation of natural resources became excessive in the late period of the Terramare trajectory, when also a climatic change occurred. A fresh speleothem record for the same region suggests the occurrence of a short-lived period of climatic instability followed by a marked peak of aridity. The unfavourable concomitance between human overgrazing and climatic-triggered environmental pressure, amplified the on-going societal crisis, likely leading to the breakdown of the Terramare civilization in the turn of a generation.

**O-2125**

## **How did Humans Adapt in the Eastern Farming-pastoral zone during the Medieval Warm Period?**

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### **Abstract**

With its extremely warm climate, the “medieval warm period” is considered analogous to the climate change humans are likely to face due to future global warming. Thus, the ability of humans to adapt to an extremely warm climate during the medieval period in Eurasia’s farming-pastoral zone has attracted some attention. The warmth of the climate during this period (900-1300 BC) is demonstrated by evidence of bamboo in charcoal remains and phytoliths found in the settlement sites and tomb murals of the Western Liao river basin in Northeast China. This warmth probably promoted agricultural diversification, as the presence of foxtail millet, broomcorn millet, wheat, barley, soybean, hemp, and buckwheat in this region can be seen in plant seeds and phytoliths found in archaeological sites. The bones of deer and birds also provide evidence of hunting, and the practice of animal husbandry is indicated in pig, dog, cattle, ovicaprid, horse and camel bones. Diversity in food structures is also shown in stable isotopes from human and animal bones. Competence in animal husbandry and hunting, and the availability of stable food resources may have contributed to the rise of the Liao people in military prowess and power, and promoted the expansion of Khitan-Liao culture.

O-2126

## Contribution of the modern traveler's accounts (1750-1920) to the geoarchaeology of subsistence strategies and settlement patterns in the Egyptian deserts.

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### Abstract

Egypt is one of the most arid countries in the world with mean annual rainfall ranging from 200mm near the Mediterranean Sea to less than 2mm in the south. The onset of this aridity is dated from around 5000 or 4500 BP. However, even during this arid period, Egypt has been widely occupied along the Nile valley and in the surrounding deserts. Numerous archaeological sites have been excavated, dating from the emergence of the Egyptian central state to the twentieth century, and yielded impressive material and textual data, which has been thoroughly studied by Archaeologists, Papyrologists and Historians. Geoarchaeological study started recently in Egypt, during the 1980's and have been prejudiced by the Egyptian legislation (sample export ban) and the available analytical material which do not allow the use of most of the dating and sedimentological analyses generally applied. It is thus essential to develop new and innovative approaches to produce new results and to fill the gap between geoarchaeology and archaeology and get results despite the practical obstacles.

Without the usual series of analyses applied in geoarchaeology, one of the best ways to gather data is to combine geomorphologic surveys and spatial analysis with the study of travel accounts from the 18th to the beginning of the 20th centuries. This method allowed us to better understand the life conditions and the socio-environmental evolution in the Egyptian part of the Sahara and offers new perspective on the Holocene geoarchaeology of Egypt.

Our communication aims to demonstrate that this method can contribute to one of the main challenges of geoarchaeology in Egypt: to better understand the settlement patterns, subsistence strategies and landscapes mobility since 5 000 BP in the Western desert and in the Eastern desert of Egypt. The first has known a continuous sedentary occupation in some oases linked with terrestrial trade routes and specialized commercial agriculture whereas the sedentary occupation of the latter has been more punctual in time and space and was mainly linked with mining and trading activity, or with harbours on the Red Sea. Nomad populations have also dwelled in these two deserts, probably during the whole period, and maybe since the beginning of the Holocene. The results included in this talk will relate mainly to water management, vegetation cover and sites distribution in the oases of Kharga basin in the Western desert (data from M. Crépy's Ph.D. Thesis) and in the Edfu-Berenice-Qena triangle in the Eastern desert (data from the ERC funded project "Desert Networks", dir. B.Redon).

O-2127

## Peatlands and the Past: When Carbon, Mineral Dust and Climate Meet

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### Abstract

Peatlands in northern regions are an important component of the global biogeochemical carbon cycle where they store a disproportionate amount of the world's soil organic carbon. Ombrotrophic (atmospherically fed) peat bogs are in some cases up to 99% organic and variations in parameters such as C, N and degree of humification can give us information on both carbon stocks and paleoclimatic change. The remaining inorganic fraction can however, also provide important paleoenvironmental information about change occurring both internally (e.g., changes in hydrology, phase transitions) and externally (e.g., effective humidity, mineral dust, pollution) to the peatland.

Store Mosse (the "Great Bog"; N57°13'37", E13°55'17") is a large peatland (77 km<sup>2</sup>) located in southern Sweden. After deglaciation (ca 14 ka) the region around Store Mosse was covered by an extensive glacial ice lake, Fornbolmen. When this lake eventually drained, its sandy lakebed was eroded by wind, creating a number of aeolian deposits and an ideal substrate for extensive wetland development. In November 2009, a sequence covering the last 9 ka was collected from Store Mosse and analysed for a range of parameters that describe both the organic (C, N, carbohydrates/lignin, carbohydrate/aliphatic, d13C, degree of humification, colour) and inorganic (ash content, elemental concentrations) fractions. By using these in compliment, we identified past shifts in effective humidity and atmospheric mineral dusts.

Perhaps the most distinct feature of the record occurs between 5.2 and 4.2 ka, where a seven-fold increase in net peat accumulation rates occurs. While climatic conditions were wetter during this high peat accumulation event (HPAE), the inorganic geochemistry reveals a distinct change in mineral character, pointing to the addition of phosphate, plagioclase feldspar and less weathered minerals to the bog. This resulted in an increase in P, K and Ca supply to this nutrient poor system, spiking productivity. An HPAE has also been found at another site in the Fornbolmen system, Draftinge Mosse, which is similar in timing, magnitude and dust character change. The source of these dusts is still being investigated but could be linked to (re)activation of local aeolian deposits or unconsolidated glaciogenic materials during the stormier conditions of the time and/or a change in wind direction, which increased additions from a local nutrient (apatite) rich saprolite. In order to establish the importance of the HPAE on broader spatial scales and estimate carbon stocks, we pair our core analyses with Ground Penetrating Radar (GPR). Using this instrumentation we can trace the fen-bog transition and, in some cases, the HPAE across both Store Mosse and Draftinge Mosse. Our work shows the interplay between organic and inorganic fractions in peatlands in stimulating primary production and its impact on carbon cycling.

O-2128

## Millennial-scale interactions between nitrogen, phosphorus and climate in Holocene peatlands

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### Abstract

Peatlands constitute a globally significant soil carbon sink and an important store for phosphorus and nitrogen accumulation through the Holocene. Meta-analyses of long-term carbon and nitrogen accumulation in global peatlands have shown that certain climatic variables, notably growing season length and evapotranspiration rates, are important drivers of sequestration rates. Less attention has been given to long-term interactions between C, N and P in ombrotrophic peatlands (i.e., those almost exclusively supplied by atmospheric inputs). We have compiled a database of global multi-millennial-scale stoichiometric measurements to explore these long-term dynamics.

Surprisingly few publications on Holocene peat profiles report C, N and P concentrations together ( $n = 32$ ) and even fewer provide chronological and bulk density data that allow mass accumulation rates to be calculated ( $n = 17$ ). Nevertheless, a number of findings can be drawn from this dataset. Firstly, mean Holocene C:N, C:P and N:P stoichiometric ratios show a wide range: 15-40, 500-4800 and 20-70, respectively. Secondly, linear regression on long-term means for individual, independent variables finds surprisingly strong, positive associations between P and N concentrations ( $r = 0.67$ ,  $p = 0.0001$ ) and rates of accumulation ( $r > 0.64$ ,  $p = 0.01$ ). We also find mean annual precipitation (MAP) is positively correlated with N concentration ( $r = 0.54$ ,  $p < 0.005$ ) but exerts a negative influence on the C:N ratio ( $r = -0.44$ ,  $p < 0.05$ ). Applying the multiple regression model of Toberman et al. (2015), developed for global surface peat samples, shows P concentration and MAP can explain 64% of variance in mean Holocene N concentration in global peatlands.

The results point to a dependency of long-term N dynamics on phosphorus and climate, potentially through a direct influence on rates of N fixation. It is plausible that variations in P supply through the Holocene influence rates of long-term burial, although it is difficult to separate the effects of internal cycling in the acrotelm. Enrichment in long-term N relative to carbon content under greater MAP supports the known influence of climatic wetness on rates of peat humification. These findings have implications for global biogeochemical dynamics in peatlands in light of future climate change and amidst growing awareness that agricultural dust represents an anthropogenic pathway for phosphorus deposition. Individual and interactive effects are difficult to quantify at this juncture and require further investigation by the community.

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O-2129

## Strong controls by peatland type on Holocene rates of carbon accumulation in the Hudson Bay Lowlands, Northern Ontario, Canada

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### Abstract

The Hudson Bay Lowlands is an extensive boreal peatland in northern, Canada storing ~30 Pg carbon (C). Despite CH<sub>4</sub> emissions from contemporary fens and release of C by slow long-term decay of existing peat, the HBL has likely been a net C sink over the Holocene; the magnitude and even the sign of that sink, however, have varied. Synthesis studies of northern peatland C accumulation suggest strong climatic controls, with the most rapid rates associated with insolation-driven warmer climates of the early/mid-Holocene. The HBL offers a unique opportunity to parse out the role of climate in rates of C burial. Firstly, the HBL is near the centre of the former Laurentide Ice Sheet, thus has experienced rapid uplift over the post-glacial. Thus, a chronosequence of peatlands varying in basal age (from close to 8000 cal yr BP at the southwestern margin to <1000 cal yr BP in coastal areas), allows an evaluation of the relative importance of hydro-climate vs successional processes in driving variability in C dynamics. Further, HBL peatlands are younger than other major peatland complexes in Siberia, Alaska or Western Canada, post-dating insolation maxima by several millennia. Finally, HBL is a heterogeneous landscape spanning numerous peatland types, allowing comparisons between fen, bog and forested peatlands. We present here a comparison of peak values of Holocene C accumulation from several regions within the HBL. Data from >25 peat cores with well constrained chronologies, time series of C accumulation and data on peatland type, corroborate more rapid accumulation rates in the earlier portion of the longest records (7500-5000 cal yr BP). These time periods, however, most often coincide with successional stages characterized by minerotrophic non-*Sphagnum* peat, herbaceous vegetation and higher inferred water table positions. These systems produce more carbon-rich peat (higher overall bulk density and organic C densities) and thus, more C can be buried per unit time. These time periods are often time transgressive, suggesting that vegetation type can override climate in terms of setting local-scale C balance. The role of climate remains difficult to quantify here because of a lack of region-specific paleoclimate records. Available pollen records indicate only subtle changes in Holocene precipitation and temperature, but this reflects in part the low taxonomic diversity of the assemblages and cosmopolitan distributions of major taxa. A lake-derived chironomid records suggests that maximum Holocene temperatures for HBL took place between 7000-5000 cal yr BP with several degrees cooling following 5000 cal yr BP. We conclude that variability in carbon accumulation is controlled by interactions between vegetation type and climate, with fastest rates associated with newly emerged substrates, minerotrophic fen type ecosystems and middle Holocene climates which may have been warmer, particularly between 7000-5000 cal yr BP.

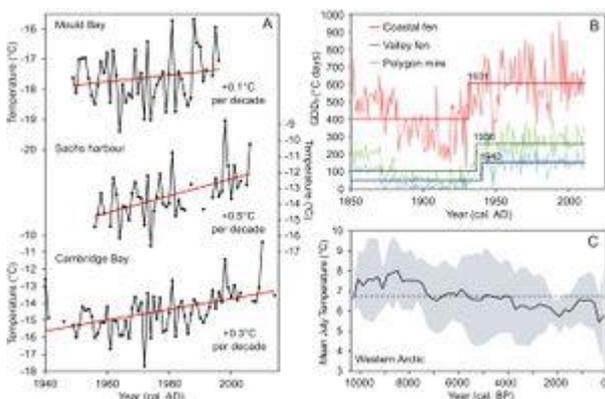
O-2130

## Pathways for ecological change in Canadian Arctic wetlands under rapid twentieth century warming

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<sup>4</sup>Queen's University Belfast, Belfast, United Kingdom. <sup>5</sup>Geological Survey Canada, Calgary, Canada

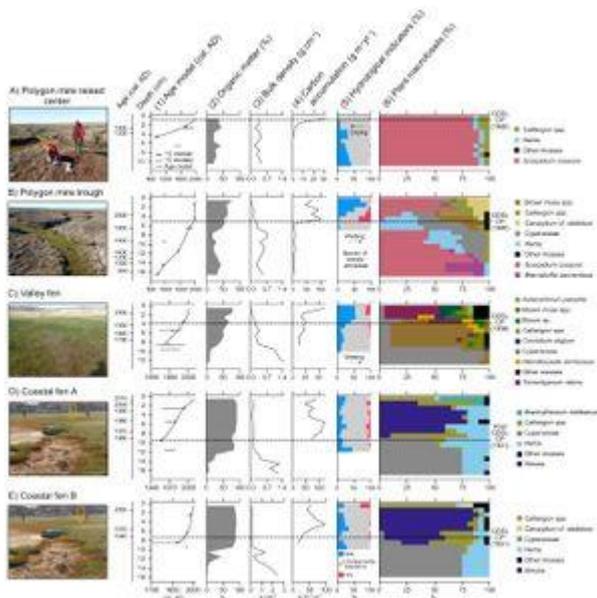
### Abstract

The response of Arctic permafrost wetlands - and their large organic carbon store - to climate change is uncertain. Enhanced plant productivity with warming may increase litter accumulation and therefore carbon sink potential, however heightened decomposition could convert these ecosystems from a carbon sink to source. We use a palaeoecological approach to investigate the response to a mid-twentieth century increase in growing degree days above 0°C (GDD<sub>0</sub>) in three wetland sites from the Canadian Arctic. These sites cover the main types of Arctic permafrost wetlands and include: an ice-wedge polygon mire, a patchy wetland (valley fen) and a coastal fen. We use plant macrofossil and testate amoeba-based reconstructions in conjunction with radiocarbon dating and analysis of peat physical properties to show differing vegetation, hydrological and carbon accumulation responses to recent warming in each wetland. We observe an increase in wetness, moss diversity and carbon accumulation in the trough of the ice-wedge polygon mire ~AD 2000, likely related to elevated ice-wedge thaw. Contrastingly, the ice-wedge polygon mire raised centre at the same site showed no clear response. In a valley fen, wet and dry-indicator testate amoebae increase concomitantly from ~AD 1980, possibly relating to greater inundation from snowmelt followed by increasing evapotranspiration later in the growing season. This has not thus far negatively impacted carbon accumulation and occurs alongside the presence of generalist hummock mosses. The coastal fen site underwent a shift from sedge to shrub-dominance sometime prior to ~AD 1950, likely linked to warming. The valley and coastal fens underwent a transition from minerogenic to organic-rich wetlands prior to the mid-twentieth century increase in GDD<sub>0</sub>. A subsequent shift to moss-dominance in the coastal fen ~AD 2000 may relate to intensive grazing from Arctic geese following a recent explosion in their population numbers. Our findings suggest that wetland type and local-scale processes are key factors influencing the pathways of ecological change in Canadian Arctic wetlands under recent warming and are likely to impact their future carbon sink potential.



**Figure 1.** Recent warming in western Canadian Arctic. a) Temperature data from nearby weather stations. b) GDD<sub>0</sub> is annual growing degree days above 0°C modelled for each site. Stepped lines indicate change point. c) Mean July

temperature for western Arctic during the Holocene reconstructed from pollen analysis [Gajewski, 2015]. Shading indicates one standard deviation.



**Figure 2.** Summary stratigraphic diagram of palaeoenvironmental variables from polygon mire raised centre (a), polygon mire trough (b), valley fen (c) and coastal fen (d and e). GDD<sub>0</sub> CP is change point in GDD<sub>0</sub>.

O-2131

## Paleodust deposition from mid-Holocene to the present in south-central Sweden from multi-element datasets coupled with mineralogy

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### Abstract

Atmospheric mineral dust plays a dynamic role in the climate system acting both as a forcing and a feedback mechanism. Despite this, dust is currently poorly represented in Holocene climate models and large regions remain unstudied for past mineral dust deposition (paleodust). To date, the majority of paleodust studies have been conducted on marine sediments or polar ice cores, while terrestrial deposition has been less studied, leaving large regional gaps. In this context ombrotrophic peat bogs are regarded as important terrestrial archives. Scandinavia is currently represented by only one paleodust study, conducted at Store Mosse, southern Sweden (Kylander et al. 2013; 2016; 2018). Here, results from an atmospherically-fed bog (Draftinge Mosse, 57°06'27"N 13°42'54"E) are presented and compared to the nearby Store Mosse (57°13'37"N 13°55'17"E) record.

The sequence has been dated with 17 AMS radiocarbon dates and analysed for botanical composition, bulk density, loss-on-ignition (LOI), and organic chemistry (elemental C, N, and  $\delta^{13}\text{C}$ ). In addition, downcore elemental concentrations were analysed every 3-5 cm by quantitative WD-XRF for major and selected minor elements, as well as by ICP-AES for trace element concentrations. These data are coupled with mineralogical analysis by X-ray diffraction (XRD) analysis to establish the mineral composition throughout the sequence. Based on the concentrations of soil dust elements (e.g. Si, Al, and Ti), several episodes of increased dust deposition are recorded at Draftinge Mosse; c. 5.7, 2.5, 1.8, 1.1 and 0.7 ka BP. Furthermore, a high peat accumulation event (HPAE) is recorded at Draftinge Mosse around 5.5 ka BP with a fourfold increase in peat growth during c. 1000 years. At the same time both the elemental and mineralogical point to a change in the mineral composition of the deposited dust.

These observations are largely consistent with the previous study from the region, but with a distinct mineral composition deposited at Draftinge Mosse during the HPAE (clays and carbonates). This mineralogy potentially suggests a more distant dust source during this period compared to the rest of the record. In this study we also explore mineral weathering processes as well as secondary mineral precipitation by analysing both peat pore waters and  $\delta^{13}\text{C}$  values of carbonate minerals. If the mineral composition is partly authigenic, the Draftinge Mosse data-set could be used to identify elements that needs to be interpreted with caution in peat, in response to internal peat processes potentially affecting their concentration.

O-2132

## Permafrost and thaw driven geochemical changes in palsa mires: a challenge to the palaeoenvironmental reconstruction of nutrient availability?

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### Abstract

Palsa mires are a common feature in the Subarctic zone of discontinuous permafrost. In these peatlands, the patchy distribution of frozen soil constrains relief, water regime and vegetation distribution. Palsa mires are very sensitive to climate warming. It has been described how permafrost degradation and increasing decomposition driven by raised temperatures lead to unprecedented changes in Carbon (C) cycling, but less is known about changes in Nitrogen (N) and Phosphorus (P) availability. We measured stoichiometry, stable isotopy of C and N, Hedley P fractionation, N extractions and elemental composition (using ICP-MS) across a thawing gradient in a palsa mire complex at Stordalen (Abisko, 68°N, Sweden). We analyzed three site types in a space-for-time approach (palsa, transition zone and collapsed palsa) at four different depths (5-10, 40-45, 70-75 and 95-100 cm). Available or relatively labile P were higher in surface samples compared to deep peat in the palsa and collapsed sites. The main P fraction of these samples was organic P bound to Iron (Fe) and Aluminum (Al) (NaOH-Porg), which made up between 40 and 70% of total P. The collapsed palsa sites had a lower proportion of P in these fractions and higher organic and inorganic available P, especially in the surface samples. Total P (TP) in deep layers (>50 cm) is dramatically reduced (between 15 and 30%) after permafrost thaw. In contrast, in surface samples (5-10 cm), TP increased by 60%. This suggest that redox and microbial activity shifts brought by hydrology and temperature changes contribute to P, Fe and Al mobilization into other forms. Permafrost thaw also results in lower surface N/P ratios, which is a pivotal constrain of ecosystem productivity, C fixing capacity and vegetation composition. Palsa mires are extremely valuable high-latitude terrestrial records. However, both (1) their origin, including their rapid development towards ombrotrophy because of uplift by ice accretion and (2) the irreversible geochemical effects of collapse and permafrost thaw make them challenging environmental archives. A multidisciplinary approach combining actuo-ecological and palaeo-ecological biological (vegetation, macrofossil and pollen), chemical, and climatic proxies is indispensable to identify the processes associated with palsa uplift and collapse and to interpret palaeo-records of palsas and other mires that may have had permanently frozen peat layers in the past.

O-2133

## Stable isotope records of last millennium changes in the Southern Annular Mode from New Zealand restiad peatlands

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### Abstract

The Southern Annular Mode (SAM), a largely zonally symmetric mode of climate variability describing sea-level pressure anomalies of opposite sign between  $\sim 40^{\circ}\text{S}$  and  $65^{\circ}\text{S}$ , drives changes in the strength and latitude of the southern westerly winds (SWW). The SWW are a major influence on temperature and precipitation patterns in the Southern Hemisphere (SH) mid-high latitudes and a significant determinant of the SH component of the earth system, including the strength of the Southern Ocean  $\text{CO}_2$  sink. A major shift towards a more positive phase of the SAM, associated with a strengthening and poleward shift of the SWW, has occurred since the 1950s, but its longer-term behaviour remains relatively poorly understood. Developing reliable reconstructions of late-Holocene variability of the SAM is therefore critical to understanding SH climate and ocean dynamics and to testing the ability of climate models to project changes in this mode of variability, but current understanding remains incomplete and contradictory and existing hypotheses need to be tested using new proxies from sensitive locations in other sectors of the Southern Ocean.

Here we present decadal- to centennial-scale resolution carbon and oxygen stable isotope results over the past millennium from a series of ombrotrophic restiad peatlands in New Zealand spanning a  $10^{\circ}$  latitudinal gradient in moisture source that primarily reflects the variable influence of the SAM and sub-tropical climate modes. In addition to the presence of strong climate gradients, New Zealand is an ideal location for this work because it registers strong correlations between the SAM, temperature and precipitation and modern calibration of our carbon and oxygen stable isotope proxies show that they can be interpreted as proxies for temperature and precipitation moisture source respectively. Palaeoclimate data is supported by robust chronologies based on radiocarbon and lead dating. We discuss results within a hypothesis-driven framework. Specifically, we aim to test the hypotheses that 1) the recent positive trend in the SAM is unprecedented over the past millennium, as suggested from limited proxy data in other sectors of the Southern Ocean, and that 2) there is a persistent relationship between SAM and ENSO over the past millennium that supports the contention that tropical Pacific variability is a key influence on past and future SAM variability.

O-2134

## Identifying drivers of engineering resilience in long-term records of Central- and South American forests

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### Abstract

Recent research suggests that there are spatial patterns across the globe of ecosystem sensitivity to climatic disturbance. Yet, further research is needed to identify possible drivers behind such patterns and behind ecosystem resilience in general. Here we address two hypotheses regarding possible drivers of engineering resilience, often measured in terms of recovery rate, in tropical forests. First, we hypothesise that faster recovery rates are associated to higher biodiversity, as suggested by the insurance hypothesis, which may in turn be spatially linked to more biodiverse regions. And second, we suggest that location specific abiotic factors, such as soils, geology and microclimate, influence ecosystem recovery rates irrespective of the present vegetation assemblages.

To test these two hypotheses, we selected 31 palaeoecological datasets across Central and South American forest ecosystems, which showed evidence of one or more forest disturbance events. More precisely, we chose sequences in which the mean time resolution between samples during a disturbance event was below 100 years. As disturbances can be either gradual or abrupt ("press and pulse"-disturbances), high-temporal resolution records are especially important to identify disturbance events and to study their effect on ecosystems. We applied a threshold approach to identify disturbances to the forests within each sequence and calculated recovery rates by looking at points of maximum decrease and maximum recovery of arboreal pollen percentages. We then compared recovery rates to pollen richness before the disturbance event to address the first hypothesis. To test the second hypothesis, we used a published global vegetation sensitivity index and compared it to the mean recovery rate of each site. Preliminary results show indeed a positive relationship between diversity and faster recovery rates, highlighting the importance of preserving ecosystem biodiversity to ensure functioning ecosystems. This is especially important as ecosystems are likely to face increased disturbances due to global and climatic changes.

O-2135

## Climate drives stability of vegetation biomes after the last glaciation in North America

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### Abstract

Changing climates, human arrivals, and megafauna extinctions in North America all had the potential to culminate in major shifts in vegetation communities and their stability on the landscape. We seek to determine the relative importance of these potential drivers of vegetation community stability following the last glaciation (20 ka BP to present). Quantifying dynamic responses of vegetation communities to these drivers has important implications for understanding biome resilience and management strategies under projected climate change.

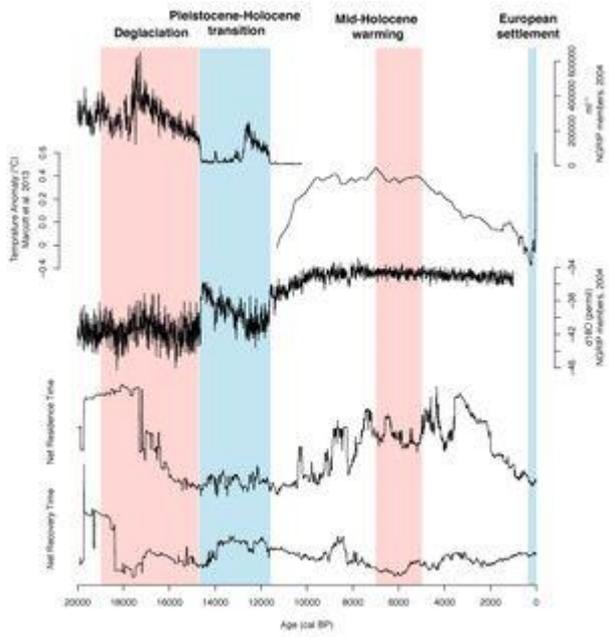
We analyzed vegetation biome stability from two perspectives: biome dynamic stability represented by residence time, and recovery ability after a shift in biome types represented by recovery time. We used 16,043 fossil pollen assemblages from 310 sites in the Neotoma database to reconstruct vegetation community residence time and recovery time across North America during the past 20,000 years after the last glaciation. We use the established modern analog technique for 10 currently present vegetation communities and the biomization method to identify two no-analog communities.

Results suggest that the median residence time of any given biome is 310 years. Forest biomes have a longer residence time of 340 years while shrub/herb biomes have a shorter residence time of 260 years. Median recovery time of any given biome is 130 years, and nearly 84% of vegetation biomes recover back after a shift in the biome types. Residence time decreases during deglaciation (19 – 14.7 ka BP) and remains short until the Pleistocene-Holocene transition (14.7 – 11.7 ka BP), when climate continues to change abruptly, including fluctuating temperature and widespread drought events. Then residence time increases and remains high throughout the stable, warm Holocene, though residence times do decrease temporarily during climate events, including Mid-Holocene Warm Period (7 – 5 ka BP). Residence time displays another decreasing trend towards the present in the late Holocene after 3 ka BP under intensified human influences, especially after European settlement in North America (0.3 ka BP). Recovery time shows an opposite trend compared to residence time, that recovery time is longer in the Pleistocene-Holocene transition when vegetation biomes have shorter residence time, and that recovery time is shorter in the stable warm Holocene when vegetation biomes have longer residence time. Neither residence time nor recovery time demonstrate a latitude gradient across North America, though biomes track glacial retreat during deglaciation. Landscape characteristics do not show strong relationships with either biome residence time or recovery time. There is no obvious change before and after megafauna extinction in residence time and recovery time.

Our work demonstrates that vegetation biomes in North America have short residence times, on the timescale of centuries. Vegetation biome stability is primarily controlled by climate, while top-down biotic influences had little impact on biome stability.



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O-2136

## A Virtual Ecology Approach to Assessing the Application of Resilience Indicators to Palaeoecological Data

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### Abstract

As contemporary ecosystems experience increasing and novel anthropogenic pressures, there is growing concern over the occurrence of abrupt regime shifts and growing interest in their prediction. Resilience indicators (RIs) have been developed to detect changes in a system's behaviour prior to regime shifts; however, the application of RIs to palaeoecological data, (i.e., sediment-core data), has had mixed success. Palaeoecological data provide insights into past regime shifts, providing opportunities to analyse the dynamics of abrupt changes. However, palaeo-data are subject to several sources of inherent uncertainty that may influence the robustness of RIs applied to them. Uncertainties may be introduced at: (i) an *environmental-level* by, for example sedimentation rates or catchment erosion; (ii) a *sample-level* by, for example, dating frequency or sampling resolution; and (iii) the *analysis-level* by post-sampling data processing such as time-averaging and RI selection.

Uncertainties introduced during sampling and analysis may decrease the robustness of RIs; furthermore, there is a danger that RI detection can become an artefact of data collection and processing themselves. We take a virtual ecology approach to assessing the robustness of RIs applied to palaeoecological data when confronted with process and observational error. We present a framework that draws together a modelling approach from (1), and concepts from (2) to create a synthetic, error-free palaeoecological record (Fig 1A) that mimics a real proxy record. The synthetic record (Fig 1C) emerges from the result of individual species' responses (Fig 1B) to a set of external forces (Fig 1A); in the model, the combined effect of forces acting through the lens of the species' responses (niche) determines the species abundance.

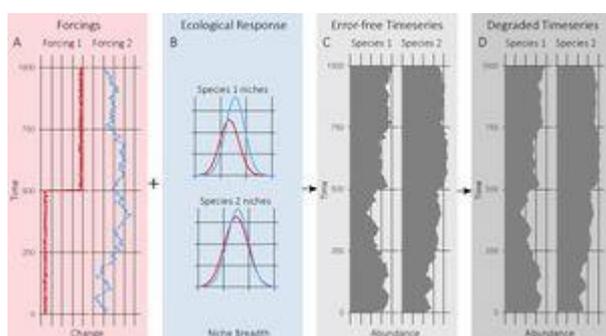


Figure 1: Framework in which an error-free synthetic palaeo-proxy record (C) is simulated as the result of a set of forcing variables (A) acting on individual species' responses (B). *Environmental-level*, *sample-level* and *analysis-level* conditions are then imposed on the data to develop a degraded record (D) (in this case time-averaging with a 20 time-step rolling window).

A set of conditions, such as decreased sampling resolution (*sample-level* uncertainty) and time averaging (*analysis-level* uncertainty) are then imposed on the data and both the error-free and degraded records are analysed for RIs (Fig 2A, B) to determine the effect of uncertainties and stochastic processes on RIs.

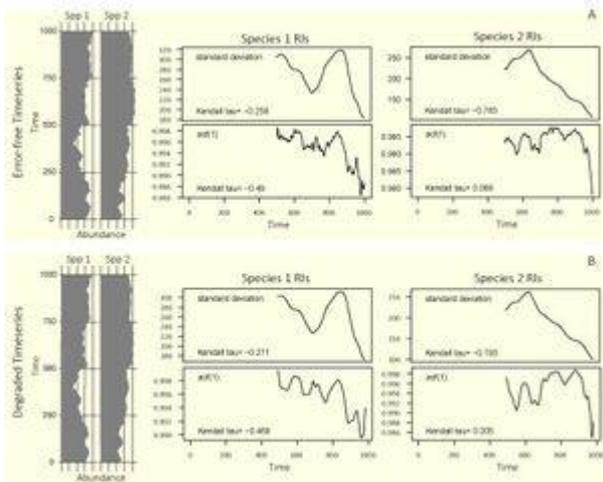


Figure 2: Illustration of RIs (lag-1 autocorrelation and standard deviation) applied to the error-free (A) timeseries and the degraded record (B) showing less variability is detected by RIs on degraded data.

We will be presenting this framework and results from the model assessing RIs.

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O-2137

## Quaternary vegetation responses to a range of volcanic disturbances in the Northern Rocky Mountains (USA)

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### Abstract

Volcanic processes produce a wide range of terrestrial disturbances, and the ecological response depends on the characteristics of the event as well as the nature of prevailing climate and vegetation. Paleoecological records from the Northern Rocky Mountains (USA) provide three examples of past volcanic disturbances with varying responses: (1) On long time scales, Pleistocene rhyolitic lava flows in Yellowstone National Park (YNP) created infertile landscapes that have shaped vegetation evolution and fire regimes for millennia. Pollen data suggest that the well-drained, nutrient-poor soils overlying these flows supported low-diversity grassland in the late-glacial period and *Pinus contorta* forests in the Holocene. These pine forests have persisted for the last 11,000 years with little change, despite variations in climate and fire activity that have altered forest composition in adjacent more-fertile locations. (2) Ash layers from eruptions of Pacific Northwest stratovolcanoes are commonly preserved in lake-sediment records in the Northern Rockies, and pollen records indicate that these events led to short-term vegetation shifts in some settings and long-term changes in others. For example, forested sites register a pulse of *Artemisia* and disturbance-adapted herbaceous pollen types following the deposition of Mazama ash (Crater Lake O, 7680-7580 cal yr BP). *Artemisia* was probably favored by the enhanced soil moisture capacity of ash-rich soils. Vegetation returned to pre-Mazama composition within 100-200 years in places with little ash accumulation. In areas of thick deposition, the ashfall catalyzed unidirectional shifts in plant composition that accelerated the gradual vegetation changes already underway as a result of climate variations. At one site in northern Idaho, for example, *Pseudotsuga/Abies* forest was abruptly replaced by *Pinus contorta* forest following Mazama ashfall (~140 cm thick). Similarly, deposition of Glacier Peak ash (B and G, 13,710-13,410 cal yr BP) at many sites may have facilitated late-glacial forest establishment, reinforcing the influence of rising temperatures at that time. Step-like changes in vegetation have also been described in New Zealand and central Oregon following ash deposition. (3) Local hydrothermal explosions have also resulted in short-lived vegetation changes in volcanic areas. In YNP, large hydrothermal explosions deposited ejecta of up to 1 m in thickness in lake-sediment records. Pollen records indicate short-lived pulses of *Artemisia* following large explosion events in late-glacial and middle-Holocene time. Apparently, the explosion detritus created substrates that were initially suitable for *Artemisia* establishment, but vegetation returned to pre-explosion composition within years to decades as soils developed. The response of vegetation to volcanic disturbances, thus, is highly varied and contextual. The composition of post-disturbance communities and their persistence are influenced by the type and intensity of the volcanic events, the antecedent vegetation, and the climate conditions at the time of the disturbance.

O-2138

## Resilience of lake biogeochemistry to boreal wildfires during the late Holocene

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### Abstract

Disturbance regimes play a critical role in the structure and function of ecosystems, and climate-driven increases in the frequency and severity of disturbance processes may reduce the ecological resilience of impacted terrestrial and aquatic systems. Anthropogenic climate warming is amplified in flammable boreal forests, which are characterized by strong threshold-like climate-fire relationships at present. Novel fire regimes are expected in many boreal areas under predicted warming scenarios, with the potential for feedbacks with the global climate system related to large boreal carbon stocks. However, it is unclear how biogeochemical cycles in boreal systems will respond to changing fire regimes. Paleoeological records offer a unique perspective on the response and resiliency of environments to climate-driven disturbance. In this study, we leverage well-documented fire history and vegetation records from the Yukon Flats, Alaska, one of the most flammable regions of the boreal biome. We present new geochemical analyses of lake sediment cores to 1) examine the response of boreal aquatic systems to fire over the past 5300 years and 2) constrain the timescale of recovery following disturbance.

We measured carbon and nitrogen content,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , C:N, and magnetic susceptibility of lake-sediment samples at decadal resolution for 110-year intervals centered on fire events over the past 5300 years. We found no significant difference between values of pre-fire, post-fire, and fire-decade samples for most of the geochemical metrics, (one-way ANOVA,  $\alpha=0.05$ ), suggesting that aquatic systems may be insensitive to fires in lowland boreal areas such as the Yukon Flats, where low topographic gradients impede lateral movement of terrestrial materials following fire. However, sediment  $\delta^{15}\text{N}$  values were significantly different based on time relative to fire (pre-fire, fire, post-fire) ( $F=4.02$ ,  $p=0.024$ ,  $df=2$ ). Specifically,  $\delta^{15}\text{N}$  values of sediments deposited in the fire decade ( $3.2 \pm 0.3$ ) were significantly higher than pre-fire values ( $2.4 \pm 0.2$ ) ( $t=3.76$ ,  $p=0.0005$ ,  $df=48$ ). However, post-fire  $\delta^{15}\text{N}$  values ( $2.2 \pm 0.1$ ) show a return to pre-disturbance conditions within 50 years. We interpret this short-term increase in lake-sediment  $\delta^{15}\text{N}$  as a signal of enhanced aquatic productivity and N-cycling associated with high N availability, likely related to enhanced terrestrial nitrification rates and *Alnus*-mediated N-fixation immediately following fire. These results were robust when using a linear mixed-effects model to account for the effect of the long-term increase in  $\delta^{15}\text{N}$  values over the past 5300 years, likely related to enhanced terrestrial denitrification rates associated with late-Holocene soil development and paludification. Our study suggests that boreal systems were resilient to fire over the late Holocene. However, we caution that other forested ecosystems are currently displaying evidence of decreased resilience to burning, and that some boreal areas may already be approaching climate-driven thresholds of vegetation structure, carbon cycling, and fire activity.

**O-2139**

## **Is the initial plant cover important for the response of vegetation to climate change?**

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### **Abstract**

Current climate warming raises concerns that plants will not be able to track their climatic niche. This lag may be due to dispersal limitation and/or the resistance of the established vegetation to new arrivals. However, monitoring periods are too short to evaluate the effects of ecosystem resistance. Climate change at the end of the last ice age provides the best opportunity to study the dynamics of climatically induced vegetation change, which is documented in pollen diagrams from around the world. Here I will use selected pollen diagrams from different European regions to explore, whether the initial vegetation occurring at a site at the end of the Younger Dryas delayed the establishment and influenced the population expansion of newly arriving taxa. Pollen diagrams from the Alps are particularly insightful as sites at different elevations or geomorphological situations were characterized by different vegetation cover at the onset of the Holocene. At low elevations a forest with boreal elements persisted during the Younger Dryas and presented an inertia for the establishment of newly arriving trees during the Early Holocene. As a result, populations of temperate trees started to grow earlier in higher locations. I will compare these examples to sites north and south of the Alps where Early Holocene forest development occurred under different competition regimes. Preliminary results indicate that a dense forest cover may delay the establishment and population increase of newly arriving trees by several hundred years. These insights indicate that land use and disturbance regime may have a strong effect on the dynamics of climate induced vegetation change and the management of protected areas should consider facilitating vegetation change.

O-2140

## Functional responses of testate amoebae in stable and disturbed *Sphagnum* peatlands

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### Abstract

Disturbances influence ecosystems at various scales and with different intensity, triggering changes in species community composition. Resilience of ecosystems is especially important when ongoing climate changes are considered. *Sphagnum*-dominated peatlands are highly important because changes in peatland functioning from sink to source of carbon can intensify already progressing warming. Here, we investigated 2000 years environmental history of two peatlands located in the lowlands of northern Poland in order to understand their contrasting hydrological response to human and climate induced disturbances. We looked at long-term functional responses of testate amoeba (TA) communities and their trait composition from two small peatlands: disturbed (Linje poor-fen, covering an area of 6 ha) and undisturbed (Jaczno bog, 1 ha). Abrupt changes recorded in Linje mire (landscape opening by human, fires and drainage) triggered rapid changes in TA communities that led to disappearance of mixotrophs and large TA, and caused the establishment of functionally different TA communities. Moreover, moss composition changed completely as an effect of disturbances. In Jaczno bog, however, we recorded almost no changes in TA community composition. The bog maintained close to pristine moss composition and stable high water table due to very low (or no) direct human impact on the mire. Mixotrophs that are typical for healthy bogs were highly abundant throughout the profile up to present times. We show that traits of TA functional trait composition can serve as good indicator of peatlands' state, mirroring environmental changes happening in and around the mire in the long temporal scale.

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O-2141

## Glacial curvilineations along the southern fringe of the Scandinavian Ice Sheet: geomorphology and mechanism of formation

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### Abstract

Glacial curvilineations (GCLs) are spectacular landforms recently detected in glaciated landscapes. They were first described in Poland (Lesemann et al. 2010, 2014) as complex sets of parallel, sinuous ridges occupying parts of tunnel valleys and interpreted as erosional features carved in older landscapes by subglacial meltwater flows. Recently, Clark and Livingstone (2018) discovered GCL sets along the southern margin of the Laurentide Ice Sheet and suggested that they were produced by subglacial slope failures in tunnel valleys or near the shores of subglacial lakes.

Our research aimed at detecting GCLs along the southern fringe of the last Scandinavian Ice Sheet in Poland, Lithuania, Germany and Denmark and analysing their geomorphic characteristics using high-resolution LiDAR data. We document around 60 GCL fields grouped into three geomorphic types. (1) *Tunnel channel GCL fields* are the smallest fields with areas of less than 5 km<sup>2</sup> and containing only a single swarm of maximum 10 ridges. (2) *Tunnel valley GCL fields* have areas between 5 and several dozen km<sup>2</sup>. They consist of up to 50 ridges in several swarms located at one, two or three topographic levels. (3) *Complex GCL fields* consist of two or more tunnel channel or tunnel valley GCL fields. They cover areas of up to several hundred km<sup>2</sup> and contain the highest number of single GCL ridges.

The biggest GCL field in the study area is the Zbójno GCL field in Poland. It is a complex field consisting of 21 separate GCL swarms with more than 300 individual GCL ridges. We document their geomorphic characteristics together with the characteristics of the inter-ridge troughs including their lengths, widths, depths, average slopes and vertical and horizontal sinuosity.

The geomorphological properties of GCLs such as: (1) occurrence in both wide and narrow tunnel valleys, (2) substantial lengths, (3) parallel, non-intersecting arrangement of ridges and troughs, (4) large horizontal sinuosity, and (5) convex-upward and irregular longitudinal profiles of the inter-ridge troughs (typical for subglacial channels), all yield support to the subglacial meltwater origin of the GCL landscapes.

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O-2142

## Subglacial landscape evolution, piecing together the mosaic of subglacial processes in southwestern Hudson Bay

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### Abstract

The deposition of sediment and development of landforms within the subglacial environment are the net result of subglacial processes at work beneath an ice sheet. Furthermore, the presence or absence of subglacial sediment, as well as subglacial topography, play an important role in governing the flow of the overriding ice. Thus, the glacial–geomorphic record holds information about the dynamic nature of bed–ice-sheet interaction, sediment availability, and the subglacial environment, which are key boundary conditions in glaciologic studies of paleo-ice-masses. We examine well-preserved glacial deposits in southwestern Hudson Bay, located within a core region of the former Laurentide Ice Sheet, as a record of past subglacial conditions. This region contains a highly fragmented geomorphic ice flow record, with numerous disjunct flowsets and palimpsest terrain, indicative of a variable basal thermal regime consistent with recent modeling experiments. We analyze quantitative till compositional data (matrix geochemistry and clast lithology) using multivariate statistics (principal component analysis and cluster analysis) and compare our results to ice flow indicators, such as striations and clast fabrics, in an effort to elucidate spatial-compositional patterns within the till deposits. While we identify till composition variations that are recorded across the study area, indicative of varying input from the Keewatin and Québec/Labrador dispersal centers of the Laurentide Ice Sheet. Our compositional analysis finds a lack of laterally continuous till sheets, with rare occasions where correlations can be made between multiple sections spanning a few kilometers. The heterogeneity of the till, as well as numerous localities containing of far-traveled exotic lithologies from eastern Hudson Bay and central mainland Nunavut provenance, is indicative of hybrid tills produced by multiple cycles of till entrainment, reworking, and deposition. Thus, we interpret the till stratigraphy to be a vertical continuation of the fragmentary surface record, resulting from a variable subglacial environment driven by ice sheet dynamics related to the waxing and waning influence of the Keewatin and Québec–Labrador dispersal centers. In total, the high degree of inheritance exhibited in this region, via the disjunct landform assemblages, patchy-preservation, and areas of hybridized tills, is indicative of a landscape that underwent a spatially punctuated evolution with periods of local remobilization and modification separated by areas and time periods of quiescence under cold-based, or sluggish, basal conditions. This fragmented geological record suggests large portions of southwestern Hudson Bay experienced limited erosion and sediment advection to the Laurentide Ice Sheet margin during the last glacial stage.

**O-2143**

## **Morphological evidence for rapid, marine ice stream shut down, central Barents Sea**

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### **Abstract**

Marine-based ice streams are responsible for a significant proportion of the ice mass loss of the present-day Greenland Ice Sheet and West Antarctic Ice Sheet (WAIS) but the processes controlling their initiation, evolution and shutdown remain elusive, hindering our understanding of how existing ice masses will respond to predicted future warming. The exposed beds of palaeo-ice streams offer a unique opportunity to study subglacial processes which are largely inaccessible in contemporary settings. We use high resolution multibeam swath bathymetry data from the Barents Sea to map the geomorphology of a palaeo-ice stream bed, located in Olgastretet (Olga Trough), approximately 75 km southeast of Kong Karls Land and 200 km east of central Svalbard. Mapping of the seabed reveals evidence for shut down of a marine-based ice stream, followed by a phase of passive retreat or lift-off of the ice stream allowing for preservation of crevasse-squeeze ridges (CSR). Subsequently, active retreat of the ice margin was re-established and is marked by recessional moraine ridges. Previously, preserved CSRs have been mainly associated with surging land-terminating ice margins, however our work adds to recent observations of CSRs on the beds of marine-based ice streams, implying that they may be more common than previously thought. It also indicates that marine-based ice streams may switch on- and off in a surge-like manner which has important implications for our understanding of ice stream life cycles and the modelling of ice sheets.

O-2144

## New geomorphological observations of changing subglacial conditions in the central part of SIS based on the LiDAR-based mapping

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### Abstract

On-going glaciomorphological mapping in Finland based on airborne LiDAR (Light Detection And Ranging) interpretation has revealed new data for the morphological interpretation that can be used in an examination of landscape development and glaciodynamic themes in the glaciated terrain. The mapping process combines the main geological unit (deposit) and new, landsystems-based glacial geomorphological feature information. Recently, the focus has been in the areas of active ice lobes in southern and central Finland, where previously detected large mega-scale glacial features, such as mega flutings, drumlins, end moraine complexes and glacial melt water systems show up in LiDAR-based digital elevation models (DEM) in greater detail than ever before. For mapping, a new definition of the landform categories has been launched (Putkinen et al. 2017).

Here we present new LiDAR-based mapping results (of the project funded by the K.H. Renlund's Foundation) close to the Late Weichselian ice-divide zone, in the central part of the Scandinavian Ice Sheet (SIS) in Finnish Lapland. The area is mostly dominated by the passive-ice, basal till cover without significant indication of ice movement. However, on both sides of the ice divide zone, there are some narrow areas having well-formed drumlin fields and onset areas for active ice lobes; Salla Ice lobe towards SE and Inari Ice Lobe towards NE. Further on south, the glacial morphology is composed mainly of moraine morphologies such as the glacial streamlined lineations of the Kuusamo drumlin field in the eastern part and different hummocky and ribbed moraines in the western part, i.e. at the core of the Kuusamo Ice Lobe. The drumlin field was formed under surging type glacial movement during the Younger Dryas while the core part of the glacier remained cold-based. Glaciofluvial deposits (eskers and delta formations) occur in places representing the last melting phase of SIS. Particularly, ribbed moraines represent the depositional formations formed under subglacial conditions at the transitional zone between the warm and cold based glacier. However, new LiDAR-based mapping showed that large areas in eastern Finnish Lapland are rich in Pulju moraine type ring-ridges and hummocks. In addition, small end moraine ridges occur in close connection to the ring-ridges, which indicate the formation of both moraine types in the marginal zone of glacier during the late phase of last deglaciation. Presence of deep pre-glacial weathered crust and tor formation are the evidence of repeated, prevailing passive and cold-based subglacial condition through the Quaternary.

**O-2145**

**Quantitative measurements of subglacial processes: a comparison of till and hydrological processes from four soft bedded glaciers.**

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**Abstract**

We use a range of environmental sensing techniques to understand subglacial processes, including *in situ* multi-sensor probes, web connected dGPS, time lapse cameras, GPR and geophones. We are able to compare and contrast subglacial behaviour from four soft bedded glaciers: Briksdalsbreen (Norway) and Skálafellsjökull, Fjallsjökull and Breiðamerkurjökull (Iceland). We are able to show that deformation occurs all year, and are able to contrast seasonal behaviour. From this we are able to reconstruct the rate and nature of subglacial till deposition. We are also able to reconstruct the different styles of subglacial hydrology which have implications of glacier response to climate change in both modern and Quaternary glaciers

O-2146

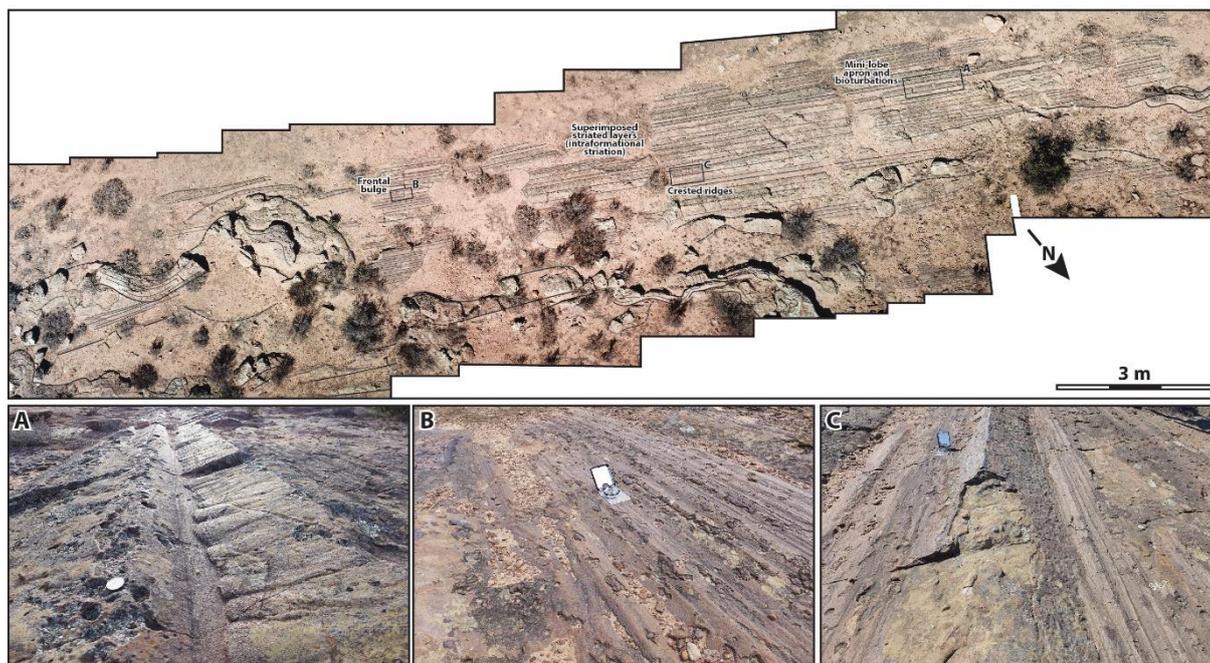
## A multiphase model for a soft-sediment striated surface of subglacial origin

Daniel Le Heron<sup>1</sup>, Pierre Dietrich<sup>2</sup>, Marie Busfield<sup>3</sup>

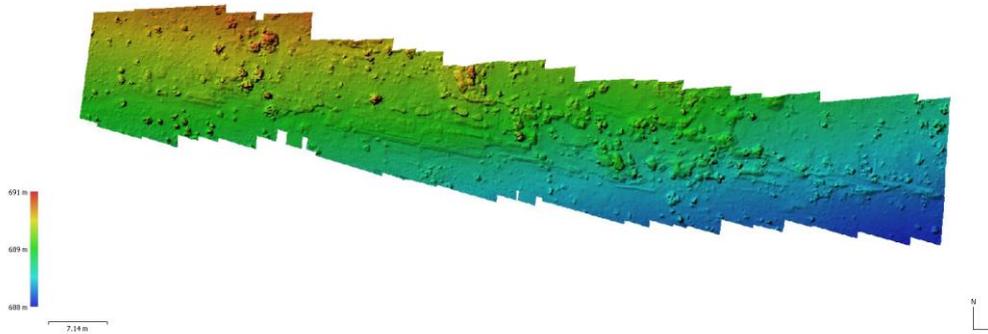
<sup>1</sup>University of Vienna, Vienna, Austria. <sup>2</sup>University of Johannesburg, Johannesburg, South Africa. <sup>3</sup>Aberystwyth University, Aberystwyth, United Kingdom

### Abstract

The aim of this paper is to showcase an ancient (Late Palaeozoic) striated surface in South Africa, and discuss its interpretation in the context of a soft-bedded ice sheet during the retreat phase. The quality of glacial geomorphic evidence, preserved in semiarid terrains of Africa, is extremely high, and allows special insight into aspects of an ancient glaciation that has gone to completion. The Dwyka Formation evidences multiple cycles of glacial advance and retreat which include a thick succession of diamictites and heterolithic strata. Painstaking work in the 1970s and 1980s produced regional palaeogeographic reconstructions, among which complex ice flows were identified. Trunk glaciers and / or ice streams appeared on a variety of palaeogeographic maps, many of which highlighted highly complex flow structures within the ice sheet. Nowhere is complex ice flow directions more apparent than in the northern Cape province, which exposes an outstanding soft-sediment striated surface at Oorlogskloof (Fig. 1). Using a combination of field observations, aerial photograph interpretations, and new digital elevation models collected from an Unmanned Aerial Vehicle (UAV), we map the macrostructure of the surface.



**Fig. 1.** Images of the spectacular Oorlogskloof glacial pavement near Nieuwoutville, Northern Cape Province. Upper image is UOV (drone) imagery from 30 m altitude, gathered in March 2018, with detailed features of the pavement shown in more detail in photographs A-C



beneath.

the Oorlogskloof pavement, revealing the extent of flutes and grooves, with a consistent WNW-ESE orientation. Palaeo-ice flow right to left.

**Fig. 2.** UAV imagery of

The inventory of structures, which include grain flow lobes at the flanks of flutes (Fig. 1), suggests that the surface was largely generated at the ice-sediment interface, with local evidence for internal deformation and shearing of the sediment pile. Most importantly, the aerial images reveal two features that reveal a composite history to this pavement. Firstly, flutes and grooves to have high length to width ratios, potentially implying rapid ice flow. Secondly, the UAV images reveal a discontinuous network of bulbous ridges which traverse, fold and distort the striations and flutes (Fig. 1). The latter features are interpreted to result from bulldozing beneath a floating ice mass. Collectively, therefore, the assemblage of structures may record two distinct phases in the construction of this spectacular pavement.

O-2148

## Oxygen and hydrogen isotopes in gypsum hydration water of playa lakes in the Thar Desert spanning the Holocene

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### Abstract

The Thar Desert (NW India) has numerous evaporative saline playa lakes. Some are still active and others are dry and preserve up to several meters of sedimentary deposits. These deposits feature a variety of evaporite minerals, including the hydrated mineral gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ). Here we present new palaeohydrological records from dry playa lakes in the Thar Desert using the triple oxygen and hydrogen isotopic composition of gypsum hydration water. Assuming no secondary exchange, the isotopic composition of the gypsum hydration water preserves the  $\delta^{18}\text{O}$ ,  $\delta^{17}\text{O}$  and  $\delta\text{D}$  of palaeolake water at the time of gypsum formation. This method provides a means for understanding the hydrologic balance in a part of the world where it is typically very difficult to obtain palaeoclimate records. Furthermore, the derived  $^{17}\text{O}$ -excess and d-excess potentially enable us to quantitatively model past changes in relative humidity, which may be used as an input for vegetation and ecosystem models. Preliminary results from two sections indicate that gypsum deposits from the Thar Desert span the Holocene from  $\sim 12$  to 1 ka BP, with an average resolution of  $\sim 10$ -40 yrs/cm. The gypsum sequences were sampled at 2-cm intervals, producing a record of decadal to centennial resolution. Results show that a source of water maintained active playa lake basins in the central Thar Desert for much of the Holocene, either by enhanced direct precipitation and/or fluvial sources. This period was marked by several intervals of drier climate, including after  $\sim 4.4$  ka BP and sometime within the last  $\sim 1$  ka BP. These records provide a valuable history of the changes in moisture balance and relative humidity in the Thar Desert over a period that included important cultural transformations in the region. These include the appearance of the earliest South Asian Neolithic agricultural societies around  $\sim 8$  ka BP, the full span of the Indus Civilization from  $\sim 5.3$ -3.3 ka BP, and later periods of human occupation and urbanization after 3.0 ka BP.

O-2149

## **Aeolian activity in the Mu Us dune field in response to climate change during the late Quaternary and at present**

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### **Abstract**

There are vast area over northern China covered by semi-arid dune fields and arid deserts, and this region is one of the largest sources of dust in the world. A significant weakening in dune activity during the recent decades has been observed in the Mu Us, a semiarid dune field in north-central China. Using remote sensing techniques and geomorphic analysis, it is found that this long-term change in dune activity and vegetation restoration is strongly associated with the dramatic decline in wind strength since the 1970s in northern China. The high sensitivity of dune field activity to climate change is also clear during the late Quaternary. A large dataset of dune chronostratigraphies accumulated in recent years clearly indicates that both monsoon precipitation and wind strength play a major role in controlling dune mobility in the Mu Us dune field. At glacial-interglacial time scale, the changes in the dune field were directly responded to ice-volume forced monsoon climate change, that the dune field was active and expanding during the cold and dry glacial period while stabilized during interglacial period. Our study also highlights that the chronology of dune records must be interpreted in light of how geomorphic processes influence dune turnover and sand preservation.

O-2150

## Environmental evolution characteristics and orbital period of arid and semi-arid areas since 3.4 Ma in the Yinchuan Basin

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### Abstract

At present, the loess and lake sediments are often regarded as the good carrier to reconstruct regional paleo-environment and paleoclimate with high resolution. However, the land still lacks long term, continuous and high-resolution records especially in areas with rare loess and lakes. It is generally known that there are a large number of floodplain deposits on land. Is it possible to use these floodplain sedimentary records to obtain relatively continuous and high-resolution climate records? For this reason, Yinchuan Basin is chosen as research region.

The Yinchuan Basin is located in the arid and semi-arid climate transition zone. The Cenozoic fault basin continued to sink and collect eroded materials from the surrounding mountains and the Tibetan Plateau. The core PL02 (the depth is 720 m), located in the center area of deposition in the Yinchuan Basin, has a thick deposit with a higher resolution and sedimentation rate, making itself practical for the reconstruction of the paleoclimate and the coupling relationship between regional tectonic activities and climate change.

The chronostratigraphic sequence of the core is established by palaeomagnetic dating. The magnetostratigraphic correlation to the geomagnetic polarity timescale shows that the PL02 core recorded the Brunhes, Matuyama, Gauss, Jaramillo, Olduvai, Kaena and Mammoth polarity chron or subchron. The results indicate that the onset of the core PL02 in this section occurred at ~3.4 Ma BP. The analysis of the core established a detailed chronological framework for regional geological research.

In addition, we present a well-dated, high-resolution pollen record for the last 3.4 Ma from the Yinchuan Basin. Variations in the *Artemisia*/Chenopodiaceae (A/C) ratio reveal the changes in moisture conditions in the Yinchuan Basin during glacial-interglacial cycles, as well as a gradual long-term aridification trend which is consistent with progressive global cooling. The *Picea* and *Abies* records reveal two phases of increased representation, at 2.1 and 1.2 Ma, which may indicate phases in the uplift of the northeastern Tibetan Plateau. Meanwhile, spectral analysis of the *Artemisia*/Chenopodiaceae(A/C) ratio shows periods of about 100-kyr and 41-kyr, which may correspond to Milankovitch periods, reflecting eccentricity and obliquity cycles, respectively. Spectral analysis of the percentage of *Picea* and *Abies* shows extra period of about 600-kyr, which is the second discovered 600-kyr period after sedimentary record of Lake Baikal in global. Besides, the high-resolution pollen record also indicates that the short humid and cold climate during Olduvai Subchron.

Thus, we believe that the floodplain deposits on land are a good carrier for studying global climate change.

O-2151

## Holocene landscape dynamics of the Ghaggar-Hakra fluvial system, India: implications for the Indus Civilisation

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### Abstract

A range of palaeoclimatic and palaeoenvironmental evidence suggests the Asian sub-continent experienced phases of arid-humid alterations on centennial and millennial scales during the Holocene, which were set against a backdrop of insolation-driven weakening of the Asian Monsoon system. These oscillations would have affected fluvial regimes on the plains of northwest India, which were occupied by the Bronze Age Indus Civilisation during the mid-Holocene. It has been suggested that a decline in regional river systems contributed to the decline of the Indus at ~4 ka (e.g. Giosan et al., 2012 (PNAS 109, E1688), Singh A. et al., 2017 (Nature Communications 8, 1617)). In a recent study Orengo and Petrie (2017, Remote Sensing 9, 735) identify a complex channel network on the Sutlej/Yamuna interfluvies, and Durcan et al. (in press, Quaternary International, doi.org/10.1016/j.quaint.2017.10.012) have highlighted complexity in the response of regional geomorphic systems to climatic/environmental change. Therefore, further work is required to understand the spatial and temporal dynamics of regional hydrological systems in order to assess the importance of changing climatic and environmental conditions in the establishment and decline of the Indus Civilisation

This paper presents luminescence dates from palaeochannel sediments and associated dune deposits on the Ghaggar-Hakra floodplain in northwest India, with particular focus on the area around the Indus site of Rakhigarhi. Rakhigarhi is the largest and potentially most important site in northwest India (Singh R.N. et al., 2010, Man and Environment, 35, 37-53), although its relationship to local and regional fluvial systems is unclear. Reconstructing fluvial activity and palaeoenvironmental variability allows a comparison between the documented archaeological record of the Indus Civilisation and an absolute chronology of regional landscape dynamism. Luminescence dating shows that the fluvial network around Rakhigarhi pre-dates the establishment of the site, and that regionally, there is no simple relationship between documented climatic deterioration and changing fluvial activity. This study presents a new reconstruction of palaeoenvironmental change on the Ghaggar-Hakra floodplain, and provides new insights into the fluvial landscapes occupied by the Indus Civilisation during the Holocene.

O-2152

## Orbital and millennial-scale drivers of Namib Desert hydroclimate over the last 50,000 years

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### Abstract

Despite being one of the world's oldest deserts, and the subject of decades of research, evidence of past climate change in the Namib Desert is extremely limited. As such, there is significant debate regarding the nature and drivers of climate change in the low latitude drylands of southwestern Africa. Here we present data from stratified accumulations of rock hyrax urine that provide the first continuous high-resolution terrestrial climate record for the Namib Desert spanning the last 50,000 years. These data, spanning multiple sites, show remarkably coherent variability that can be clearly linked to orbital cycles and the evolution and perturbation of global boundary conditions. Contrary to previous predictions orbital-scale phases of increased summer insolation coincide with periods of increased aridity in the region. Supported by climate model simulations, we link this to variations in atmospheric pressure cells modulated by hemispheric and land-sea temperature gradients. These dynamics induce cycles of hydroclimatic variability driven by upwelling and sea-surface temperature variations, and are in phase with the northern tropics. In contrast, millennial-scale reductions in the strength of Atlantic meridional overturning circulation, such as those occurring during Heinrich stadials, triggered periods of interhemispheric asynchrony due to a progressive build-up of heat in the Southeast Atlantic, and are strongly manifested in the Namib as phases of increased humidity. These findings provide new perspectives on the synoptic-scale dynamics determining multi-millennial and abrupt changes in low latitude climate.

O-2153

## Increased hillslope activity in the hyper-arid core of the Atacama during the Pleistocene – evidence for palaeo-climatic fluctuations?

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### Abstract

Hillslopes represent areas of predominant denudation and constitute the transition and trajectory to floodplains; they play a crucial role in understanding the long-term landscape evolution of desert environments. However, although hillslope processes are known to be very slow or even stagnant in (hyper-)arid environments, process mechanisms under the absence of water are poorly understood, and process rates are essentially unknown. Therefore, sub-project C03 of the DFG-funded Collaborative Research Centre 1211 (CRC 1211) “Earth – Evolution at the dry limit” is dedicated to the investigation of hillslope processes in the (hyper-)arid zones of the Atacama Desert. It aims at contributing to a better understanding of controls and processes of hillslope dynamics in the driest parts of the earth on both recent and geological time scales using a variety of different methods. Based on irrigation experiments, different monitoring techniques, geomorphological, stratigraphical, geochronological, sedimentological and geochemical investigations, as well as  $\mu$ CT scans of sediment cores, this contribution presents detailed insights into the chronostratigraphy of tongue-shaped, 70 m-long and 30 m-wide fine sediment lobes located along a 10-20° steep thrust-related slope east of the Salar Grande (Atacama, Chile). Irrigation experiments were performed in order to gain insights into precipitation thresholds for surface runoff or moisture-driven hillslope dynamics using a simple and portable irrigation device (2 x 5 m plot size). Although artificial rainfall intensities were  $\sim 46$  l/m<sup>2</sup>/h, infiltration was 100 %, and none of the experiments initiated surface runoff or (detectable) slope material displacements. Nevertheless, we detected increased post-irrigation TOC concentrations in the moist sediment layers, i.e. the uppermost  $\sim 15$  cm of the irrigated sediment. However, we found a distinct stratigraphic pattern with buried palaeo-surfaces and palaeo-biological surface crusts in several trenches, suggesting increased slump-, creep-, or solifluction-like hillslope activity in the past. OSL datings of stratigraphic units point to a late Pleistocene age of the sediment lobes, potentially activated by changes of (fog-induced?) humidity, salt and gypsum shrink and swell processes, or palaeo-seismicity. While a variety of geo-bio-archives document periods of increased precipitation in the Andean parts of the Atacama Desert throughout the quaternary, evidence for contemporaneous paleoclimatic changes from areas disconnected to Andean precipitation fluctuations (i.e., the coastal cordillera) is scarce. In this regard, the investigated landforms potentially represent one of only few sediment records recording paleoclimatic changes in the central desert, independent from Andean rainfall.

O-2155

## Chironomid-based Mid- to Late Holocene reconstructions of rapid ecosystem transitions in the Central Asian lake Son Kol

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### Abstract

Climate in arid Central Asia is controlled by the Westerlies and the Siberian High. As precipitation is mainly provided by the Westerlies, even minor changes in their interplay with the Siberian High can lead to major differences in the water budget. Here we present a chironomid-based ecosystem reconstruction from a 141 cm long sediment core from the lake Son Kol, Central Kyrgyz Tian Shan, that covers the last 6000 years. Diatom- and ostracod-based reconstructions suggest that the lake transformed from a closed-basin saline lake to an open freshwater lake (Schwarz et al. 2017). Preservation of these two bioindicators is rather poor in core sections characterized by stronger Westerlies influence. Thus, we used chironomid data to establish a continuous paleoenvironmental record.

We observed two abrupt shifts in the chironomid abundances. Prior to 5050 cal. yr BP, the salinity indicators *Psectrocladius sordidellus*-type and *Cricotopus intersectus*-type formed the major part of the chironomid assemblages. After the first abrupt shift, they were replaced by the dominating *Chironomus anthracinus*-type. After the second abrupt community change around 4400 cal. yr BP, *Tanytarsus gracilentus*-type dominated the chironomid assemblages. In contrast to the sediment-bound *Chironomus anthracinus*-type, this taxon is associated with aquatic vegetation, similar to the first two taxa. From 4400 to 3800 cal. yr BP, chironomid concentrations increased while at first moderate *Procladius* percentages decreased. The increase in concentration suggests an increase in productivity which is supported by carbon isotope data from chironomid head capsules and ostracod shells.

Combined bioindicator and stable isotope data suggest a phase of strong Westerlies influence lasting from 5050 to 4400 cal. yr BP. This led to a lake level increase combined with a shift from saline to freshwater conditions. The abrupt shifts at the onset and end of this phase may have resulted from collapsing macrophyte vegetation, potentially due to increased turbidity caused by higher sediment input as a result of increased precipitation. The gradual change observed after 4400 cal. yr BP may have been driven by increasing macrophyte density or decreasing water depth due to the establishment of the modern outflow. Alternatively, increasing productivity may have favored the *Tanytarsus gracilentus*-type over the free swimming *Procladius*.

Our results show how Son Kol shifted from a hydrologically closed to an open system marked by two tipping points at the onset and end of a ca. 650 year-long phase of increased Westerlies influence.

Schwarz, A., Turner, F., Lauterbach, S., Plessen, B., Krahn, K. J., Glodniok, S., Mischke, S., Stebich, M., Witt, R., Mingram, J., Schwalb, A. (2017): Mid- to late Holocene climate-driven regime shifts inferred from diatom, ostracod and stable isotope records from Lake Son Kol (Central Tian Shan, Kyrgyzstan). *Quaternary Science Reviews* 177: 340–356.

O-2156

## Climatic variations during mid Holocene in Ladakh (Karakorum Himalaya), India

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### Abstract

The monsoonal precipitation over Indian subcontinent is largely controlled by the thermal gradient between the Tibetan Plateau and Indian subcontinent and is highly variable with contrasting precipitation patterns seen from east to west and north to south, especially over Himalaya. This can be contributed significantly to the varied geomorphology of different sectors of the Himalaya. In Indian part of Himalaya itself, hydro-climatology of the central and northeastern parts is largely influenced by Indian summer monsoon, but for western Himalaya the winter time weather and westerlies bring moisture from northwest of Indian sub-continent and plays a lead role. Bulk of the precipitation over Ladakh and Karakoram region is received as snow between November-April which is crucial to replenish and maintain the water budget of the ten major rivers originating from the third pole area and catering almost 20% of the world's population. This mid latitude, high altitude glaciated region thus hold key to understanding of several climate uncertainties. Recent uprising trend in flash floods induced by abrupt and intense precipitation events in the high altitude Himalaya are becoming worrisome. A spatial variation exists in the studied records and to understand this concurrent variability it is very important to have good knowledge of past variability especially since mid-Holocene. As the proglacial lakes have significance in assessments of glacier dynamics and aquatic ecosystem monitoring, a multi-proxy study using mineral magnetism, sediment texture, total organic content, palynofacies and diatoms as proxies was taken up to give the picture of the lake productivity and past climatic variations at North Pulu (NP; 5098 m AMSL) in Ladakh, bracketing between 4585 to 360 cal yrs BP ( $^{14}\text{C}$  AMS). The first high-resolution palaeolimnology record from Karakorum Himalayas shows that between 4585-4294 cal yrs BP, an oxic lake condition existed with freeze-thaw action, prominent weathering and less organic productivity. The following period is of 320 year, severely cold and dry phase. Between 3974-2064 cal yrs BP, an initially cooler climate but a transition phase with some moderate warm climatic condition and high lake levels are recorded. Glacial melting due to a warm climate, high TOC%, and well-preserved OM, reducing conditions were prevailing, due to high lake level, is followed by a 260 year period between 1244-984 cal yrs BP of warmer climatic conditions. LIA in the region is documented at between 984-620 cal yrs BP. However at 620-360 cal yrs BP warm climatic condition which were of a local extent and were not severe. This mid-Holocene record is culturally important being a rich heritage of ancient India as well as the Chinese civilization and can throw light on the appearance and decline of the Indus valley and Chinese civilizations reigning during this time span.

O-2157

## Fossil green algae indicated middle-late Holocene abrupt temperature change in central Asia and its impact on cultural evolution

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### Abstract

We present the results of a synthesis of the modern distribution of *Pediastrum* (including *Pediastrum. simplex*, *P. duplex* and *P. boryanum*) in freshwater bodies in Asia, together with a stratigraphic study of *Pediastrum* in the Holocene sediments of Bosten Lake in Xinjiang, China. The results show that *P. simplex* and *P. duplex* have an unambiguous thermophilic character compared to *P. boryanum*. In addition, *P. simplex* has a narrower ecological amplitude, preferring warm water, and thus it can be used to indicate climatic warmth. According to the fossil *Pediastrum* record from Bosten Lake, the largest inland freshwater lake in China, the only occurrence of subfossil *P. simplex* is during 4.8-3.5 cal kyr BP; its occurrence indicates a relatively warm climate interrupted by several abrupt cold events. The concentration of *P. simplex* peaked during 4.7-4.2 cal kyr BP, and reference to independent geological records indicates that this interval corresponds to a strengthened global monsoon and intensification of drought in arid central Asia (ACA). By contrast, the low concentration or total disappearance of *P. simplex* reflects several cold events, such as at 4.2 and 3.5 cal kyr BP. The prosperity and decline of human civilizations was probably linked to the transitions between warm and cold conditions during the middle-late Holocene. A favorable climate would have promoted the development and enhanced the prosperity of ancient civilizations in the monsoonal regions of both Asia and Africa. By contrast, a series of collapses and cultural transitions in Asia and Africa at ~4 cal kyr BP were probably linked to abrupt cooling and a weakened monsoon. In ACA, the 4.2 kyr cold event may have led to population migration southwards from the Eurasian steppe to lower latitudes such as the Tarim Basin, Hexi Corridor, and even to Indian sub-continent. This event may have enhanced the prosperity of the Xiaohu and Siba cultures along the edge of deserts, which was associated with the introduction of wheat, sheep and related agricultural technologies.

O-2158

## A Multi-Proxy Reconstruction of Late Holocene Climate and Environmental History in Western Sri Lanka

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### Abstract

The distinct geographical location of Sri Lanka in the Inter-Tropical Convergence Zone makes it an ideal place to track past variations in Indian Ocean monsoon intensity and related climate and environmental changes. A 4.1-m undisturbed sediment core retrieved from the coastal lake of Bolgoda reveals the terrestrial climate and environmental history since 3000 yrs BP in south-western Sri Lanka that is influenced mainly by summer monsoon rainfall. Different biomarkers (*n*-alkane, *n*-alkanoic acids, *n*-alkanol and triterpenols) were analysed together with compound specific stable carbon isotopes of *n*-alkane to reveal source specific paleoenvironmental information. In addition, a pollen analysis was also conducted to understand the vegetation changes in the watershed. Salinity in this coastal lake is controlled by seawater intrusion due to variability in freshwater input to the lake. Presence of brackish water molluscs in the lake and the density of mangrove vegetation showed a direct link to the lake salinity. Based on the results of these palaeoenvironmental proxies, and a Bayesian model based on radiocarbon dates, we divide the depositional history of Bolgoda Lake into four zones. *Zone 1* (2942 – 2391 cal yr BP) is characterised by decreasing salinity with increasing stream water input. Rhizophoraceae mangrove is dominant during this period whereas tree taxa such as *Dipterocarpus*, *Mallotus*, *Macaranga* and *Trema* indicate wet conditions in the catchment. *Zone 2* (2391 – 1782 cal yr BP) is characterised with rapid and abrupt changes of salinity and rainfall. The first phase of this zone (2391 – 2064 cal yr BP) is clearly identified as a dry phase, as inferred by high lacustrine salinity together with dominance of Avicenniaceae mangroves. Shrubs and small trees that are characteristic to arid conditions were common in the catchment. Rainfall increased but was mostly steady in *Zone 3* (1782 – 1299 cal yr BP) lowering the salinity level because of higher freshwater input. As a result, the mangrove vegetation was sparse, and the catchment was dominant with trees growing under wet conditions. *Zone 4* (1299 cal yr BP - present) is characterised by very slow accumulation rate with high clay content. Salinity increased during this period, and Rhizophoraceae reappeared during the latter part of this stage (545 – 217 cal yr BP). This suggests a higher rainfall in *Zone 4*, though the overall intensity of precipitation was decreasing slowly with the time. Vegetation in the upper catchment was similar to *Zone 3*. The paleoclimate and paleoenvironmental evidence in this study showed a good agreement with our previous investigation in the Bolgoda Lake based on bulk geochemical proxies. This study reveals high-resolution information about past climate and environmental changes in the lake and its catchment, providing detailed and specific information that is relevant for reconstructing the regional climate history.

O-2159

## Investigating the impacts of climate variability on prehistoric communities using a multi-proxy salt lake archive from the Iberian Peninsula, Spain.

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### Abstract

This preliminary paper aims, through detailed environmental analysis (pollen, NPP, a strong chronology (eight  $^{14}\text{C}$  ages) and XRF analysis) to expand our understanding of Pictish settlement, landscape and land-use during the early medieval period. A 1.86 m core was extracted from a valley fen adjacent to the Waters of Bogie, slightly south of the village of Rhynie in north-eastern Scotland, and within 270 m of a Pictish settlement and Craw stone dated to the 6<sup>th</sup> century. The bottom of the core produced a calibrated age of AD 260-415 and all but one of the radiocarbon dates are in good chronological order. Initial pollen counts have revealed relatively good preservation with a number of distinct changes in the vegetation record. Most of these changes appear to be associated with natural environmental transitions linked to a weakening in fluvial/stream energy after the 12<sup>th</sup> century and a gradual accumulation of peat, although some evidence also suggests agricultural activity.

In the archaeological record evidence, from the nearby Pictish settlement, highlights high status metalworking as well as a range of Continental imports (e.g. late Roman Amphora pottery and fragments of imported glass drinking vessels from western France), signifying that Rhynie was an important power centre during the early Medieval period. A series of radiocarbon dates and Bayesian modelling however indicate only a short phase of construction and use during the late fifth to mid-sixth centuries. What is particularly interesting about the palaeoecological results is that there is evidence of cereal pollen and a pronounced representation of herbivore dung fungi throughout the record, which suggests continuity of farming activities from AD 260-415 onwards, despite the 6<sup>th</sup> century abandonment of the Pictish settlement.

O-2160

## MWP and LIA revealed by multiple proxies in varved lake sediments in the Tibetan Plateau

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### Abstract

The Tibetan Plateau (TP) is alternatively controlled by the Indian monsoon and the westerlies at glacial-interglacial, millennial scales. It remains unclear how the two climate systems influenced the TP climate at decadal- to centennial- scales because that high-resolution climate records with reliable chronology are scarce. Here we present sub-annual to biennial scale multiple proxies at a varved lake in the central TP over the past two millennia. The biennial-resolution oxygen isotope records revealed temperature variation, while the Titanium reflect precipitation, both based on proxy validation with meteorological data. The temperature records showed evident warming at 600 and 1000AD, coinciding with the Medieval Warm Period (MWP), while the relatively cool temperature at 1400-1700 AD indicating Little Ice Age (LIA). However, the precipitation showed different patterns on the TP, suggesting decoupling between temperature and precipitation over the past 2000 years. The decoupling could be attributed to changes in the monsoon intensity and interplay between the monsoon and the westerlies, which likely played an important role in civilization on the TP.

O-2161

## 'Stable' hydroclimate is specific to a narrow temperature window: observations from Guatemalan varves, 1413±4 to 2015±0 CE

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### Abstract

Increased frequency of extreme weather events is considered to be closely linked to recent global warming. However, reliable meteorological data are available only since the industrial revolution, i.e., after the beginning of the present global warming. Before that, it is generally difficult to find geological archives that enable us to detect extreme weather events, which, in turn, prevents us from assessing the relationship between present global warming and instability of weather.

Sediment cores recovered from Lake Petexbatún (Guatemala) in 2015 (GPB15) are ideal materials for this purpose. Counts of their clear varves (annual laminae) and 29 <sup>14</sup>C dates for the last 600 years enabled us to establish a chronology with exceptionally high precision and accuracy. We then performed ultra-high resolution (on average, ca. 180 data points per varve, i.e. ca. 2 days interval) X-ray fluorescence scans of the cores. Changes in the Ca/Fe ratio, a proxy for precipitation – evaporation balance, show that long-term drying proceeded in parallel with contemporary warming. More importantly, amplitude of the estimated dryness has increased during the same interval, suggesting a dramatic change in the instability of the climate system. On the other hand, during the Little Ice Age (LIA, ca. 16th to 17th century CE), rainfall increased and became unstable (the frequency of extreme rainfall events increased). During the 300 year period from the LIA to the 1970's, we were in the narrow window of the 'stable' climatic mode.

A clear increase of the both dryness and wetness oscillation amplitudes is only visible, and is very visible, in monthly data because impacts of spiky events are not suitably represented in long-term means. Strong weather extremes included in the climatic oscillation cannot be seen in the geo-archives at annual or lower resolution.

O-2162

## The resource space of Early *Homo* in Europe – implications from vegetation dynamics and plant food resource availability in the Caucasus

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### Abstract

The earliest hominid expansions from Africa into Eurasia date to at least 2 Ma. It is evident, that records in Southern Europe (notably from Spain and Italy) are much younger and extend back to up to 1.4 Ma. Climate change is considered a major driving factor of hominin evolution and dispersal patterns. In fact directly or indirectly by its severe influence on vegetation, physiography of landscape, and animal distribution, climate modulates the availability of resources. As plants contribute to the amount and variety of obtainable food resources vegetation and vegetation diversity are important factors for human habitats. Based on own results from the Caucasus region, we extrapolate the maximum extend of forests and mosaic landscapes for different climatic phases during Early Pleistocene as a prerequisite for the reconstruction of early human environments and evaluate different vegetation units with respect to their potential plant food.

This study aims at exploring the resource space of early humans in the Early Pleistocene. The main research questions here are, which and how many edible plant parts can be found in different vegetation units and how is the availability distributed in the course of the year. Vegetation units are chosen according to palaeobotanical reconstructions in the region, based on fossil records from plant macro fauna and pollen data. The units range from steppes to altimontane forests, comprising published taxa lists of dominant and most frequent species. The database PlantBITES hosts the relevant information compiled from the literature.

It is widely assumed that *Homo erectus* relied on a mixed diet of meat and plant food. However, it is not yet assessed in detail which plants may have contributed to their diet and to what extend different vegetation types can deliver necessary nutrition. This study is an attempt to quantify plant food resources and their availability for early *Homo* showing the importance of access to edible plant parts from forests for a stable supply of an energy- and nutrient rich diet.

O-2163

## Multicycle loess-palaeosol sequence and repeated hominin occupation on the Chinese Loess Plateau since about 2.12 Ma

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### Abstract

Considerable attention has been paid to dating the earliest appearance of hominins outside Africa. We found a new successive and multicycle aeolian loess-palaeosol section, which is located in Shangchen area (34° 13' 33" N, 109° 28' 39" E) of Lantian county, Shaanxi province of north China and lies on the southern margin of the Chinese Loess Plateau. This section is complete from L5 to L28 (equivalent to marine isotope stage 12 to marine isotope stage 80). The section contains 17 bring-artefact layers within the segment from S15 to L28, which of the age ranks from 1.26 to 2.15 Ma BP during the Early Pleistocene. In Shangchen the 82 flaked and 14 unmodified stones between S15 and L28 were collected from 6 loess and 11 palaeosol strata. The stone artefacts include cores, flakes, scrapers, points, borers, hammerstones, picks and bifaces. These oldest artefacts (2.12 Ma), which were found within L28 layer between the Olduvai Subchron and the Réunion Excursion of palaeomagnetic stratigraphy, are c. 270,000 years older than the 1.85 million year old skeletal remains and stone tools from Dmanisi, Georgia, which were previously the earliest evidence of humanity outside Africa. Because no skeletal remains were found with the stone tools from Shangchen, we do not know who made them, but it is likely to be an early form of our own genus *Homo*.

The oldest artefact age of approximately 2.12 Ma at Shangchen implies that hominins had left Africa before the date suggested by the earliest evidence from Dmanisi (about 1.85 Ma). This makes it necessary to reconsider the timing of initial dispersal of early hominins in the Old World. Moreover, the length of our artefact sequence – of 17 stone cultural horizons (probably with a high average occupation of ~ 50 ka) found in the same locality – is very rare world-wide, and indicates a repeated hominin occupation of the Chinese Loess Plateau for almost a million years between 1.26 and 2.12 Ma, and most occupations were in the palaeosol layers (11 layers of total 17 layers) which indicate a kind of warm-wet climate. This breakthrough expands a new direction of research on the internationally leading Chinese loess-palaeosol sequence.

This research was supported by the National Basic Research Program of China, projects of NSFC and Projects of Chinese Academy of Sciences.

O-2164

## Feeding ecology of European Early Pleistocene Deer: what does it tell about the paleoenvironmental context early Homo faced in Europe?

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### Abstract

Due to their taxonomic diversity and marked abundance, cervids represent a major component of the European terrestrial fauna during the Early Pleistocene. In paleoenvironmental reconstructions, deer are traditionally considered as forest inhabitants, witnessing a substantial tree cover. However, insights into extant deer ecology uncover a marked diversity of feeding behaviors and occupied habitats. For example, *Cervus elaphus* is present from the arid Spanish dehesas, consuming up to 95% of herbaceous monocotyledons, to the Polish primeval forests, behaving there as a browser. The plasticity of *Cervus elaphus* feeding behavior reflects the principal resources available in the habitat. Exploring the trophic plasticity of extinct eurytopic cervids hence constitutes a key to better apprehend paleoenvironments and paleoenvironmental variations through time.

By reflecting what has eaten an animal during the last few days or weeks of its life, dental microwear textures of herbivores constitute a bridge between an organism and its environment. Textures of 211 specimens of *Eucladoceros ctenoides* and 176 *Metacervoceros rhenanus* from 11 Early Pleistocene European localities were analyzed using a Dental Microwear Texture Analysis via Scale Sensitive Fractal Analysis.

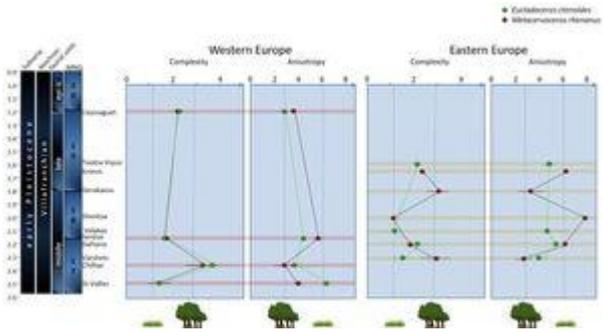
Results illustrate the diversity of the resources these two taxa are able to consume: either dicot foliage, seeds or tough and abrasive monocots. These Early Pleistocene deer are therefore eurytopic and constitute appropriate proxies to track vegetal resource availability in paleoenvironments. For some localities, our results corroborate previous paleoenvironmental interpretations. For others, it brings new perspectives. Senèze (MNQ 18, France) for example, was previously considered as a mosaic habitat based on the co-occurrence of cervids and bovids in the fossil record. Alternatively, our results show that Senèze deer were engaged in grazing, indicating a much more opened habitat than previously considered. For both deer, similar oscillations through time were identified between a browsing and a grazing pole. We propose that these results witness vegetation changes from steppe-like to wooded conditions induced by the Early Pleistocene glacial interglacial oscillations.

This large scale work challenges the paradigm considering deer as a paleoenvironmental indicator of an important tree cover and therefore modifies our vision of the paleoenvironments of several European Early Pleistocene localities. This approach impacts our understanding of the paleoenvironmental context of Early Pleistocene *Homo* dispersion.

Figure1: Evolution through time of the complexity and anisotropy of dental facets for *E. ctenoides* (green) and *M. rhenanus* (red). Localities from Western Europe are on the left side of the figure. Localities from Eastern Europe are on the right. A grazing diet corresponding to a more opened habitat is represented by herbaceous monocotyledons on the bottom of the figure while a browsing diet in a more forested habitat is illustrated by trees.



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O-2165

## Paleoenvironmental reconstruction of the Early Pleistocene of Baza Basin, Southern Spain

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### Abstract

The Early Pleistocene of the intramontane basin of Baza (Granada, SE Spain) contains a long and continuous sedimentary record depicting a lacustrine environment that spans from the late Miocene to Middle Pleistocene. The Basin has provided numerous vertebrate fossil sites, including some of the oldest *Homo* findings of Western Europe in the locality of Orce (1.2-1.4 Ma) in the form of fossil teeth and lithic industry. Analysis of pollen grains is conducted on the Early Pleistocene lacustrine facies of Baza, sampled by the Palominas drill core which is dated between 1.6 to 1.1 Ma. Paleoclimatic parameters for temperature and precipitation are obtained by applying the Coexistence Approach method. The biome succession for the Early Pleistocene of Baza is reconstructed using the Biomization technique of assigning Plant Functional Types (PFTs) to each pollen taxa. The resulting pollen profile shows high taxa diversity, typical for that time in the Iberian Peninsula, but dominated by a few pollen groups. The paleoclimatic parameters picture an overall wetter climate when compared with modern values. The biome succession alters between a clear steppe biome during the dry phases and semi-open temperate/cool forest biomes appearing during the wet stages. It is concluded that the Early Pleistocene environments in SE Spain were heavily controlled by humidity. The dry stages would see the development of steppe with xeric elements while the wet stages allowed for the formation of a *mosaic* landscape with open environments and patches of forested areas. These environments with more humid climatic conditions would allow access to a variety of plant resources and, thus, be favorable for the development of hominin communities.

O-2166

## An ecometric perspective on early human occupation in western Eurasia

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### Abstract

The environmental context of early human dispersal in Eurasia has been a popular topic for decades, but lack of vegetational and climatic proxies in many of the sites has limited comparisons between individual sites. In the absence of direct environmental proxies, the rich and well-documented large mammal fossil record in western Eurasia has been studied extensively to investigate the timing and potential causes of early human occupation. A largely unexplored approach to this question is using computational models based on large mammal communities to characterize fossil sites with and without humans over large spatial and temporal scales.

Species interact in their abiotic and biotic environment via traits that allow them to persist and maintain populations. An important feature of these interactions relevant to community and dispersal dynamics over time is species sorting; species differ in their ability to perform and compete in environments that vary in their abiotic conditions. Therefore, the composition of local communities in terms of their functional traits is expected to be informative of certain aspects of local environments that the traits in question are associated with. The computational approach that quantifies the distribution of functional traits in communities to reconstruct past environments is called ecometrics. Dental functional traits of large herbivorous mammals are useful for the study of hominin environments because they can be used to estimate past climate, a likely limiting factor for early humans. The composition of local herbivore communities is influenced by climatic variables that limit the availability of edible plants over the year, mostly precipitation and temperature, the latter of which has been found to be better predictable from herbivore teeth in western Eurasia. The ecometric estimates of temperature are comparable to other independent proxies absent in many sites, therefore enabling a larger sample size for quantitative analyses of Pleistocene palaeoenvironments. It moreover seems that humans already occupied a wide variety of environments at that time, which could indicate ecological flexibility, or specific, favoured microhabitats.

Our analysis presents a comprehensive overview of the climatic setting when humans first entered European ecosystems, changing from mostly absent towards extensively present, in the climatic context of a mild overall cooling trend. Dental ecometric estimates currently reveal no clear distinction between sites with and without positive records of humans. However, ecometric species distribution modelling, treating humans as part of the large



mammal community, may yet allow estimating relative abundance of humans across environments by modelling the suitability of environments based on co-occurring large herbivorous mammals. Pilot results indicate that, for example, of the Orce sites (southern Iberian Peninsula), Venta Micena, lacking lithic artefacts, appears ecometrically less suitable for human occupation than do Fuente Nueva 3 and Barranco León, which both have a rich lithic record.

O-2167

## Latest Villafranchian climate and landscape reconstructions at Pirro Nord (southern Italy) based on amphibian and reptile assemblages

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### Abstract

The Early Pleistocene terrestrial climatic conditions in the Mediterranean Region, especially for the time range between 1.3 and 1.7 Ma, are poorly known. The Early Pleistocene palaeontological record of Pirro Nord (southern Italy; locality also known as Cava Pirro or Cava Dell'Erba) is preserved inside a karst network at the top of Mesozoic limestones and filled with continental sediments, often containing numerous vertebrate remains, both macro and micro, representing highly diversified palaeocommunities: 23 amphibians and reptiles, 47 birds, and over 40 mammals. Even if such vertebrate assemblages have been found in different fissures, nevertheless, they have been considered almost contemporaneous from a biochronological point of view on the basis of the evolutionary degree of the analyzed mammals. These fossils refer to a homogeneous vertebrate fauna aged latest Early Pleistocene that represents the last Faunal Unit (Pirro Nord FU or Pirro FU) of the Villafranchian Mammal Age in the Italian biochronological scale. The most important bioevents characterizing the Pirro FU are the first occurrence of *Equus altidens*, *Bison degiulii* and *Xenocyon lycaonoides*. The Pirro FU is also characterized by the European first occurrence of *Homo*, as indicated by the rich lithic tool record found at Pirro 13. Here, the amphibian and reptile fossil record from various karstic fissures is used to infer quantitative paleoclimatic and paleoenvironmental reconstructions. From such numeric data, it is shown that mean annual temperatures may have been lower (-1.6/-3.6°C) than present ones and mean annual precipitations higher (+90/+240 mm) in comparison with modern values. Seasonality was much higher with cooler summers (-0.4/-2.0°C) and colder winters (-1.2/-6.0°C). Distribution of rainfall during the year shows higher precipitations during winter (+14/+43 mm), but summer rainfall similar (-1.7/+6.6 mm) to modern values. Associated landscape is reconstructed as open dry environment with scattered patches of woodlands eventually along water courses or swamps. Such ecological scenario fits with Early Pleistocene "glacial" conditions. Such results are concordant with other sites of similar age in the Mediterranean Region as Venta Micena (Spain). The temporal homogeneity of the different sites from Pirro Nord is strengthened by such an analysis. Paleobiogeographic interpretation also suggests an interesting pattern of Balkan influence when climate is colder, thus bringing a scenario for trans-Adriatic dispersals as it may have probably been also the case for the earliest Europeans. This paper is part of projects SGR2017-859, CGL2016-80000-P, and UV-INV\_AE17-708551.

O-2168

## Resources availability and hominin subsistence strategies in European Pleistocene.

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### Abstract

The term *Mammuthus–Coelodonta* Faunal Complex means more or less cold-adapted Pleistocene large mammal assemblages with similar or identical faunistic structures, known from transregional expansion in Eurasia (Kahlke, 2014). A crucial ecological factor in the formation of *Mammuthus–Coelodonta* Faunal Complex was the formation of the Eurasian steppe–tundra (MIS 12; marine isotope stage), a biome that no longer exists today, but which enabled species of Arctic tundra origin to disperse towards the south and southwest, as species of steppe origin spread into northern and western regions.

The various animal species are included in the Middle Pleistocene faunal complex and the Late Pleistocene faunal complex, respectively, which is related, among other things, to the evolution of the fauna at that time. Potentially, all of them could have contributed to hominin subsistence level.

This paper is intended to present the current state of knowledge concerning mega-fauna that have been established in Poland in order to examine their contribution to the subsistence level along with evaluation of its diversity. Both well-known localities and those more recently discovered (such as Bełchatów, Sitkówka and Sierakówko in Poland) will be shown and compared between the European Early and Middle Pleistocene. The data suggest that large mammals, in contrast to plant resources, constituted the main subsistence resource for hominids in the European Pleistocene. The overall picture of the resource availability, where ruminants predominate, as the results show, will be discussed along with the evaluations of the development of resource exploitation strategies.

**O-2169**

## **A novel approach to local and regional application of paleoecological perspectives in dry forest management and restoration**

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### **Abstract**

A relatively new development in the discourse of Quaternary science, which has yet to be rigorously evaluated, concerns the utility of long term perspectives for addressing land and resource management and other socially mediated practices. To test this notion, I conduct a case study of the Quaternary science perspective on the management and restoration of fire-prone dry forest of the Pacific Northwest region of North America. To frame this research agenda, I ask the following questions:

1. When management plans are being written, who contributes to the pool of scientific knowledge considered, how is that knowledge integrated, and how are long-term perspectives represented in these decision processes?
2. Can long-term perspectives be retooled and re-framed to better address the existing challenges of land management groups at local and regional scales?

With this study, I have two aims. First, I provide a reference point to the Quaternary science community to frame paleo-data for use by agencies and organizations actively engaged in managing landscapes and resources. Second, I produce an epistemic road map for land and resource management communities to access long-term perspectives on management issues they face. The methodological approach of this study is to engage personnel involved in public, private and tribal resource management to assess the potential for collaboration between Quaternary science-workers and land managers in this region with diverse land ownership and management strategies. The qualitative research plan involves two primary efforts: first, a series of interviews with the personnel of management groups; and second, analysis of planning documents and other relevant documents identified by interview participants.

Planning document analysis reveals that as practiced, Quaternary science perspectives are not well represented even as context for resource management plans. This holds even for issues such as fire regime shifts related to changes in climate, about which Quaternary perspectives may be most useful. Interviews with resource managers suggest that capacity for interpreting and synthesizing data and findings from scientific publications is a primary barrier to more integration of these perspectives in planning. Further, access to information about Quaternary science appears to be highly mediated by the social and professional networks of resource managers, suggesting novel approaches to science communication and co-producing knowledge will be important and effective. For Quaternary science researchers interested in the applications of their work to environmental issues, this study suggests beginning projects collaboratively is vital to realizing the potential of paleo-data for guiding society toward better informed natural resource policy and outcomes.

**O-2170**

## **Contemporary applications for the study of Quaternary geology in the Canadian mining sector**

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### **Abstract**

The Quaternary Period, defined by many glacial and inter-glacial cycles, is relevant to all who practice in British Columbia, Canada, as it has left a landscape fraught with engineering challenges. The study of Quaternary Geology is often overlooked in engineering assessments and will go unnoticed until “unforeseen” geological conditions result in poor performance of engineered structures. As practitioners in applied earth sciences we must take initiative to expand our influence and recognize the importance of our work to the modern world.

BGC Engineering Inc., an applied earth sciences consulting company, in Vancouver, Canada recognized the need internally to maintain a culture of getting the geology right. To support this, BGC developed a training program focused on glacial landforms and processes and specific training in air photo interpretation. These training opportunities have been developed with support from project teams. The Red Chris mine in northwestern British Columbia is an example, where the complex glaciated landscape provided BGC with an invigorating training and mentoring ground for teaching and developing an understanding of glaciolacustrine environments and the associated implications on engineered structures. The geologic model for this project has been recognized by the project independent external review board as industry leading and the framework for how geologic models should be carried out.

Proactive training initiatives for young professionals is only one method to support skill development in the study of Quaternary geology. Effective communication and partnership with industry, government, academia and the public to promote education and outreach is another key component. As an example, BGC took their internally developed glacial landforms and processes training seminar and offered the session to undergraduate and graduate students at a Canadian University to help support the teaching of Quaternary geology and bridge the gap between practitioners and students. The positive feedback was overwhelming and has led to further collaboration efforts. Initiatives such as this, internally at BGC and externally in academia illustrate an excitement and commitment to optimize our collective ability in Quaternary geology.

The key to instilling relevance in the Quaternary will be realizing potential opportunities for mentoring and inter-generational knowledge transfer, thereby instilling curiosity and excitement in others. Given the complexity of this field and the collection of site specific experiences, mentoring is a key component of maintaining relevance, encouraging collaboration, and ensuring continued commitment to our science.

O-2171

## The 3D Pollen Project: a new, free source of scans and 3D-printable models for outreach, engaging teaching, and research.

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### Abstract

The study of fossil pollen has been described as ‘the single most important branch of terrestrial palaeoecology for the late Pleistocene and Holocene,’<sup>1</sup> although most people only know pollen as an irritating allergen. Pollen also plays key roles in areas as diverse as forensics, biotechnology, honey identification, and cuisine – as well as being essential to reproduction in higher plants. Pollen shells (exines) are made of sporopollenin – ‘one of the most extraordinarily resistant materials known in the organic world’<sup>2</sup>, ‘the diamond of the plant world’<sup>3</sup> – and their shapes exhibit beautiful diversity.

But despite all this, engaging others about the importance and relevance of pollen is extremely challenging without the use of microscopes, something which is impossible in many outreach settings. And even with microscopes, it can be difficult to interpret a pollen grain's three-dimensional structure from flat, two-dimensional images – a fact which makes learning pollen identification (using photos and drawings in a process that has hardly changed for decades) a significant challenge.

3D-printing has the potential to transform these areas. Methods of preparing, scanning and printing pollen have been developed, but the few accurate models that have previously been produced are not freely available to the public. In this talk I introduce the 3D Pollen Project, which aims to address these shortcomings.

Firstly, I will discuss the motivation and methods underpinning the project, in which we are using laser scanning confocal microscopy to produce accurate, printable 3D models of pollen grains from reference and herbarium material, and making the resulting files available online for free.

Secondly, I will present the results of research into the impact of using physical pollen models and interactive scans on the learning experiences of students in pollen identification modules. The use of these resources in undergraduate modules represents a logical – yet so far impossible – enhancement to existing teaching practice which could be integrated with minimal disruption and little monetary cost, bringing potentially significant benefits. Students have already expressed the opinion that these resources would make the task ‘more fun and so easier to learn’; this talk will discuss how the use of 3D pollen models affects the different stages in learning pollen identification, and highlight its impact on overall student experience.

Finally, I will share examples of the models’ use in outreach and engagement activities worldwide, examining how they affect people’s interest and understanding of pollen and its relevance – to the Quaternary and beyond.

<sup>1</sup> Roberts, N. *The Holocene, an environmental history* (Wiley-Blackwell, 2009), p.29

<sup>2</sup> Faegri, K., Iversen, J. *Textbook of pollen analysis* (Blackwell, 1964), p.15

<sup>3</sup> Kessler, I. (2004), in Mackenzie, G., et al. (*Front. Mater.*, 2015) doi: [10.3389/fmats.2015.00066](https://doi.org/10.3389/fmats.2015.00066)

O-2172

## Quaternary palaeo-environment and archaeology skills enhancement in Uganda

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### Abstract

The main aim of the project was to provide skills and enhance the teaching and researching of archaeology and palaeo-environment in Uganda through vibrant multi-proxy and inter-disciplinary research and exchange, within Uganda and the wider eastern African region. The skills enhancement training was also meant to impart relevant skills to explore the long-term environmental dynamics in the interlacustrine region of Uganda and provide a historical context of interpreting human-environment interactions and the response to climate variations in the region. Despite a long history of archaeological and palaeo-environmental investigations in Uganda since the 1960s, there was little public awareness and appreciation of the rich heritage in Uganda. Furthermore there was limited teaching, researching and public promotion of history, heritage, archaeology and palaeo-environment in Uganda. The skills enhancement training was a strategy to create public awareness and appreciation of the rich history, archaeology and heritage in Uganda and impart knowledge and skills through field training. The objectives of this training were to: enhance hands-on practical skills combining significant original research and data collection with extensive theoretical and practical training for students; Impart skills on survey and descriptions of archaeological sites, including excavation of archaeological materials, identification of artifacts, attribute analysis, and interpretation; impart skills on methods of extracting sediments from peat / swamps, lakes and archaeological sites for macro fossils and micro-fossils analysis; impart skills on analysis of sediments for macro fossils and micro-fossils to reconstruct palaeo-environment; Impart knowledge on sediment analysis, radiocarbon dating techniques and use of sedimentary proxies to detect the nature and timing of past vegetation changes, including anthropogenic activity and interaction with the environment; To integrate innovative research approaches to reconstruct environmental history from multi-proxy records to understand the dynamics of past climate and environment and the main drivers of such changes. A major component of the skills enhancement project involved an intensive training of students in the theory and practices of archaeology, heritage and palaeo-science. This was intended to present a vital opportunity to promote and strengthen Quaternary research and create an informed generation of Quaternary research scientists in Uganda and build capacity of paleo-scientists in the region to join the INQUA research community. The long-term plans of the Skills Enhancement Project were to bring together experts within east Africa and outside the continent for a future plan to develop an INQUA International Focus Group to address the Quaternary palaeo-environmental changes in East Africa. The activities begun with a two days training seminar /workshop at the Uganda Museum followed by three days of field training at Nsongezi in western Uganda. Students participated in excavation and coring and laboratory analysis. The result indicate an increased awareness and zeal for quaternary sciences in Uganda.

**O-2173**

## **UNESCO global geoparks; a natural habitat for teaching quaternary sciences**

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### **Abstract**

With over 140 geoparks present in over 35 countries and 4 continents, the concept of geoparks has been rapidly taking hold since their early beginnings 20 years ago, in large part due to the creation of the UNESCO global geoparks label in 2015. This label has elevated geoparks at the same status as World Heritage status. They not only focus on the geological heritage of an area but are also strong vectors of regional economic developments through local community involvement.

The very nature of geoparks lend themselves to strong links with quaternary sciences outreach and education. The mission of a geopark is to promote and enhance the knowledge on the local geological heritage but also the influence the geology has on the landscape, habitats and biodiversity and culture. It carries a de facto multidisciplinary approach with the added interest of involving continuous human interaction with their environment. Quaternary sciences are the perfect framework for presenting these various interactions and their evolution through time.

This paper will take the point of view of the Joyce Country and Western Lakes aspiring geopark in the west of Ireland but expand for comparison to other geoparks worldwide. The developing nature of this project and its underlying landscape offer many opportunities to develop a strong message on the importance of quaternary science to sustainable rural development driven by the pride of local communities.

O-2174

## Reconstructing past climatic changes using deep sea microfossils and neural network classification: a citizen science experiment

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### Abstract

Citizen science has raised over the last decade as an innovative way to (i) explain the scientific process, (ii) educate people and pupils on a range of societal issues, and also to (iii) give access to scientists to large scale process studies, based on crowd experiments. Though a wide range of studies have been designed in natural sciences, from botany (e.g. observation of phenological stages, cross identification of organisms), to seismology (involving cell phone accelerometers) or marine sciences (sampling and genomics of plankton), no studies, to our knowledge, has been developed for paleoecological studies.

Here, we will present a project aiming to involve a large number of kids into a single paleoclimatic reconstruction. In this experiment, we are sharing some deep-sea sediments (foraminiferal ooze) from a single deep-sea core with multiple groups of pupils in schools in Southern France. They are given some sieves to extract the coarse fraction ( $>63\mu\text{m}$ ), and will take some pictures under the microscope of foraminifera and microfossils included in the larger ( $>150\mu\text{m}$ ) coarse fraction. To process those images in the different schools, we will classify the images using a common classifier. This classifier is based on an in-house convolutional neural network, developed under TensorFlow (ForamTrieur). Using this classifier, the pupils will be able to recognize the main species of planktonic foraminifera. Based on those faunal changes, they will document the main climatic shifts. All pupils from the different schools will join an event at our institute where they will compare their results. In our research group, we will also check some random data to verify their analyses, and assess the confidence level of this experiment.

We plan to run this experiment in the spring 2019, in close collaboration with an outreach organization, les "Petits Débrouillards", with a final meet up in late 2019. Each analytical step is detailed in technical notes, and contextualized in the largest frame of the wide questions tackled by the project : e.g. climatic change, artificial intelligence, oceanography, marine biology, etc...A dedicated website is also underwork.

In this presentation, we will report the advances of this project, and discuss the lessons and outcomes from this unique experiment.

O-2176

## Stable and clumped isotopes in shell carbonates of land snails *Cathaica* and *Bradybaena* in China and implications for paleoclimate studies

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### Abstract

Knowledge of eco-physiological characteristics of different land snail species is crucial for defining climatic significance of snail faunal assemblages. However, little work has been done in this aspect, hindering our obtaining unambiguous paleoclimatic information using these proxy indicators. Here we document for the first time the different eco-physiological characteristics of *Cathaica* sp. and *Bradybaena* sp. land snails in China using the stable isotopes and clumped isotope ( $\Delta_{47}$ ) of the shell carbonates. The  $\Delta_{47}$ -derived temperatures ( $T_{\Delta_{47}}$ ) for both species were apparently higher than both mean annual and seasonal temperatures. Nevertheless, the  $T_{\Delta_{47}}$  revealed a robust correlation with growth season temperature. Moreover, the temperatures for *Cathaica* sp. are 3~5°C higher than those for *Bradybaena* sp. land snails, possibly indicating different eco-physiological adaptations. Specifically, *Cathaica* sp. snails prefer living in trees with more chances to expose to sunlight, whereas *Bradybaena* sp. snails are inactive and stay in shady and damp litter layers under trees. Differences in color, thickness and appearance of shells between the two species lend support to the contrast eco-physiological traits. The result testifies to the  $\Delta_{47}$  in snail shell carbonates as a promising paleothermometer in monsoonal region and presents new insight into paleoclimatic explanation of these land snail species. This finding highlights the importance of constructing species-specific  $\Delta_{47}$ -T transfer function for precise paleotemperature reconstruction using clumped isotope in land snail fossil shell of the kind.

O-2177

## Stable carbon and oxygen isotopes in shell carbonates of modern land snails in China: their relationships to environment variables

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### Abstract

Stable isotopes of land snail fossil shell carbonates ( $\delta^{13}\text{C}_{\text{shell}}$  and  $\delta^{18}\text{O}_{\text{shell}}$ ) open a window to decipher paleodietary and paleoenvironmental changes. However, the environmental meanings of  $\delta^{13}\text{C}_{\text{shell}}$  and  $\delta^{18}\text{O}_{\text{shell}}$  remain elusive especially in monsoonal climate region. To fill the gap, we analyzed  $\delta^{13}\text{C}_{\text{shell}}$  and  $\delta^{18}\text{O}_{\text{shell}}$  of the two common species of land snails (*Cathaica* and *Bradybaena*) in China.

Results show that  $\delta^{13}\text{C}_{\text{shell}}$  of *Bradybaena* and *Cathaica* exhibited robust correlations to mean annual precipitation (MAP), mean annual temperature (MAT) and altitude. For example, the  $\delta^{13}\text{C}_{\text{shell}}$  values for *Bradybaena* and *Cathaica* showed a generally decreasing trend with increases in MAP and MAT. By contrast, the  $\delta^{13}\text{C}_{\text{shell}}$  values of both species displayed a positive correlation to altitude. The observed negative response of  $\delta^{13}\text{C}_{\text{shell}}$  to MAT doesn't represent a real relationship, which is biased by precipitation since temperature and rainfall co-varies in monsoonal region. Instead, we obtained a positive correlation of *Bradybaena*  $\delta^{13}\text{C}_{\text{shell}}$  to MAT when merely using the  $\delta^{13}\text{C}_{\text{shell}}$  data around a 500 mm contour line of precipitation. To reveal dietary information, we measured carbon isotopes in shell-bound organic matter ( $\delta^{13}\text{C}_{\text{SBOM}}$ ) for the two species from some selected sites with a goal to determine carbon isotopic fractionation (CIF) of shell carbonate relative to diet. A strong positive correlation was observed between  $\delta^{13}\text{C}_{\text{shell}}$  and  $\delta^{13}\text{C}_{\text{SBOM}}$  for both species, with a mean  $^{13}\text{C}$  enrichment factor of  $+15.18 \pm 0.26\text{‰}$  for *Bradybaena* and  $+13.89 \pm 0.15\text{‰}$  for *Cathaica*. Accordingly, the inferred dietary  $\delta^{13}\text{C}$  for *Bradybaena* documents isotopic signal of  $\text{C}_3$  plants even in  $\text{C}_3/\text{C}_4$  mixing region and retrieves water stress, temperature and altitude effects on  $\delta^{13}\text{C}$  of  $\text{C}_3$  plants (i.e., decreases with rainfall and increases with temperature or altitude). Comparatively, the inferred dietary  $\delta^{13}\text{C}$  for *Cathaica* registers  $\text{C}_3/\text{C}_4$  mixing signal in  $\text{C}_4$  maximum zone and exhibits strong altitude effect and moderate water stress influence.

At the same time, an overall positive correlation can be found between *Bradybaena*  $\delta^{18}\text{O}_{\text{shell}}$  and MAT ( $R^2=0.26$ ) and can be obviously improved after eliminating two deviated data points in southern China where amount effect emerged ( $R^2=0.52$ ). By contrast, correlation of *Cathaica*  $\delta^{18}\text{O}_{\text{shell}}$  to MAT is not statistically significant. Furthermore, the positive correlation became more significant for *Bradybaena* ( $R^2=0.84$ ) and *Cathaica* ( $R^2=0.55$ ) in northeast China. The robust positive correlation of *Bradybaena*  $\delta^{18}\text{O}_{\text{shell}}$  with MAT over a broad area testifies its usefulness to paleotemperature reconstruction at least in inland China. However, in Southern China, a strong negative correlation between precipitation and *Bradybaena*  $\delta^{18}\text{O}_{\text{shell}}$  is convincing ( $R^2=0.71$ ) and this becomes further prominent for study sites in coastal area ( $R^2=0.97$ ). A weak negative correlation existed between *Cathaica*  $\delta^{18}\text{O}_{\text{shell}}$  and MAP ( $R^2=0.11$ ). Meanwhile, the  $\delta^{18}\text{O}_{\text{shell}}$  of both *Bradybaena* and *Cathaica* showed a moderate correlation to  $\delta^{18}\text{O}_p$ . The strong  $\delta^{18}\text{O}_{\text{shell}}$ -MAP relationship means a potential to reconstruct MAP in coastal area.

O-2178

## U-Th dating of a cold seep carbonate chimney in the Okinawa Trough

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### Abstract

The Okinawa Trough, a back-arc basin formed by extension within the continental lithosphere, is one of the most significant ocean basins between the East China Sea and the Pacific Ocean, where cold seep carbonate deposits has been found. In this study, U-Th geochronological techniques have been applied to seawater and cold-seep carbonate chimney at the Okinawa Trough (OT). One well-structured chimney (MS), 19-cm thick in diameter, having a cylindrical shape with a vent hole at the center, was selected by submersible on the western slope of the northern section of the OT. To assess the composition of the detrital end-member, three sediment samples were also analyzed which were collected in the studied area. These samples were recovered at ~800m water depth.

Seven seawater samples for ST12 vertical-profile analyses indicate that U concentration is 3.170 to 3.226 ppb, with an average value of  $3.189 \pm 0.035$  ppb, and  $\delta^{234}\text{U}$  range from 145.8 to 147.1‰, with a mean of  $146.3 \pm 0.9$ ‰. The  $^{230}\text{Th}/^{238}\text{U}$  activity ratios are  $0.00009 \sim 0.00052$  for seawater samples, and indicate that the seawater may contribute a minor amount of non-radiogenic  $^{230}\text{Th}$  to the OT carbonate deposits. Five carbonate samples drilled across the section from inside to outside for MS chimney,  $^{238}\text{U}$  concentrations ranging from 3354-7020 ppb in the inner samples to 1322-1438 ppb in the outer samples. Contents of  $^{232}\text{Th}$  follow an inverse trend from 3994-6247 ppb in the inside to 6627-8854 ppb in the outside of the MS chimney. The  $\delta^{234}\text{U}$  of all samples ranged between 134 and 207‰ with a mean of 158.0‰, which is slightly higher in comparison to seawater value. Correction for initial  $^{230}\text{Th}$  has been made by Rosholt regression approach. We obtained ages of  $142.1 \pm 1.5$ ,  $146.2 \pm 7.0$ ,  $150.7 \pm 4.1$ ,  $159.2 \pm 4.7$  and  $167.7 \pm 5.1$  ka for MS chimney, which provides evidence for continuous growth from outer to inner at the studied site during the 167.7-142.1ka BP. These new  $^{230}\text{Th}/\text{U}$  ages of carbonate chimney in association with biogeochemical processes of cold-seeps at the OT area provide valuable geochronologic information for study of active fluid venting on continental margins.

O-2180

## Spatial core top variation of planktonic foraminiferal assemblages on the Uruguayan Margin

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### Abstract

Oceanographic processes offshore Uruguay are exceptionally complex and energetic, with the mixing of warm equatorial waters (Brazilian Current and North Atlantic Deep Water) and cold Antarctic waters (Malvinas Current, Antarctic Intermediate Water and Antarctic Bottom Waters), bathing the margin<sup>1</sup>. Planktonic foraminifera show ecological affinities for water masses based on temperature and thus within an oceanic mixing environment a transitional assemblage may be expected. Plankton tow transects conducted during the 1990s provide a regional picture of the relationship between planktonic foraminiferal communities and the associated oceanic water masses of the South American margin<sup>2,3</sup>. This project aims to relate surface sediment planktonic foraminifera distributions and assemblages to the overlying water masses, in order to assess any population heterogeneity present in the core tops across a portion of the margin associated with oceanic mixing.

The dataset covers a region of 7400 km<sup>2</sup>, within which a series of 200 piston cores were collected. A subset of this collection has been sampled, ranging from one to three kilometres water depth and covering the breadth of the margin, including drift, channel and terrace deposits. This range of environments is sampled to assess the spatial difference in planktonic foraminiferal assemblages and whether potential differences reflect the expected ecological affinities of taxa based on the oceanographic setting, or if ocean current transport and sedimentary affinity influence assemblage compositions.

Initial findings relating to the heterogeneity of planktonic foraminiferal assemblages obtained from core top samples will be presented. Results will be focusing on the variability of the assemblage signal margin-wide and correlation to the modern oceanic setting using current species ecological preferences, and whether transport effects explain assemblage variation and species distributions. Ecological mapping of the region lays the groundwork for this project, enabling assessment of assemblage variability in a geographically dense region coinciding with complex oceanographic boundaries.

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O-2181

## Replicated small-sample radiocarbon measurements as a corrective lens for sedimentary proxy records.

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### Abstract

Due to mixing processes, sediment samples taken from a single depth can contain particles (e.g. foraminifera) with a wide range of ages. When radiocarbon measurements are made on samples containing many of these individual particles, the resulting values can hide a lot of internal age variation. Furthermore, if the measured samples contain a material from only a small number of individual particles, the resulting <sup>14</sup>C ages will be noisy estimates of the true mean age of material from that depth. Similarly, for proxies such as Mg/Ca, or d<sup>18</sup>O, the range of ages contained in a single sample results in measurements that represent average values for an extended time period. Again, these values will be noisy if the number of particles per sample is small, but even with large samples, the resulting proxy records are “smoothed out” and the reconstructed amplitude of climate transitions is reduced.

The advent of ultra-small-sample <sup>14</sup>C dating means that samples consisting of very small numbers of foraminiferal shells now can be dated. This poses both a problem, as individual <sup>14</sup>C ages will be less representative of their layer, but also an opportunity as it allows for a direct estimate of the heterogeneity in the age of material at a given depth. We used <sup>14</sup>C measurements on samples of 3-30 foraminifera to estimate the underlying standard deviation in the age of individuals picked from the same depth. We repeated this for cores with sedimentation rates ranging from 3-30 cm/kyr and found age-variances consistent with simple sediment mixing models and typical bioturbation depths.

These direct estimates of age-variance allow for more realistic estimates of age uncertainty and have already proven useful to use in reconciling apparently inconsistent age-depth profiles from adjacent sediment cores. They also allow for a better-informed interpretation of proxy records, both in terms of the relative timing of events and in terms of the amount of amplitude reduction of the climate signal to be expected at different timescales. Knowing the length of time represented in a single sediment sample also allows us to more clearly interpret changes in the statistics of individual foraminifera variation, whether they can be interpreted as changes to the amplitude of the seasonal cycle, the strength of ENSO variations, or multidecadal climate variation.

O-2183

## Tracing the trigger of the Younger Dryas event: Spread of freshwater at 13 ka in the Arctic and Nordic Seas

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### Abstract

Recently published sediment core data from the Beaufort Sea continental margin, Arctic Ocean (Keigwin et al., 2018, *Nature Geoscience*), provide the long-sought convincing evidence for an oceanic freshwater event at the onset of the cold Younger Dryas interval. To significantly affect northern hemisphere climate, the freshwater which entered the Arctic Ocean via the Mackenzie River had to reach the area of deepwater renewal in the Greenland Sea where it could impact on the Atlantic meridional overturning circulation. Here we present foraminiferal stable oxygen and carbon isotope records from a collection of >20 radiocarbon-dated sediment cores along the pathway of the freshwater from the Canada Basin of the Arctic Ocean through the Fram Strait into the Greenland Sea. Only few cores from the central Arctic show evidence of the freshwater event. Usually it is hidden due to very low sedimentation rates and bioturbation. However, in several cores from continental margins in the Siberian Arctic and both sides of the Fram Strait, as well as the central Greenland Sea, sedimentation rates exceed 1-2 cm/ky. Here, low-oxygen isotope spikes are found which point to a clockwise spread of the Beaufort Sea freshwater in the Arctic Ocean and an export through the western Fram Strait into the Greenland Sea. Our data from older and from recently recovered sediment cores provide convincing proof of a strong freshwater export from the Arctic at 13 ka and support the hypothesis of an oceanic trigger of the cold Younger Dryas event.

O-2184

## Spatial fingerprint of temperature changes in eastern North America during the Younger Dryas

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### Abstract

The Younger Dryas cold event is clearly identifiable throughout much of eastern North America (ENA) in lacustrine and palustrine pollen records and geochemical proxies, but the signal varies spatially. Sites in New England and Maritime Canada record a cooling during the Younger Dryas, apparently synchronous with Greenland records. In contrast, fossil pollen records from Florida exhibit increases in plant taxa associated with warm/wet conditions during the Younger Dryas. This suggests the existence of a temperature dipole in ENA, but the spatial structure of this apparent temperature dipole remains unknown.

We present pollen-inferred temperature reconstructions for sites throughout eastern North America combined with branched glycerol dialkyl glycerol tetraether (brGDGT) inferred temperatures for five sites on a latitudinal gradient. Pollen-inferred temperature anomalies between the Holocene and Younger Dryas show a strong Younger Dryas cooling (2.5 to 5 °C) in New England and Maritime Canada and a more moderate Younger Dryas (0 to 2.5 °C) cooling in sites surrounding the Great Lakes. All sites south of 40° latitude indicate a warm Younger Dryas with cooling into the Holocene. Linear regressions of pollen-inferred temperatures against latitude indicate that the latitudinal temperature gradient became more gradual from 18 ka to 8 ka. The latitudinal temperature gradient steepened during the Younger Dryas, indicating diverging temperature trends in New England/Maritime Canada and Florida.

Independent brGDGT inferred temperatures support the spatial patterns in the pollen-inferred temperatures. Bonnet Lake, Ohio and Silver Lake, Ohio, near the Great Lakes, cool by 2-3°C, but lag the onset of the Younger Dryas at Greenland and New England. In addition, brGDGT temperatures from White Pond, South Carolina agree with pollen-inferred temperatures, with no Younger Dryas cooling. Instead, temperatures remain constant from ~14 ka until ~9 ka, after which temperatures begin to cool. However, the brGDGT temperature record from Sheelar Lake, Florida seemingly contrasts that of nearby pollen-inferred temperatures with a cold Younger Dryas. This apparent cooling may be an artifact within the brGDGT proxy, as both southern sites exhibit high sample variability relative to the two northern sites. Possible mechanisms that could generate a spatial dipole in temperature changes include changes in oceanic heat transport from the equatorial Atlantic or changes in atmospheric circulation advecting heat from the Gulf of Mexico.

O-2185

## Marine environmental changes in front of the Scandinavian Ice Sheet during the last deglaciation derived from foraminiferal geochemistry and assemblages

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### Abstract

The Baltic Sea-Skagerrak region shows evidence of strong coupling with North Atlantic climate over recent glacial-interglacial cycles, but insufficient long, continuous, high-resolution Baltic region climate records have often limited evaluating such links. Ultra-high-resolution sediment cores collected during IODP Expedition 347 allow such records to be generated, including foraminiferal geochemistry records reflecting seawater environmental changes directly adjacent to the Scandinavian Ice Sheet (SIS) during the most recent deglaciation. We present deglacial benthic foraminiferal oxygen and carbon isotope, trace element, and species assemblage results from IODP Site M0060 (located between Sweden and Denmark in the Kattegat seaway) to constrain bottom water environmental changes (salinity, temperature, and oxygenation) between ~18-13 kyr BP. We also demonstrate a screening method for appropriately interpreting trace element proxies for paleoenvironmental reconstruction in an inherently challenging proglacial environment (where typical proxy controls may be altered).

Three clear deglacial phases occurred at this site: 1) an initial large, rapid freshening event at ~17.9-17.8 kyr BP; 2) a slower, step-wise freshening from ~17.8-15.6 kyr BP with poor ventilation of bottom waters, sea-ice formation and fjord-like conditions; 3) a change to more saline, warmer and more ventilated conditions between ~15.6-13.0 kyr BP, beginning before the Bølling-Allerød (as defined in ice-core stratigraphy at 14.7 kyr BP). These phases reflect the fluctuations of the SIS and major meltwater releases from the SIS, and likely indicate key phases in northern European deglacial climate.

Our data suggest that 2-3 large meltwater releases from the SIS occurred at ~17.8 kyr, ~17.1 kyr (smaller), and ~16.5 kyr. These meltwater releases are driven by the fluctuations of the SIS, which represent either responses to or drivers of changes in Atlantic Meridional Overturning Circulation (AMOC) observed in various other North Atlantic records during early deglaciation. The timing of these  $\delta^{18}\text{O}$  declines is similar to other negative  $\delta^{18}\text{O}$  excursions seen in records from the North Atlantic and Nordic Seas, indicating that these are regional rather than local signals. The ~16.5 kyr meltwater release in our record corresponds approximately to Heinrich Event 1, and suggests a potential role of melting of the SIS in Heinrich Event 1.

O-2186

## Variability of sea-surface conditions along the west Greenland margin over the Holocene

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### Abstract

Marine sedimentary cores were collected off western Greenland margins to reconstruct changes in sea-surface conditions during the Holocene and to document the climate-ocean-ice dynamics. In the south, close to Nuuk in eastern Labrador Sea, core SA13-ST3-20G provided records with a centennial resolution over the last 12,000 years. North of Davis Strait, in the eastern Baffin Bay, core MSM343300 from Disko Bugt permitted to document changes through the last 10,000 years in complement to other Baffin Bay records (cf. Gibb et al. *the Holocene* 2015). The dinocyst assemblages provided information on past sea-surface conditions, including temperature (SST), salinity and sea ice based on modern analogue technique. Both cores recorded significant changes throughout the Holocene. At regional scale, during the early Holocene, a change from harsh conditions with dense sea-ice cover to interglacial conditions occurred in two steps: at ca. 10 ka BP significant decrease of heterotrophic taxa (*Islandinium minutum* and *Brigantedinium* spp.) and the occurrence of phototrophic taxa (*Pentapharsodinium dalei*, *Spiniferites* spp. *Operculodinium centrocarpum*), corresponds to an increase of summer SST and a decrease of the sea ice cover; after 7.5 ka BP, the establishment of full interglacial conditions both south and north of Davis Strait is marked by maximum percentages of phototrophic taxa and the occurrence of *Nematosphaeropsis labyrinthus* in dinocyst assemblages, which corresponds to onset of minimum sea ice, optimum SST and salinity. Optimal conditions persisted until about 2.5 ka BP south of Davis Strait and 1.5 ka BP in the Disko Bugt. The change towards more unstable conditions during the Late Holocene is notably marked by decrease in the percentages of *Pentapharsodinium dalei* and increase of *Islandinium cezare*. It corresponds to spreading of sea ice and successive cooling pulses. The changes towards harsher and more unstable conditions seem to coincide with the disappearance of the Saqqaq culture at about 3 ka BP and to the gap of human occupation in western Greenland, which was recorded from about 2 to 1 ka BP between the Dorset and the Norse settlements.

O-2187

## Oceanic pacing of the Late-Holocene summer moisture variability in northern continental Europe

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### Abstract

Century-to-millennial scale shifts in moisture and temperature are important to understanding variability in European Holocene climates and future water availability. Unfortunately, the spatial patterns and mechanisms behind these swings are poorly understood. Most records stem from the marine realm, whereas terrestrial records are rare and loaded with dating uncertainties for which reason acquiring a coherent picture of these climatic events and their drivers is difficult. Moreover, most of the existing hydroclimate records reflect predominantly winter precipitation, while information about summer moisture variability is scarce. Here we present high-resolution record of the summer moisture variability during the last five millennia obtained from an exceptionally well-dated peat core from a southern boreal raised bog in Finland. The record was based on calibrating fossil plant macrofossil data against the modern vegetation/water table relationship. We further examined, which of the detected features in the reconstruction were statistically significant in different time scales using a Bayesian scale space analysis (BSiZer) to the reconstruction. The reconstruction showed that the mire water table depth varied between 38 and 2.5 cm during the late-Holocene, and included repeated periods of seasonal moisture deficit. Significant increases in effective moisture occurred during the Dark Age Cold Period (DACP) about 300-800 AD, Little Ice Age (LIA) between 1550-1800 AD and during the Current Warm Period (CWP), from 1920 onwards, whereas drier conditions prevailed during the Roman Warm Period (RWP) prior to 300 AD, Medieval Climate Anomaly (MCA) 800-1200 AD, transition period between the MCA and LIA between 1400-1550 AD, and during the latter part of the LIA, i.e. about 1800-1920 AD. The inferred moisture increases correlated well with recurring episodes of unusually cold North Atlantic surface water (Bond Cycles), showing that these Bond events have left their signature in the Finnish peat record. We discuss the role of ocean dynamics in triggering abrupt climate change at centennial scales during the Holocene.

O-2188

## Lipid biomarkers quantify Holocene temperature in Icelandic lakes and soils

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### Abstract

Iceland currently lacks reliable and continuous quantitative records of Holocene temperature, which are vital to better understand the Holocene climate history of Iceland. We first report downcore paired branched glycerol dialkyl glycerol tetraethers (brGDGT) and alkenone records that quantify Holocene temperature change in Skorarvatn, a 25-m-deep lake in northwest Iceland. A combination of recent qualitative proxy-based climate reconstructions from Skorarvatn lake sediment and modeling experiments from the nearby Drangajökull ice cap provide a framework to evaluate the veracity of biomarker paleothermometers. Due to the lack of an Arctic calibration that removes the influence of 6-methyl brGDGT isomers, we apply the existing global lake calibration to quantify mean summer air temperature (MSAT). Compared to previous records from Skorarvatn, relative changes in brGDGT-inferred MSAT closely tracks biogenic silica (BSi), a proxy for qualitative summer temperature in Iceland. Furthermore, brGDGTs and BSi both show synchronous cooling at  $\sim 2.4$  ka, consistent with the first late Holocene appearance and subsequent growth of the temperature-sensitive Drangajökull ice cap. Analysis of alkenones from Skorarvatn show an abundance of C<sub>37:4</sub> alkenones in addition to an isomeric C<sub>37:3</sub> alkenone component. These distributions, in addition to RIK<sub>37</sub> values between 0.48 and 0.63, indicate that alkenone producers in Skorarvatn are Group I haptophytes and, thus, allow the application of published Group I calibrations. Alkenone-based temperatures exhibit less variability than brGDGT and qualitative climate proxies from Skorarvatn, and instead, closely track smoothly decreasing Northern Hemisphere June insolation. In addition to the lake-based proxies, we also examine brGDGT-based temperature reconstructions from stacked soil sequences that span the last 10,000 years in the central highlands. Due to the region's proximity to the active volcanic zone, the soil sequences are separated by thick ash layers, which have diagnostic geochemical fingerprints that permit robust correlation to tephra of known age. Additionally, soil-derived records may circumvent complications associated with multiple brGDGT producers contributing to lake sediment. Using the global soil calibration, brGDGT-inferred temperatures from the soil sequence conform to regional qualitative lake sediment climate records and capture periods of documented abrupt climate change in Iceland. Modeling experiments for Drangajökull and Langjökull, an ice cap in central Iceland, both pin peak Holocene Thermal Maximum (+3°C modern) and lowest late Holocene (-0.8°C modern) temperature estimates near those inferred from lake sediment and soil brGDGTs, as well as alkenones. Hence, these new quantitative records will provide valuable constraints on the glacier and climate sensitivity of Iceland during the Holocene, and important insight into the warming expected over the current century.

O-2189

## Holocene oceanic conditions and sea-ice variability off North-East Greenland

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### Abstract

The acceleration of climatic changes in the Arctic and Subarctic regions is particularly marked by the drastic reduction of summer sea-ice cover. According to model simulations, the Arctic Ocean may become seasonally ice-free as early as 2040-2050. Despite the extreme societal and environmental relevance, our understanding of processes determining sea-ice cover and variability is associated with significant uncertainties. The insufficient knowledge about late-Holocene marine environments and natural sea-ice states around Greenland makes it essential to develop high-resolution reconstructions extending back in time beyond the instrumental and satellite era. For this purpose, a sediment core sampled on the North East Greenland shelf (79°06'N, 11°90'W) was analyzed in order to establish multidecadal to millennial-scale time series of general oceanic conditions and sea-ice variability during the Holocene, with primary focus on the last few millennia. Water temperature, salinity and bioproductivity reconstructions were based on a combination of foraminiferal assemblage and Mg/Ca analyses. The sea-ice record was established using IP<sub>25</sub> and IRD analyses.

**O-2190**

## **Assembling a jigsaw puzzle: An introduction to the International Quaternary Map of Europe project (IQUAME2500)**

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### **Abstract**

The project of the International Quaternary Map of Europe project (IQUAME 2500) is a major international initiative coordinated by BGR under the auspices of the CGMW (Commission of the Geological Map of the World, Sub-Commission Europe) and with support of INQUA. It started in 2011 at the INQUA congress in Bern. Using the first edition of the map (BGR and UNESCO, 1967 – 1995) as a base, the project aims to show the distribution of Quaternary deposits at the land surface and general marine deposits across the entire European continent. The map is planned as geographical information system (GIS) with accessibility on the internet and is going to include the Quaternary on- and off-shore information on:

- age and lithology of Quaternary units,
- extent of permafrost,
- last extent of ice sheets (Weichselian, Saalian, if possible Elsterian)
- directions of ice movement,
- genetic descriptions of the units,
- faults, active faults
- off-shore Quaternary information (in cooperation with the EU EMODnet Geology project).
- key localities (e.g. geologically and anthropologically interesting sites)

For a multinational and cross-boundary project like this, international collaboration is the key to success. Partner institutions from more than 30 countries including geological survey organisations from Russia in the East, Portugal in the West, Norway in the North and Cyprus in the South are participating; a scientific board of Quaternary researchers ensures the high scientific quality of resulting map. This project requires also that data originally set up in a plethora of regional and national classifications need to be adapted, integrated and harmonized in respect to semantics, structure and geometry. To achieve this aim common rules needed to be set up and applied by all participants: structured vocabularies to describe the above contents, cartographic guidelines to suite the scale and last but not least generally applicable tools to aid the partners to submit their data to the project.



Ultimately, the aim is to create a harmonized, comprehensive, spatial, pan-European geological database where relevant properties of the Quaternary layers can be retrieved, combined, selected and cross-referenced across political boundaries and to provide a summary of the current status of European Quaternary geological research.

The presentation will show the current status of the map compilation and demonstrate aspects of the project's challenges while assembling the jigsaw puzzle of the International Quaternary Map of Europe.

**O-2191**

## **The Quaternary Map of Europe and the alpine Glaciations**

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### **Abstract**

The main question when producing geological maps is simple: at what stage of the process is a map finished? This inspiring dilemma is illustrated by the early history of the Quaternary Map of Europe as it has been planned during the "classical period" of INQUA with the administrative form of a commission. After a decade-long quiet phase and as the result of some diplomatic steps, fortunately, the BGR has resumed the process and IQUAME has been formally installed by INQUA. The Quaternary Map of Europe will soon be finished.

In 2009 swisstopo has published a map at 1:500'000 on "Switzerland during the Last Glacial Maximum". This map in itself has a history too and will be evaluated 10 years after publication. Field mapping has continued and especially numerical modelling of the LGM ice build-up in the Alps has opened relevant questions: in the central inner-alpine areas of both major ice lobes (Rhein to the east and Wallis/Rhone to the west) some ice volume is "missing" in order to produce the ice extension as it is given on the map. New paleoglacial and glacial morphological observations are contributing to the final map - in this case 10 years after the first publication

O-2192

## The development of an All-Ireland Quaternary map

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### Abstract

The Geological Survey Ireland (GSI) and Geological Survey Northern Ireland (GSNI) collaborative project to develop an All-Ireland Quaternary map at the scale of 1: 500,000 involved the reconciliation of Quaternary geology classification schemes and concomitant rationalization of terminology across two jurisdictions with a common political boundary. The project exploited available Quaternary mapping products of both geological surveys and soil geochemical and airborne Gamma-ray detection data collected by the Tellus and Tellus Border surveys.

The GSI 1: 50,000 classification scheme consist of eighty-three sediment types. These categories were generalised for the 1:500,000 scale map into sixteen broader categories: peat, lacustrine sediments, alluvium, windblown sands, marine and estuarine sediments, slope deposits, glaciofluvial sand and gravels, glaciomarine sediments and tills. Twenty-seven till types categorised in the 1:50,000 scale map according to their dominant petrologic component and their age were generalized into eight classes indicating the dominant clast lithology. Thirteen man made ground categories (e.g. Urban, Industrial, Spoil heap) were manually reclassified into the above categories based on neighbouring categories and geomorphological expression.

The GSNI 1: 250,000 Superficial classification scheme consists of twelve categories. Of these twelve categories, four were generalised: glacial sands and gravels and glaciolacustrine deposits were combined to glaciofluvial/glaciolacustrine sands and gravels, and diatomite was combined with lacustrine sediments. The till category, composed of undifferentiated glacial till, was subdivided into the eight classes listed above.

To achieve this subdivision a number of steps were taken. Firstly, the geochemical properties of different GSI till types were classified by compositional data analysis of soil geochemistry data. Secondly, this classification scheme was applied to NI Tellus soil geochemistry to determine till lithology types in NI. Finally, remaining till types that are not represented in RoI (e.g. basaltic till) were reclassified using principal component analysis of the Tellus Border soil geochemistry data.

The project used a combination of Python and Matlab scripting to implement both the topological generalisation and subdivision of Northern Irish (NI) till domains. Furthermore, lookup tables to enable two-way translation between Geological Survey Ireland (GSI) iQuaD database and GSNI NIDigMap database attributes.



The All-Ireland Quaternary Map is an important scientific and educational product for both geological surveys and, in a modified form, is part the data contribution to the 1:2.5 Million International Quaternary Map of Europe project.

**O-2193**

## **A new, comprehensive geological map of the Kingdom of the Netherlands**

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### **Abstract**

In 2018, TNO-Geological Survey of the Netherlands created a new geological map of the Kingdom of the Netherlands at the centennial anniversary of systematic geological mapping by the Survey. This first nationwide map since 1975, presented to an international audience at the end of the year, includes not only the onshore and offshore European Netherlands, but also the Caribbean part of the Kingdom.

The new map, at scales of 1:600,000 (European part) and 1:400,000/300,000 (Caribbean part) summarises our present knowledge of the subsurface. It illustrates the geological history of the Kingdom to professionals and the general public alike. From an applied perspective, it highlights the potential of geological resources and the presence of geohazards. Onshore and offshore sand and gravel are mined for construction and infrastructural works and for coastal maintenance, and dense Pleistocene sand forms a solid foundation for buildings. Two of the Caribbean islands are dominated by active volcanoes, all of the islands run the risk of earthquakes and tsunamis, and tropical hurricanes frequently lead to coastal erosion, flooding and landslides.

By applying a profile-type legend, describing unit sequences rather than just the top unit, we are able to show 3D information on a 2D map. It gives maximum insight into the geological history of the country and clearly demonstrates the occurrence of similar deposits on both sides of the current coastline. Our biggest challenge was the construction of a harmonised legend respecting the diversity of the onshore and offshore geology, yet simple enough to be understandable to the intended user. The number of map units was kept to a minimum; much of the active open-marine sand, for example, was included as a potential cover of various profile types defined for the onshore realm.

The map forms the Dutch contribution to international projects like the International Quaternary Map of Europe (IQuaME 2500) and the European Marine Observation and Data network (EMODnet). It is also the starting point of renewed and intensified mapping of the Caribbean islands Aruba, Bonaire, Curaçao, Saba, Statia, and St. Martin (Dutch part). Finally, it helps the Survey to market state-of-the-art subsurface models that are much more suitable for resource and risk analysis but more difficult to understand.



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O-2195

## Quaternary geological mapping in Spain and contribution to the update of the International Quaternary Map of Europe

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### Abstract

Accelerated erosion is an essential attribute of geological environments in the Mediterranean area, which distinguishes them from those of northern Europe. In addition, young mountain ranges (Alpine orogeny) are also common features in countries like Spain (average elevation 660 m). Therefore, Quaternary deposits are scarce, soils are thin (Leptosols, Regosols) and the bedrock frequently outcrops. Larger Spanish Quaternary formations are associated with local specific geological conditions, among which the following can be highlighted:

- Alluvial deposits of the main rivers (terraces and floodplains) over soft-rocks of the Cenozoic basins (e.g. Duero river).
- Estuarine and coastal sediments of the Gulf of Cádiz.
- Neogene - Quaternary sedimentary basins linked to the fault-systems of the Betic mountains (figure 1)
- Shore sediments, delta-fans and deltas in the Gulf of Valencia.
- Aeolian sediments in the central plateau.
- Volcanic rocks of Canary Islands.

Other Quaternary materials, such as mountain glacial deposits, continental volcanic rocks or materials related to karstic processes are usually very small in size, but of great scientific interest (e.g. Atapuerca).

Geological mapping in Spain start in 1849, with the creation of the "Commission for the Geological Map of Madrid and General of the Kingdom", later "Geological and Mining Institute of Spain (IGME)". The first maps were made with the same standards used at that time in Europe (mid nineteenth century), portraying the bedrock and the key Quaternary deposits in a single map. Due to the characteristics of the territory, the preparation of detailed thematic maps of Quaternary materials in a systematic way for the whole country, as is usual in Northern and Eastern Europe, would be as useless as expensive. Other thematic maps, such as geomorphological maps showing slope-slides and other erosion processes (in addition to key Quaternary deposits), are more helpful in Spain and are made regularly.

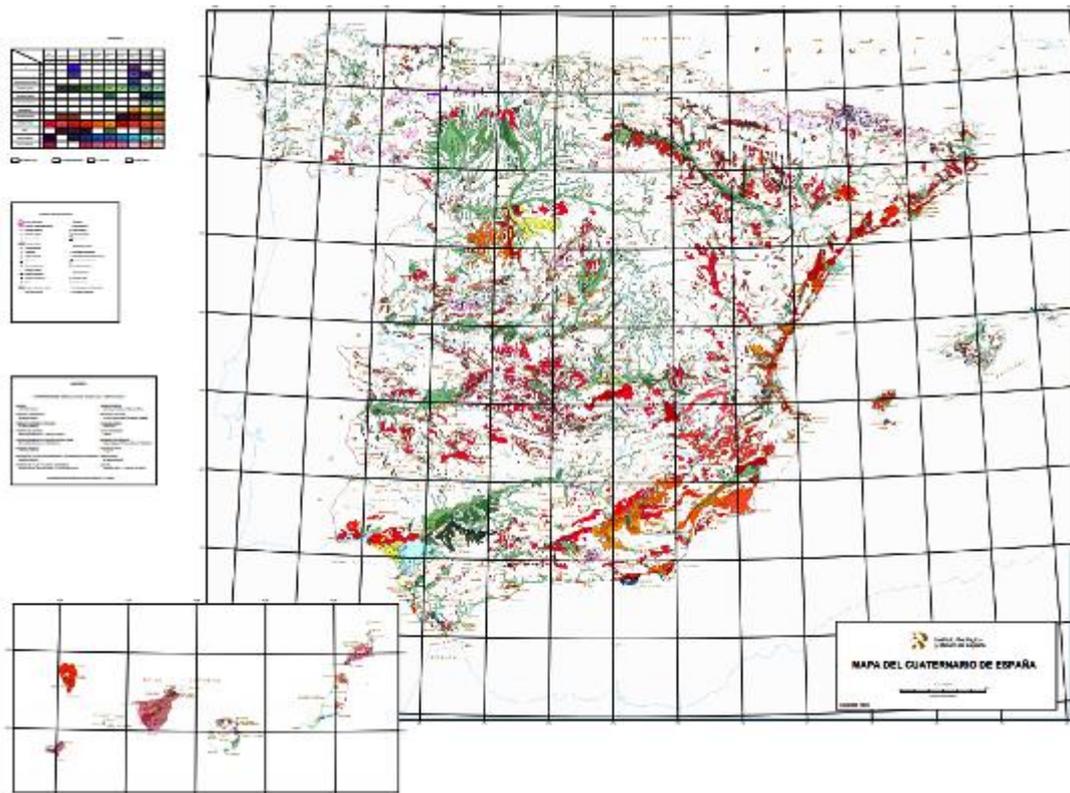
Geological maps of the Quaternary are only made in Spain to meet special needs, such as cooperation on European maps. The IGME published in 1989 a "Map of the Quaternary of Spain" at scale 1:1,000,000, with a vector version in 2010, but with no update (Figure 2). This map is outdated because at that time (1989), only half of the basic geological maps (scale 1:50,000, MAGNA project) of the country had been finished.

A new digital version of the Quaternary Map of Spain is being finalized (scale 1: 1,000,000, resolution 500 m), with reference systems ETRS89 (Iberian Peninsula and Balearic Islands) and REGCAN95 (Canary Islands). The data model

for the new map is in accordance with the specifications and vocabularies of the INSPIRE directive and meets the requirements established for the IQUAME-2500 project.



Figure 1. Pleistocene alluvial sediments of the tectonic basin of Guadix-Baza (Granada).



of Spain scale 1:1,000,000 (1989 version)

Figure 2. Quaternary Map

O-2196

## **Compilation of the Quaternary Deposits Map under the international project “Atlas of 1:5 M Geological Maps of the Circumpolar Arctic”**

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### **Abstract**

Large international project Atlas of 1:2.5 M Geological Maps of the Circumpolar Arctic, which has been conducted since 2003 by Geological Surveys of Russia, Norway, Denmark, Canada, Germany, Sweden, and the United States with the participation of experts from national universities and academies with the active support of the Commission on the Geological Map of the World at UNESCO was devoted to the geological and tectonic structure of the Arctic. In 2009, the Geological Map of the Arctic coordinated by the Geological Survey of Canada was compiled as part of the project, and in 2012, the maps of the magnetic and gravity fields, supervised by the Geological Survey of Norway, were finalized. In 2017, the new Tectonic Map of the Arctic coordinated by the Russian Geological Research Institute was created.

It is planned to compile the Quaternary Deposits Map of the Circumpolar Arctic as part of this project. In the course of preparations, we had discussions with representatives of the Geological Surveys of Norway, Canada, Germany and the United States and we are ready to be a coordinator of this work.

We compiled the 1:2.5 M Quaternary Deposits Map of Russia, which covers the land, inshore and adjacent offshore water areas. This is the first general map of Quaternary formations of our country based on the Neopleistocene Scale, correlated with the stages of the global oxygen-isotope scale, and built in compliance with the stratigraphic-genetic principle. In the map legend consisting of two blocks: genetic and stratigraphic, genetic types and their parageneses are distinguished as main mapped genetic taxa. When compiling the map, space and airborne photographic materials were used to clarify the position of the most recent faults, genetic diagnostics of sediments, particularly closed or poorly studied areas, through the documentation of specific landforms typical of them related to permafrost, aeolian, glacial and gravity processes.

Compilation of the Quaternary Deposits Map of the Circumpolar Arctic is necessary to identify the latest tectonic movements as part of constructing the up-to-date plate tectonic model of the Arctic.

O-2197

## The role of climate in peat initiation since the Last Glacial Maximum

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### Abstract

Since the Last Glacial Maximum peatlands have spread across nearly 3% of the Earth's land surface, and have sequestered between a sixth and a third of all global soil carbon. Postglacial peat initiation therefore represents the activation of a globally-important carbon sink, but the drivers of peat initiation remain unclear. A variety of mechanisms have previously been proposed to explain the spatiotemporal dynamics of peatland initiation in such diverse biogeographical locations, but until now the role of climate has been relatively understudied. We used palaeoclimate simulations from a state-of-the-art Earth system model to estimate local changes in climate during the initiation of 1,097 peatlands around the world. First peat initiation in deglaciated landscapes in both hemispheres was driven primarily by warming growing seasons, likely through enhanced plant productivity, rather than by any increase in effective precipitation. In Western Siberia, which remained ice-free throughout the last glacial period, the initiation of the world's largest peatland complex was globally-unique in that it was triggered by an increase in effective precipitation that inhibited soil respiration and allowed wetland plant communities to replace pre-existing forest and tundra. Peat initiation in the tropics was no more than weakly related to climate change, and seems likely to have been driven mainly by non-climatic mechanisms such as waterlogging due to tectonic subsidence. Our findings shed light on the genesis and Holocene climate-space of one of the world's most carbon-dense ecosystem types, with implications for understanding trajectories of ecological change under changing future climates.

O-2198

## 11,000 years of atmospheric dust deposition in NW Spain recorded by Tremoal do Pedrido bog

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### Abstract

Atmospheric dust (AD) plays an important role in terrestrial and marine ecosystems, particularly in those which are nutrient-limited. Despite most AD being emitted from arid and semiarid regions, recent research has shown that past dust events may have also been involved in boosting productivity in boreal peatlands.

We investigated dust deposition in a small, raised bog located in mid latitude, oceanic area (Xistral Mountains, NW Spain). The geology surrounding the bog is quite complex, including paragneis/schist (where the bog is located), granite, quartzite and granodiorite. Peat properties (ash content, bulk density, total C and N, and colour) were used to assess the nature and stratigraphy of the bog. As proxies for dust fluxes we used accumulation rates (AR) of lithogenic (Ti, Zr, Rb, Sr, Y) as well as two major (K and Ca) elements. Principal components analysis of the AR records enabled to identify four main geochemical signals. The first one reflects total AD deposition; the second is essentially related to the Sr, and partially to Ca and K fluxes; the third accounts for the superficial enrichment of biophilic elements (K, Ca and Rb); and the fourth reflects secondary controls on Y fluxes.

Change point modelling suggests that the largest AD deposition occurred between ~8.6 and ~7.4 ka, with a maximum at ~8.1 ka (most probably during the 8.2 ka climate event). This event had a large impact in the evolution of the mire since from ~8.1 ka to ~6.7 ka it transitioned from a fen into a raised bog. In the early Holocene, by ~9.9-9.7 and ~9.2-8.8 ka, AD deposition may have also been elevated but the lower time resolution of this section of the core increases uncertainty of the results. From ~6.7 to ~4.0 ka AD fluxes were very low. After ~4.0 ka relatively major AD deposition events occurred at ~3.2-2.5, ~1.4 ka and ~0.35-0.05 ka, and minor events at c ~4.0-3.7, ~1.7, ~1.10-0.95 ka and ~0.74-0.58 ka. While sharing part of this chronology, most particularly from ~11 to ~6.7 ka, Sr fluxes were decoupled from those of the other lithogenic elements since the mid Holocene. Two large deposition events occurred during ~6.7-5.1 ka and from ~1.1 ka to present. This seems to be a specific source signal as the granodiorite batholith, located nearby the mire, has a Sr anomaly.

The reconstructed variations in mineral fluxes were more likely driven by climatic events (in particular the 8.2 ka, 4.2 and 2.8 events), including increases in storminess, and human activities. This finding agrees with a previous study of a shorter core from the same peatland. Both geochemical and pollen research in the area suggests that human impacts on forests were accompanied by enhanced dust emissions from soils.

O-2199

## Peatland carbon balance controls and fire frequency in the western Hudson Bay Lowlands, Ontario, Canada

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### Abstract

The Hudson Bay Lowlands (HBL) is a vast continuous peatland region surrounding the Hudson and James bays of eastern Canada and is therefore an important region for understanding the role of peatlands in the global carbon cycle. Peatland initiation and long-term carbon accumulation are influenced by Holocene climate, succession, hydrology, and isostatic uplift in the region. This study presents multi-proxy paleoecological records of long-term environmental change to understand spatial and temporal variation of these influencing factors due to local to regional-scale landscape variation. Further, we provide a Holocene paleo-fire record to increase our capacity for predicting long-term impacts of changing fire regimes on carbon balance. This paper addresses how local vegetation, hydrology, and disturbance have impacted Holocene carbon balance by analysis of peat cores from three sites on the western margin of the HBL. A bog and a fen site with basal ages of >7500 cal yr BP were selected to investigate local changes in vegetation and hydrology. Through comparisons between these and regional paleoclimate records, we aim to isolate the role of Holocene climatic change. At the bog site, a transition from N-rich (1.1-2.5%) to moss-dominated and N-poor (0.3-0.7%) peat occurs early in the record, around 7400 cal yr BP. A transition to ligneous peat and increased nitrogen content (0.6-1.5%) occurs around 5800 cal yr BP; these changes reflect successional trajectories coupled with hydro-climatic drivers. At the fen site, in contrast, C and N values remain relatively consistent through the record, underscoring the role of peatland type in estimating paleo- and future C balance. Plant macrofossil and testate amoeba records are used to further constrain peatland types through the Holocene. By assigning average methane and carbon dioxide fluxes derived from contemporary data from the region to each peatland type, we estimate carbon fluxes through the Holocene. The potential role of fire on carbon accumulation in the HBL is investigated at a recently burned site by analyzing charcoal within three cores along a transect of burned to unburned area. Carbon accumulation rates are compared to the charcoal records to determine to what extent fire has decreased carbon accumulation rates for the HBL, as shown for western boreal regions of North America. Overall, using paleoecological approaches at multiple sites within the same region will allow for an improved understanding of the role of local-scale processes in the long-term carbon balance of HBL peatlands. Furthermore, by providing more robust multi-proxy paleoecological datasets in underrepresented areas of the HBL region, this work will contribute to future regional synthesis for Holocene climatic change.

O-2200

## Holocene blanket peatland development in eastern Scotland

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### Abstract

To study long-term peatland dynamics, several models have been developed in recent decades. Most modelling efforts have focussed on peat bogs, but for other peatland types, such as blanket peatlands, modelling studies are limited. Although blanket peatland is a relatively rare ecosystem type on the global scale, 87 percent of the peatlands in the UK is of this type. Hillslope topography is fundamental to blanket peatland development and an improved representation and understanding of the relationships between climate, topography, hydrology and peat growth is crucial to better understand the effects of environmental change on blanket peatland evolution and the carbon balance.

Here, a new spatially explicit peat growth model is presented for blanket peatlands, which couples a detailed hillslope hydrology model with a peat accumulation and decomposition module. The resultant model allows to study the hillslope hydrology and blanket peatland development along topographically complex hillslopes over a Holocene timescale. Calibration and validation of the model parameters is based on a dataset of more than 900 peat thickness measurements along 56 hillslope transects in the headwaters of the river Dee (Cairngorms National Park, north-eastern Scotland).

For the 56 hillslope transects, the Holocene peatland development was modelled using pollen-based land cover and climate reconstructions, resulting in a current mean peat thickness of 0.4 metre or 20 kg per square metre of organic carbon for the studied area. The model results further show that the hillslope topography has a strong influence on the resultant peat development, stressing the need for spatial models in studying blanket peatlands. The simulated peat growth initiation dates are situated mostly in the period 9000 – 6000 a BP, which corresponds largely to periods with increasing temperature. Parameter sensitivity tests further indicate that an increase in tree cover results in higher peat accumulation rates because the positive effect of the increased biomass production exceeds the negative effect of higher evapotranspiration rates. The model simulations show that the blanket peatlands developed during the early Holocene before the decline in woodland cover and under low human impact. This points towards a natural peatland formation driven by climate and topography rather than by (anthropogenic) land cover changes. Overall, the model allows to study the effect of changes in environmental factors such as land cover, temperature and precipitation on the resultant peatland dynamics, providing a new tool to study blanket peatland evolution on long time scales.

O-2201

## Bering Sea peat cellulose oxygen isotopes show late-Holocene hydroclimate is influenced by Arctic sea-ice extent

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### Abstract

Bering Sea climate is strongly influenced by the Aleutian Low (AL) and sea-ice extent, which can influence atmospheric and ocean circulation in the region. Holocene records of northern Bering Sea paleoclimate remain sparse, largely because of low sediment accumulation on the Bering shelf. Here we present a 5.5 kyr record of stable oxygen isotopes from analyses of peat cellulose ( $d^{18}O_c$ ) from St. Matthew Island, Alaska. St. Matthew Island (60.4°N, 172.7°W) is a small (357 km<sup>2</sup>) island in the central Bering Sea. It lies within the median winter sea ice extent but can be surrounded by open water during some winters. The  $d^{18}O_c$  primarily reflects the source water at the time of plant cellulose synthesis and therefore should record changes in ocean-atmosphere circulation. Results from St. Matthew Island show a strong anti-correlation to Greenland ice core  $d^{18}O$ , a temperature proxy, over the last 5.5 kyr and to changes in inferred Arctic and North Pacific influence. From 5.5-3.2 ka, the St. Matthew Island record shows millennial-scale cyclicity, with an amplitude of ~5‰ and anticorrelation to Greenland  $d^{18}O$ . A positive  $d^{18}O_c$  shift of ~5‰ occurs at 3.2 ka, with lower amplitude (18O record). The directionality of the shift suggests wind and moisture were dominated by a southern (North Pacific) influence. A ~10‰ decrease from 1.8 to 1.0 ka coincides with the Medieval Climate Anomaly and a strengthened relationship with Greenland  $d^{18}O$  record that continues until 0.15 ka, suggesting a strengthened connection with North Atlantic climate and a predominant wind and moisture source from the north (Arctic). Overall, the patterns are consistent with modern isotope anomalies that show higher  $d^{18}O_c$  when the dominant wind direction is from the N. Pacific, while lower  $d^{18}O_c$  values correspond to dominant wind direction from the north, consistent with more zonal flow (weak AL) or Arctic influence, a pattern that could be related to sea-ice extent. After ~0.15 ka, St. Matthew Island  $d^{18}O_c$  becomes progressively higher, despite rapid warming in Greenland, a pattern not observed over the last 5.5ky. The relationship of the St. Matthew Island record to the Greenland  $d^{18}O$  record and Arctic Ocean seasonal sea-ice extent suggests Arctic climate responded to similar forcing mechanisms during the Holocene. Furthermore, the results suggest that the St. Matthew Island hydroclimate is strongly related to sea-ice extent.

O-2202

## Widespread drying of European peatlands in the last 300 years

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### Abstract

There is much concern that climate warming and human impacts are causing peatlands to become drier, potentially converting them from sinks to sources of carbon through enhanced aerobic decomposition. However, the current hydrological condition of peatlands, and how this contrasts with their natural baselines, remain unclear. We use testate amoeba-based hydrological reconstructions to illustrate that many European peatlands have undergone a marked shift to drier conditions at some point over the last ~300 years. We identify key shifts to dryness in the records through statistical change-point analysis: Britain and Ireland (CE 1914); Scandinavia (CE 1777 and 1990); and Continental Europe (CE 1756). When data from all regions are combined a change-point at CE 1751 is identified across Europe. We found that 60% of sites are drier now than they have been for the last 500 years and 40% of sites are drier than they have been for >1000 years. This widespread drying of European peatlands was driven by the compound pressures of climate warming, decreasing precipitation and human impacts on the sites (cutting, drainage, burning and changes in land-use). Our results suggest that many European peatlands are in a highly vulnerable condition and highlight the need for effective management and restoration in the context of current and future climatic change.

O-2203

## Geochemical and isotopic records of anthropogenic pollutants and dust input over southeastern Europe during the Holocene

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### Abstract

Reconstructions of variability in dust flux provide valuable insights into past atmospheric circulation and moisture availability. By investigating several peat archives we provide a detailed record of variability in dust deposition over the Holocene in southeastern Europe. Using qualitative ITRAX core scanning and quantitative inductively coupled spectrometry (ICP-OES; ICP-MS) measurements of lithogenic (K, Si, Ti, Sc, Zr) elements, we identify 10 periods of major dust deposition between 9500–9200, 8400–8100, 7720–7250, 6350–5950, 5450–5050, 4130–3770, 3450–2850, 2000–1450, 800–620, and 60 cal yr BP to present. Our data highlight several discrepancies between eastern and western European dust depositional records including highly complex hydrological regimes over southeastern Europe, as since 6100 cal yr BP, the geochemical indicators of dust flux have appear uncoupled from the local hydrological variability. This shift coincides with the onset of centennial-scale cycles in dust input variability and a change in geochemical composition of dust traceable in different peat records. We show that this is indicative of a shift in dust provenance from local–regional to distal Saharan sources.

Furthermore, exploitation of natural mineral resources during last millennia had a tremendous impact on humanity, leading up to our highly industrialized world. The indirect history of past metal resource exploitation in Europe is based on a limited number of geochemical records from central-western and northern Europe. This is despite archaeological data showing that southeastern Europe experienced a long history of social, economic, and cultural traits revolving around ore processing and long-distance metal trading. Using stable lead isotopes (<sup>204</sup>Pb, <sup>206</sup>Pb, <sup>207</sup>Pb, <sup>208</sup>Pb) coupled with the stratigraphy of selected elements (ie., Pb, Sb, Cu, Sn) associated with smelting we provide the first long-term reconstruction of past metallurgical activity in southeastern Europe. Our results present a new view on the human impact through resource exploitation, and the results, in conjunction with existing geological, archaeological, and archaeometric evidence, allow for a comprehensive assessment on the history of metal-use development over southeastern Europe. This is then compared with variability induced by natural sources such as dust input. Through a comparison with records from other parts of Europe we document the existence of strong regional differences in the magnitude, temporal, as well as spatial shifts in our understanding of past emission sources.

O-2204

## Long-term trends in algal diversity, stability and community biomass over sub-orbital timescales

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### Abstract

Biological diversity is inextricably linked to community stability and ecosystem functioning, with rapid climate change posing serious threats to both. Our understanding of these relationships in freshwater ecosystems are largely based on short-term observational, experimental, and modelling approaches. Yet because extrinsic and intrinsic forcings linked to climate change often take place over much longer timescales, palaeoecological approaches become essential to determine the ecological dynamics of environmental change which unfold only over longer timescales.

Using a multidecadal (30-yr resolution) diatom record from the world's oldest and deepest lake, Lake Baikal (Russia), we show that on sub-orbital timescales over the past 16,000 years community stability, richness and diversity are impacted by abrupt climate change in a major way. During the Younger Dryas, for example, abrupt changes in diatom richness and diversity are part of a network of responses across southern Siberia as a result of extrinsic forcing, linked to variability in Atlantic meridional overturning circulation. More gradual changes, such as the increasing dominance of autumnal communities during the Holocene may be a response to intrinsic forcing, linked to a gradually cooling climate driven by declining summer insolation. Community biomass (as an indicator of palaeoproductivity) exhibits a weak positive relationship with N2 diversity over the Holocene period, that strengthens considerably when only Spring biomass is considered. Over the whole 16,000 year record however, the relationships become unimodal, similar to those hypothesised from modelling and experimental studies. In contrast, we show that community biomass – diversity relationships are much weaker during the Last Interglacial, highlighting context dependency between measures of productivity and biodiversity especially during time windows with markedly different boundary conditions.

O-2205

## Did fire influence the expansion of *Araucaria* in southern Brazil?

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### Abstract

Woodland - grassland boundaries are generally mediated by fire and understanding the dynamics of such limits requires a long time perspective at high resolution. In the mosaic between *Araucaria* forest and grassland (Campos) in southern Brazil, the forest cover increased during the Holocene, often in a stepwise manner. While the general increase in forest may be due to a raise in summer precipitation the dynamics of it may have been controlled by fire. To investigate this Late-Holocene spread of *Araucaria* forest, we choose to study the small lake "Lagoa Dourada" (815 m asl) in Vila Velha State Park (Paraná State, southern Brazil). The lake is located near an *Araucaria* forest covering a low hill and adjacent remnants of natural grasslands. We obtained a 14,5 m sediment core, of which the upper 9 m cover the last 7 ka allowing high resolution analysis. Results show the dominance of Campos for the last 16 ka, with a stepwise expansion of *Araucaria* around 5.5 ka and 3 ka. We will present a high resolution fire history and explore to which extent fire may have played a role in the expansion of the *Araucaria* forest.

O-2206

## Holocene fire dynamics mitigate the negative effect of catchment acidification on mountain submerged macrophytes (*Isoëtes*) in Central Europe

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### Abstract

Modern populations of submerged macrophytes, *Isoëtes*, are classified as a critically endangered species after undergoing large declines in Central Europe. Recent studies have attributed *Isoëtes* decline to modern human impact, namely eutrophication, acidification or alkalization induced by land-use changes. However, anthropogenically driven environmental changes may not be an exclusive cause of *Isoëtes* decline. Paleoecological reconstructions illustrate a wide distribution of *Isoëtes* populations in the past, especially during the Early and Middle Holocene when human impact was less intense. Here, we aim to investigate how local environmental factors may have impacted the distribution and abundance of *Isoëtes* populations during the Holocene. To complete our research aim, we used a multi-proxy approach utilizing plant macrofossils, macrocharcoals, pollen, diatoms and chironomids from four lakes (Prášílské jezero, Plešné jezero, Černé jezero, Rachelsee) located within the Bohemian/Bavarian Forest mountain range in Central Europe. Our results show regional, synchronous patterns, with *Isoëtes* colonization beginning between 10 300 – 9 300 cal yr BP, and substantially declining around 6 500 cal yr BP. Results from Prášílské jezero imply that *Isoëtes* dynamic was mainly driven by processes connected with a change in vegetation structure and composition and fire regime around 6500 cal yr BP. Specifically, *Fagus* expansion and peatland extension coincide with decreasing fire activity, which changed soil chemistry in the lake catchment, and through surface water runoff, altered both the physical and chemical properties of lake water. This is reflected by a shift in diatom assemblages towards more acidophilous species and a distinctive drop in chironomid abundance. These environmental changes likely lead to an attenuation in the light availability, which subsequently resulted in the decline in *Isoëtes* abundance. Our study demonstrates the importance of vegetation development and fire dynamics in determining the abundance and distribution of critically endangered *Isoëtes* populations. These results have major implications for management and highlight the importance of long-term records in policy making.

O-2207

## Abrupt late Holocene ecosystem change in Central European mountain forests

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### Abstract

The projected climate warming and intense anthropogenic influence cause increasing pressure on the temperate mountain spruce forest ecosystems in High Tatra Mountains in Slovakia. Investigating the past changes in these forest ecosystems and the processes behind them can provide valuable information for understanding the present and future ecosystems dynamics. To investigate the late Holocene stand-scale forest dynamics in the region, we sampled transect of four small forest hollows ranging from lower elevation sites Diera Hollow at 982 m.a.s.l. (circa 1500 cal. yr BP) and Lomnica Hollow at 974 m.a.s.l. (circa 1100 cal. yr BP) to Smokovec Hollow at 1067 m.a.s.l. (circa 4700 cal. yr BP) and to Velicka Hollow at treeline at 1354 m.a.s.l. (circa 3200 cal. yr BP). Temporal resolution of the analysed peat cores ranging between 10 to 40 years provides valuable opportunity to detect the ecosystem response to disturbances and changing environmental conditions.

We used pollen analysis to reconstruct the changes in forest composition during the study period. To investigate the role of natural drivers and anthropogenic influence in the ecosystem change, we assess the role of climate, forest fires and human impact as the potential drivers on the past forest dynamics. The climate variable will be constructed from climate model data for the last 4000 years and for the past 1000 years we will use climate reconstruction from the tree-ring records from the region. Fire history is analysed using macroscopic charcoal counts and charcoal area measurements. We will apply CharAnalysis software for statistical detection of significant peaks in charcoal records indicating fire events. As variable for the human influence on ecosystem dynamics, we will use human indicator pollen taxa to indicate human activity in the area.

Preliminary results demonstrate opening of the landscape circa 800-500 cal yr BP. Presence of the human indicator pollen taxa, such as *Cerealia*-type pollen, suggest landscape opening in connection to anthropogenic activity in the region. In addition, the charcoal records demonstrate change in the fire regime coinciding with the opening of landscape and it is plausible that change in the fire regime is connected to the human activity in the area. However, it is important to note that the ecosystem change occurs first in uppermost site at the treeline at 800 cal yr BP and 200-300 years later in lowermost sites. Furthermore, macroscopic charcoal records show rather simultaneous peak around 700-600 cal yr BP in all four sites suggesting fires across the study region. These results will be discussed further in the presentation in the light of climate data and further data analysis.

O-2208

## At sub-centennial temporal resolution, Icelandic palynological records show environmental responses to the Black Death.

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### Abstract

Having supposedly escaped the first Black Death outbreak in Europe in the mid-14<sup>th</sup> century, the plague reached Iceland in AD 1402. Both the nature of the plague and mortality rates are debated. Estimates of the latter range between 25% and 60%. Some scholars argue for long-lasting societal impacts, such as permanent farm abandonment and population decline, and change in land-use strategies. The environmental sciences have mostly ignored this historical feature with only three published records discussing the plague in Iceland in any detail (Jónsson et al. 2012, Streeter et al. 2012, Riddell et al. 2018).

This paper uses palynology at a sub-centennial temporal resolution to examine environmental responses to a reduction in population and a consequent release of pressure from land-use. The examination covers four land holdings, two in Western Iceland (Örnólfsdalur and Norðtungusel) and two in North Iceland (Þingeyrar and Skógar). All the sites classify as “off-sites”, i.e. samples have been accrued from the pastures associated with each farm, whereas much of the available pollen data are from the immediate vicinity of farms. The pollen records are furnished with precise tephra-constrained chronologies, supplemented with <sup>14</sup>C age estimates from macrofossils.

All the sites exhibit a period of land-use over several centuries prior to the 15<sup>th</sup> century. Woodland and shrub contraction is indicated by decline in *Betula* (birch) and *Salix* (willow). Increasingly open landscapes are shown by e.g. increases in the pollen of Poaceae (grasses), Cyperaceae (sedges) and *Thalictrum alpinum* (alpine meadow-rue). This being the result of land-use rather than climate is indicated by the parallel loss of grazing sensitive taxa such as *Angelica* spp. (angelicas), as well as increases in microscopic charcoal and spores from coprophilous fungi. All four sites show a change in and around the 15<sup>th</sup> century AD. Although the degree to which the change is reflected varies, the signals indicate reduced land-use pressure. All sites show recovery of *Betula* woodland or shrub. Further signals are different between sites, but include raised organic content values, increased values for *Salix* and other grazing sensitive taxa, and reduced numbers of Poaceae, coprophilous fungal spores and microscopic charcoal. We conclude that the decline in human population associated with the plague and consequent reduction in livestock (grazing) and wood harvesting was of sufficient magnitude to leave its mark firmly in the Icelandic environmental archive.

O-2209

## Palynological ice record reveals industrial footprint in European vegetation

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### Abstract

Intensive land use, globalization, and rapid climate change are threatening ecosystems across Europe. Paleoecological studies from natural archives provide valuable information on long-term environmental dynamics and thus contribute to future ecosystem conservation (Lamentowicz et al. 2015). Natural archives are hardly ever used to investigate the long-term impact of industrialization and globalization on continental-scale vegetation. Here we present a unique palynological record from the high-alpine glacier Colle Gnifetti (4452 m asl) in the Swiss Alps, spanning the past millennium with exceptional temporal resolution and precision (Jenk et al. 2009; Sigl et al. 2018). Our ice archive is located at the interface between Western, Central, and Southern Europe, and therefore integrates fire, land use, and pollution dynamics across major important biomes of Europe. We analyze pollen and spores as proxies for vegetation composition and agricultural activity, microscopic charcoal as a proxy for fire activity, and spheroidal carbonaceous particles (SCPs) as a proxy for fossil fuel combustion which preserve in ice cores over millennia (e.g. Brügger et al. 2018). We combine the ice core-derived continuous data with historical sources to provide novel insights into industrial impacts on land use, fire activity, and vegetation dynamics. Our multiproxy-ice core data suggest that in Europe, the transformation from solar to fossil fuel-based industrial land use (e.g. shift to large scale maize production and massive fire increase) started shortly after 1750 AD together with first signs of large-scale atmospheric pollution. We conclude that lowland vegetation such as temperate beech-oak forests suffered from progressive globalization of economies that intensified industrialized production on fertile soils. While these formerly forested areas are still disrupted, marginal areas such as mountain forests and alpine grasslands may benefit from a further concentration and intensification of industrial agriculture.

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O-2210

## 200 years of anthropogenic and climate-driven environmental change in northeastern China.

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### Abstract

This study compares multi-proxy palaeoenvironmental records (pollen, charcoal, particle size, loss on ignition, C:N ratios and radioisotopes, <sup>210</sup>Pb and <sup>137</sup>Cs) from three lakes in the Songnen Plains and five lakes in the Great Hinggan Mountains of northeastern China. These data provide high-resolution records of vegetation history and catchment dynamics over the past 200 years.

Records from the Songnen Plains find vegetation initially responded to a cooler and drier climate during the Little Ice Age with high values of *Pinus*, *Ephedra* and *Amaranthaceae* and low values of *Cyperaceae*. As anthropogenic activity increased in the lowlands of northeastern China, *Pinus* gradually declined while broad-leaved deciduous vegetation increased from 1900 CE. Aquatic taxa in the Songnen Plain lakes increased from 1900 CE as the wetlands responded to changing water levels and agricultural activities. Records from the Great Hinggan Mountains record little fluctuation in the composition of the dominant broad-leaved deciduous forest in the 1800s.

Population expansion and land policy implementation had a profound impact on vegetation in both the lowlands and alpine region of northeastern China. Arboreal pollen in the Songnen Plains declined from 1900 CE as marginal land was reclaimed, and agricultural activities significantly increased. Vegetation diversity increased as agricultural activities caused environmental disturbance, with pollen taxa indicating human disturbance including *Humulus*, *Polygonum* and *Xanthium*. Silt and organic content increased and C:N ratios declined after 1940 CE as erosion in the catchment and productivity in the lakes increased. In the Great Hinggan Mountains *Pinus* was selectively logged from 1900 CE and reached minimum values in the 1980s. Arboreal pollen declined from 1940 CE as timber harvesting increased, with *Betula* and *Quercus* increasing across the region from 1970 CE. Regional fire events in the mountains increased after 1970 CE, with a significant increase in microscopic charcoal occurring between 1990-2000 CE after a period of active fire suppression. Re-vegetation strategies and forestry protection in the late 1990s in northeastern China caused arboreal taxa and diversity to increase in the pollen records from the Songnen Plains and the Great Hinggan Mountains. This multi-proxy palaeoenvironmental study compares environmental change in the plains and alpine region of northeastern China and improves our understanding of natural and anthropogenic driven environmental change in the last 200 years

O-2211

## MIS 5a to MIS 4 climate transition in NE Poland—the palaeoenvironmental record

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### Abstract

In central Europe the transition from MIS 5a (early Vistulian = early Weichselian) to MIS 4 (Lower Plenivistulian) is poorly understood in terms of feedback-mechanism relationships associated with climate shift and land-surface processes. The first Vistulian Ice Sheet advance reached northern Denmark and southern Sweden during the Late Pleistocene in MIS 4. Changeover dynamics during that turn remain a source of controversy in regards to eastern Poland, as that region's geomorphic history appears to be at variance with the rest of the country due to its higher continentality during warm interstadials and its decreased continentality during cold intervals. In example of this regional divergence numerous small shallow water bodies were present in northeastern Poland after MIS 6 (Saalian), which persisted until the end of MIS 5a (early Vistulian). In addition dry valleys are common landforms here, characterized by a distinctive hierarchical fourth-order tributary system, which in configuration have uneven longitudinal sections with numerous widening and narrowing valley floor. Also, in the upper parts of first-order tributaries and at dry valley bottoms there are in-abundance small depressions that once were either filled with open water or existed as bogs that accommodated peat, being independent of interconnection or intercommunication along their way. Northeastern Poland's MIS 5a to MIS 4 transition is marked by a drastic change in water body conditions, and correspondingly there is a geomorphic adjustment to dry and river valley system structure. During MIS 5a (middle Odderade Interstadial), the mean July temperature rose from about 12°C (the older Odderade Interstadial) to >13°C, which was accompanied by the spread of pine, spruce, and larch. Afterwards, both summer and winter temperatures gradually decreased as signalled by a further transformation of vegetation cover. That change in flora indicates the emergence of a cold continental climate with a lowering of both temperature and evaporation, which was accompanied by a rising water table. Some water bodies experienced a change in sedimentation from gyttja and organic mud accumulation to that of clayey-silty deposits. Pollen succession occurrences that extend into the Schalkholz Stadial are sporadic, their presence being limited to the occasional water body. Abundant small water bodies inside dry valleys then become drained for the first and only time, with contemporaneous erosion reaching the underlying MIS 5e (Eemian Inerglacial) deposits. Some dry valleys were transformed into rivulets that then drained the previously endoheiric depressions within them. Eemian Interglacial deposits formed along present river bottoms but are today rarely preserved on river valley slopes. Aeolian processes had activated in northeastern Poland, but any associated wind transport occurred on a small scale with limited aeolian deposition mostly occurring in valleys. A research was supported by the Polish National Science Centre (No. UMO-2013/09/B/ST10/02118).

O-2212

## Northern Cordilleran Ice Sheet displays a diachronous response to MIS 4 forcing, Yukon Territory, Canada

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### Abstract

Yukon Territory has been repeatedly affected by the northern Cordilleran Ice Sheet (CIS). This complex of coalescing ice lobes sourced from separate mountain ranges, produced irregular, digitate, horseshoe-shaped glacial limits on the plateau area of Yukon. Many of these ice lobes had separate source areas and dynamics but three broad, mappable, chrono-geomorphic regions have been defined that were thought to represent regionally coherent advances of the CIS. The intermediate mapped limits were thought to represent a single glaciation, but our results show in central Yukon it is MIS 6 while in SW Yukon it consists of 4 and 6.

Central Yukon was affected by west-flowing ice from the continental divide. Previous age estimates for the penultimate glaciation were MIS 6, largely based on an interglacial soil developed on these deposits. This MIS 6 age is confirmed by the presence of Old Crow tephra (124 ka) above deglacial outwash along the Pelly River. There is no evidence for a MIS 4 glaciation that is more extensive than MIS 2. The MIS 2 limit is >100 km to the east of the MIS 6 limit. Much older glaciations extended up to 115 km to the west of the MIS 6 limit.

SW Yukon was affected by north and eastward flowing ice from the Coast and St. Elias mountains, respectively. Near where the Coast Mountains and St. Elias ice coalesced, cosmogenic <sup>10</sup>Be ages on boulders of 54-51 ka (n=4) on penultimate drift indicate this limit is MIS 4. This is the first confirmed MIS 4 glaciation in the Canadian Cordillera. Recent mapping in the area suggests that the MIS 4 advance was comparable in extent to the MIS 6 advance. This mapping also indicates that ice caps and cirques may have contributed substantially to the local extent of late Pleistocene limits and could account for the local all-time limit corresponding to MIS 4 advance.

Further west the chronology provided by tephtras from sections exposed near the all-time limit along the White River, confirms that the MIS 4 limit is nearly identical to that of the MIS 6 glaciation. Here the MIS 2 limit is 15-20 km further upstream.

Thus, there is a dichotomy between the extents of MIS 4 glaciation from different source areas for the northern portion of the CIS, indicating different glaciological responses to this climatic forcing. The northern CIS was a precipitation-limited system. We propose that variation in regional precipitation, specifically how moisture penetrates the coastal mountains, is a possible cause for the observed differences between glacial advances in different source areas. Causes for this regional variation in precipitation will be discussed.

O-2213

## Diverse records of Quaternary mammals, water isotopes and plant communities during MIS 4 across eastern Beringia

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### Abstract

The penultimate cold stage, MIS 4, is well represented across the unglaciated region of interior Yukon and Alaska or collectively eastern Beringia. At sites from the Klondike to Fairbanks, the Sheep Creek-K tephra-K (SCt-K) and Dominion Creek tephra (DCt) are present, and mark the transition from MIS 5a to MIS 4 at ca. 70-80 ka BP. These tephra also provide a means to correlate paleoenvironmental records between sites. The most abundant sites are in the Klondike region, where SCt-K/DCt are preserved in syngenetic loessal silts (or yedoma-like deposits) that have been preserved in relict permafrost since deposition. These deposits include meteoric waters in pore ice and wedge ice, soils, and plant macroremains, along with diverse and abundant Quaternary mammals dominated by horse, bison and mammoth. Paleoenvironmental analyses of fossil arctic ground squirrel middens, in direct association with SCt-K/DCt indicate a cryoxerophilous (steppe-tundra) vegetation growing on well-drained substrates with deep active layers during MIS 4, functionally similar to MIS 2. Water isotopes from pore ice and wedge ice reflect meteoric precipitation, and have values of -215 to -235‰ (d2H) and -28 to -32 ‰ (d18O), suggesting temperature depressions of more than 10 degrees C relative to modern. The broad functional similarity between MIS 4 and MIS 2, reflected in water isotopes, sedimentation, faunal communities and vegetation suggests the regular appearance of the mammoth-steppe biome in eastern Beringia through cold stages of the late Pleistocene.

O-2214

## The Last Interglaciation and unique stature of MIS 4 in central North America

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### Abstract

Continuous paleoecological records in kettle basins in Illinois, U.S.A., provide evidence of climate change during the waning of the penultimate glaciation (Illinois Episode) to the onset of the last glaciation (Wisconsin Episode). Traditionally, North American stratigraphers use the occurrence of loess and/or till as the basis for glacial episodes. At 38-42 °N, glacial episodes in the interior of North America are also marked in lake records by abundant *Picea* pollen and *Limnocythere friabilis* (ostracod) valves. Combined pollen and ostracod DCA analyses of three continuous records (Raymond, Bald Knob, and Pittsburg basins) have eigenvalues of 0.54 and 0.26 explained by temperature and relative moisture, respectively. Last Interglacial (Sangamon Episode) warm-wet periods feature abundant deciduous tree pollen and benthic ostracods, whereas Sangamon Episode warm-dry periods feature plant groups that tolerate drought and thrive on mudflats and nektonic ostracod species that crawled or swam amongst aquatic vegetation, indicating relatively shallow water. The nature of the contact between Illinois and Sangamon Episode deposits is abrupt, whereas the Sangamon-Wisconsin contact is gradual, characterized by increasing *Picea* and *L. friabilis* abundance beginning at about 55 ka.

The precise chronology of the Sangamon Episode biozones is based on wiggle matching of interval values of the 2<sup>nd</sup> DCA axis (moisture) from Raymond Basin with the well-dated  $\delta^{13}\text{C}$  speleothem record of Crevice Cave, Missouri (located ca. 170 km SW of Raymond Basin). Not surprisingly, a notable “pacemaker” of changes in vegetation and relative moisture is insolation. In general, our wiggle-matching correlations are vetted by ages determined from fifteen SAR OSL analyses of quartz subsampled from outcrops and sediment cores from Raymond Basin.

The most striking result of the new chronology is that what would traditionally be interpreted as the wettest, warmest interglacial climate period (marked by abundant *Liquidambar* and *Fagus* pollen) occurred from 76-71 ka, with a peak in these conditions from 74-72 ka during early MIS4. The ostracod evidence for this period suggests winters were non-freezing, unlike modern climate. Additional evidence for warm winters are fossils of *Hesperotestudo crassiscutata* (an extinct large tortoise) at nearby Hopwood Farm. This paradox can be partly resolved by considering high winter insolation values during this time, but likely also requires that atmospheric circulation during this unique interval excluded incursions of arctic air into the region as occurs today. We suggest a strong southerly flow of air from the Gulf of Mexico that fed a rapidly growing ice sheet to the north, and bathed Illinois in moist and year-round warm conditions. These unique conditions lasted for about 5,000 years before climate shifted to a more continental mode and non-analog biotic assemblages from 71 to 55 ka, corresponding to the remainder of MIS4 and onset of MIS3.

O-2218

## **“Patchwork” loess of Central Asia: A high-resolution spatio-temporal record of Pleistocene palaeoclimatic variability in piedmont loess along the Northern TienShan**

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### **Abstract**

Loess deposits are important terrestrial archives for palaeoclimatic reconstruction, especially in arid and semi-arid continental regions. The Central Asian loess deposits lie in a dynamic climatic zone under the influence of the mid-latitude westerlies and north-south shifting polar fronts, and at the peripheric influence of the Asian monsoon from the south. The loess deposits that blanket the piedmonts of the Asian high mountains in this region are relatively widespread and relatively thick, and therefore provide us with an invaluable archive for understanding the relationships between loess accumulation, palaeoclimate and topography within continental, arid and high terrain environments.

However, contrary to popular perception, the Central Asian loess deposits are neither evenly distributed along the piedmonts nor uniform in thickness, and vary in age and the timing of peak accumulation phases substantially. Here we present an integrated, high resolution chronostratigraphic record from seven loess sites from a 250 km east-west transect along the tectonically active piedmont of the Northern Tien Shan, southeast Kazakhstan, thus, demonstrating the importance of spatial as well as vertical palaeo-investigations of aeolian deposits in this region. Our dataset is based on grain-size analysis and magnetic susceptibility, set within a robust and absolute chronological framework using multiple luminescence dating approaches. We find that in addition to chronostratigraphic variability between the sites, the magnitude and peak of loess accumulation rates varies substantially along the Tien Shan range front. There is significant variation in the timing of loess deposition across the piedmont from west to east, with the western end dominated by late Pleistocene deposits contrasting with mid-Pleistocene deposits at the eastern end. These findings suggest non-uniform and asynchronous deposition of loess through time. Thus, the inter- and intra-variability between sites along the piedmont allow us to develop an integrated approach to study the influence of climate and topography on loess formation processes and accumulation.

Furthermore, we integrate our record with other existing loess datasets from the Ili basin in southeast Kazakhstan and China to develop a conceptual spatio-temporal model for aeolian dynamics along the loess piedmont of the Northern Tien Shan.

O-2219

## Unraveling residence time and migration history of aeolian deposits by combining cosmogenic nuclides and luminescence data into a unified model

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### Abstract

Luminescence-based dating methods are usually applied to date episodic events in the history of aeolian sand deposits. These methods are restricted to the late Quaternary, and only reveal the last cycle of sediment burial. Burial ages modeled from cosmogenic nuclides, on the other hand, reach further back in time but are usually inferred as the minimum residence time of sand in the landscape. An approach that integrates luminescence dating and cosmogenic burial dating into a unified model was developed to reconstruct the migration history of sand and to constrain the timing of sand introduction to the landscape (Vainer et al., [Quaternary Geochronology, 2018](#)). The coupling of the two dating methods extends the time-scale and possible interpretation compared to their individual applications. Published luminescence ages from a large array of sand deposits are converted in the model to empirically-determined vertical displacement rates. These rates are consequently used to simulate migration of quartz grains through a sand column, simultaneously with the accumulation of cosmogenic nuclides. Each simulation is terminated when the modeled concentrations of  $^{26}\text{Al}$  and  $^{10}\text{Be}$  reach analytically measured concentrations of actual sand samples. Model results show that optically stimulated luminescence ages, which range in the order of 1-100 ka, only reflect the last cycle of sand migration, whereas cosmogenic nuclides indicate sand residence time over 1 Ma. The application of the model to samples collected from the Kalahari Erg in southern Africa indicates that most of the sand was introduced to the Kalahari during the Late Pliocene to Early Pleistocene, concurrent with the regional environmental framework. Furthermore, this empirical data-based approach allows quantifying migration-related processes such as the amplitude and periodicity of sand recycling. Our model reveals that since the Kalahari Sand was available for aeolian migration, it was exposed to the surface 22 times, on average. The presented model provides a powerful tool for estimating the emergence of sand in a given landscape, and also for understanding the dynamic evolution of any sand field and the mechanisms behind aeolian sand migration.

O-2220

## Past changes in erosion in antipodal active orogens – unsurprisingly, French and New Zealanders disagree

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### Abstract

Mountains erode. A lot. And fast. But what happens in the context of Quaternary climate change is much less understood. This is mostly because of the lack of proxies for reconstructing past changes in catchment erosion. Uranium isotopes ( $^{234}\text{U}$  and  $^{238}\text{U}$ ) are sensitive to the mechanisms of hillslope erosion (shallow sheet wash vs mass wasting) and the rate of sediment transport. Thus, a high  $^{234}\text{U}/^{238}\text{U}$  denotes deep hillslope erosion and rapid sediment transport. Applying this tool to sediment records could help us understand how catchment erosion responds to climate variability. We have applied this approach to two marine cores collecting sediment from two antipodal active orogens: the French and New Zealand Alps.

In the Mediterranean Sea, turbidite sequences record 75 kyr of erosion in the Var River catchment, which drains a portion of the southern French Alps. Uranium isotope ratios of these sediments show higher values during the Last Glacial Maximum, followed by a decrease in the Holocene. This suggests that glacial erosion was resulting in the production and rapid export of sediments, while during pluvial conditions shallower erosion and slower sediment transport were taking place.

A marine core of the west coast of New Zealand's South Island shows contrasting results. Here, the record spans the last 200 kyr, and the lowest uranium isotope ratios correspond to glacial stadials. In this case, this suggests that erosion was shallower and/or slower, compared to interstadials. While glacial cover was more extensive during these periods, it is possible that the sediment produced was not exported, only to be delivered to the Tasman Sea during the following interstadial. Taken together, these results show that rugby is not the only source of disagreement between French and New Zealanders. The response of mountainous catchments to Quaternary climate variability is complex, and the application of novel isotopic proxies, combined to other approaches, should shed the light on this complexity.

O-2221

## Numerical tracking of cosmogenic nuclides during sediment erosion and transport in glacial landscapes

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### Abstract

In steep mountain ranges, glacier surfaces often carry rocks and boulders that largely stem from erosion of ice-free bedrock hillslopes. Similar to river sediment, the concentration of cosmogenic nuclides, such as  $^{10}\text{Be}$ , in supraglacial sediment can, in principle, be used to infer erosion rates. However, supraglacial sediment has been exposed to cosmic rays during its exhumation on the hillslope as well as during transport within and on top of the ice. Furthermore, cosmogenic nuclide production rates vary strongly with elevation, and glaciers do not mix sediment as efficiently as rivers. Therefore, sampling of supraglacial sediment and converting cosmogenic nuclide concentrations to erosion rates is challenging.

Here, we present a new approach for tracking cosmogenic nuclides during sediment erosion and transport in glacial landscapes. We implemented Lagrangian particle tracking (LPT) in the coupled ice- and landscape evolution model iSOSIA and applied the model to the Chhota Shigri Glacier in India. With each particle, we store its birthplace and its cosmogenic nuclide concentration, which gets altered during transport. This enables us to identify distinct source areas and cosmogenic nuclide production rates for sediment that is found in different parts of the glacier surface. Model results from transient simulations of the Chhota Shigri Glacier during phases of advance and retreat, reveal changing cosmogenic nuclide concentrations due to mixing of sediment from different source areas (with different production rates), despite uniform erosion rates. We furthermore used the model to test if different erosion laws for steep bedrock hillslopes produce distinct patterns in cosmogenic nuclide concentrations. Although our existing samples from the Chhota Shigri Glacier do not help distinguishing different erosion laws, because the limited altitudinal range of the source area, new samples from elsewhere on the glacier may do so. Our approach provides new ways to prepare a sampling campaign and helps interpreting measured cosmogenic nuclide concentrations in supraglacial sediment.

O-2222

## An empirically tuned simulation of the last British-Irish Ice Sheet: Comparison to evidence and implications for landscape evolution

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### Abstract

Palaeo-ice sheets provide us with a long-term record which enables us to better understand how ice sheets behave, influence the landscape and respond to climatic changes. The extent and dynamics of palaeo-ice sheets can be inferred by two methods: i) empirical reconstructions based on evidence left behind by an ice sheet; and ii) numerical ice sheet models based on the known physics of ice sheets. The ideal would be to reconcile these approaches, enabling empiricists to utilise model physics and modellers to compare to data. Here, we demonstrate an approach to simulating the last British-Irish Ice Sheet (BIIS) which draws upon empirically based knowledge of ice sheet extent. A novel climate forcing is used, which combines reconstructed palaeo-ice sheet surfaces with output from global climate models, to direct the simulation towards empirically reconstructed ice limits. The simulation takes output from a glacio-isostatic adjustment model, which is calibrated against relative-sea level records, as input for basal topography. To explore the uncertainty of ice-flow parameters we perform an ensemble experiment and consider different schemes for determining basal conditions. Members of the ensemble are compared to three sources of data, the particulars of which require three separate tools: i) geochronological data, recording the timing of ice-free conditions; ii) flowsets of subglacial bedforms, recording ice flow direction; and iii) the position of moraines, recording ice-margin position and shape. These comparisons enable us to quantify the fit between the simulation and data. For places or times where the fit is poor this could be a basis for questioning the empirical data or interpretations. Our best-fit simulation represents the dynamics of the BIIS as it grows, joins with the neighbouring Fennoscandian Ice Sheet and then deglaciates, capturing ice stream locations, potential ice-shelves and grounding-line positions. Furthermore, the simulation enables us to infer the likely glaciological conditions that existed during the deglaciation of the BIIS, which we would be unable to estimate from an empirical reconstruction alone. These enable us to better understand landform genesis, subglacial processes and landscape evolution during the operation of the BIIS.

O-2223

## First luminescence dating of flash-flood gravel clasts: Deposits from draining of glacial Lake Missoula, Montana, USA

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### Abstract

Paleoflood deposits are used to reconstruct flood magnitudes and frequencies along streams for events that occurred in recent, historical, or ancient past. Paleoflood hydrology must include reliable ages of flood-transported deposits. Large floods commonly carry coarse clasts, such as cobbles and boulders where preservation of datable material requires unusual circumstances.

Here we test the applicability of infrared stimulated luminescence (IRSL) rock surface dating techniques to measuring burial ages of flash-flood transported gravel. A key requirement for the technique is that the luminescence signal, developed during exposure of fluvial cobbles to ionizing radiation, must have been bleached within clasts prior to burial. For short-term flood events, bleaching would likely occur only prior to entrainment. Examination of the IRSL-depth profile across the rock surface helps to discriminate those cobbles which were sufficiently exposed to daylight prior to entrainment thus providing the true burial age. Thus, this technique of measuring clast burial ages has the potential to both date flood events and to evaluate sediment routing during flood events based on the degree of prior bleaching.

Glacial Lake Missoula formed during Pleistocene glacial impoundment of the Clark Fork River in a bedrock canyon near the present border of Idaho and Montana in the northwestern United States. During one or more megafloods, a gravel bar with >10 m tall cross stratification and open-work fabric, formed on the downstream side of a bedrock hill. The gravel deposit is about 170 m above flood-eroded bedrock in the valley floor and about 250 m below the maximum water level attained by the lake. From a pit dug after sunset, cobbles were sampled and placed in light-tight bags. Eight oblate, subrounded clasts were selected, as these would tend to rest so as to expose one of the two sides.

Each of the flat surfaces was cored and sectioned into ~1mm-thick disks under darkroom conditions. IR<sub>50</sub> SAR protocol was used to measure the IRSL profiles. Two of 8 cobbles showed no light exposure, 4 showed limited light exposure, and at least one surface of 2 cobbles were sufficiently bleached before burial. Data from additional cores resulted in mean estimated doses of 58.5±2.5 Gy and 50.6±2.9 Gy. Environmental dose rates for the two cobbles and one matrix sample were measured using high-resolution gamma spectroscopy. Using two fading correction methods, field saturation-laboratory saturation ratio and g-values respectively, comparable burial ages were calculated for each cobble, 13.9 ±0.8 ka or 14.8±1.8 ka and 25.8±1.8 ka or 24.5±3.9 ka. The younger age is consistent with a late-stage catastrophic draining of the lake, whereas the older age likely represents an inherited age of a previously buried fluvial clast. These preliminary results suggest flash flood deposits are amenable to dating.

O-2224

## A centennial-scale cyclicity of flood events in the Peruvian Andes as recorded in fluvial deposits

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### Abstract

The Huancayo basin the Peruvian central Andes contains an extensive flight of fluvial terraces belonging to the Mantaro and Cunas Rivers. Terrace mapping revealed the presence of seven main levels and locally 11 terraces in the Cunas valley and five main levels in the Mantaro valley. The highest terrace level is located at 34 m above the local floodplain (+FP) level. A reconstruction of longitudinal profiles reveals that the terraces trend parallel to one another and made it possible to correlate the terraces of both river valleys. The Mantaro T5 level located at 34 m +FP is cut in lacustrine sediments indicating that at the time of terrace formation, the Huancayo basin was a lake. Twenty-two samples for luminescence dating were extracted from several terrace levels as well as eight samples for radiocarbon dating. The results showed that the lacustrine sediments were deposited between  $\sim 12.000$  and  $4418 \pm 500$  years ago, after which the Mantaro and Cunas Rivers incised and formed their terraces. The onset of valley incision and terrace formation is coeval with the onset of a higher frequency of South American Summer Monsoon (SASM) events, as evidenced by speleothem, lake and glacier records in the region. The other terrace levels, however, were formed after  $2245 \pm 217$  years ago coinciding with an intensification of SASM events to heights that had not occurred since the early Holocene. Dating of the other terrace levels revealed that deposition of fluvial sediments occurred approximately every 250-300 years between  $2245 \pm 217$  and  $1188 \pm 60$  years ago. After that until the present the frequency of deposition increased to once every 150 years. The timing of fluvial sedimentation can be correlated to peaks in precipitation as registered by the aforementioned paleoclimatic archives. We postulate that the increases in precipitation resulted in large flood events in the region. A comparison with existing literature shows that the onset, frequency and timing of sedimentation events occurred synchronously in Peruvian river valleys extending from at least  $10^\circ$  to  $18^\circ$  S latitude. Those events were formerly attributed to the El Niño Southern Oscillation (ENSO), but since these are events with an interannual frequency, we dismiss ENSO as a controlling factor. Instead, we propose that changes in the temperature of the North Atlantic surface waters are responsible for the sedimentation events.

**O-3000**

## **Understanding the warm climates from past interglacials to the future**

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### **Abstract**

Given the predicted future warming and that we presently live in an interglacial (the Holocene), past interglacials are of particular interest to understand better the climate processes characterizing the warm climate conditions. In my study, the climate response to insolation and CO<sub>2</sub> during the interglacials of the past 800,000 years are investigated by using climate models. My simulations show that the relative contributions of insolation and CO<sub>2</sub> to the intensity and duration of each interglacial vary from one interglacial to another. They also show that CO<sub>2</sub> plays a dominant role on the variations of the global annual mean temperature and of the climate in the Southern high latitudes, whereas, insolation plays a dominant role on the variations of monsoon precipitation, vegetation and the climate in the Northern high latitudes. Compared to the projected future climate, the past interglacials are cooler during boreal winter, but are warmer over the continents during boreal summer due to their much higher summer insolation. This suggests that the sensitivity of climate to the latitudinal and seasonal distribution of insolation must be kept in mind for the climatic projection at the century-millennium time scales. My results underline the diversity of the warm climates of the last million years and therefore the potential but also the difficulty to find exact analogues for our interglacial and its future. They show that the best analogue to the Holocene and its future depends critically upon the criteria used to select such an analogue.

**O-3001**

## **Geochronology of Late Pleistocene Paleohydrological Extreme Events in Upper and Middle Don River Basin**

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### **Abstract**

The relicts of large meandering palaeochannels (macromeanders) are found in the river valleys of the East European Plain. Channel widths of macromeanders are few times (sometimes up to 10-15 times) larger than the recent meanders of the same rivers. Such macromeanders are spread globally in the temperate climate zone of the Northern Hemisphere. Formation of large paleochannels is usually associated with Late Glacial (the end of MIS 2), however there are some evidences of formation of such landforms in earlier times (MIS 3).

The main aim of our study is establishing of absolute chronology of large paleochannels formation and periodization of the phase of extremely high river flow in Don River basin.

We studied a few key sites in Don River basin: Upper Don river valley near Epifan town (Tula region), Khoper and Vorona river valleys near Borisoglebsk town (Voronezh region) and Savala river valley near Savalskiy settlement (Tambov region, Russia). On these key sites rivers have wide floodplains with big paleochannels on their surface, which were the main subject of our study. These paleochannels are the signs of high flood activity epoch(s).

In our research we used a number of field and laboratory methods: hand and mechanical coring, examination of natural exposures, topographic profiling; radiocarbon (including AMS) and OSL dating, spore-pollen analysis. Also we made the reconstructions of paleo-discharges of the studied rivers based on paleochannels' parameters.

Data analysis shows that river incision was detected about 30-35 ka BP. Before LGM rivers had already been incised down to the modern river levels or deeper. LGM time was characterized by cryoaridic conditions, low runoff and accumulation in the river valleys. After LGM the high runoff epoch started, which was dated 13-19 ka BP. In that time large meandering palaeochannels (macromeanders) and modern wide high floodplains were formed in the river valleys. Our data shows that this epoch of high runoff was interrupted by a short low runoff period (~15-16 ka BP). So the Late Pleistocene epoch of high floods and large paleochannels formation had two periods – about 17-19 ka BP and 13-15 ka BP. Runoff in Holocene was lower than in Late Pleistocene.

This study contributes to the Russian Foundation for Basic Research (RFBR) Project № 18-35-00028 "Geochronology of extreme hydrological events in Don river basin in the end of the Pleistocene".

**O-3002**

## **Stratigraphy proves scores of last-glacial Missoula jökulhlaups through high tracts of Channeled Scabland**

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### **Abstract**

About 90 late Wisconsin Missoula-flood beds each separated by varved beds prove that each gigantic Missoula flood—peak discharge as much as 25 million m<sup>3</sup>/s—lays but one major graded bed. Critics have for many years billed the evidence for repeated Missoula floods as being only low-energy deposits confined to low routes. But stratigraphy of high-energy gravel bars and backflood deposits also show that numerous great floods swept down high scabland tracts such as the Cheney-Palouse.

At least 25 separate gravel-bearing floods backwashed from the Cheney-Palouse into Willow Creek. Rhythmic backflood beds in Tucannon valley also record at least 25 floods down the Cheney-Palouse. Rhythmic beds record at least 21 separate Cheney-Palouse débâcles backflooded far up Snake valley. Intercalated 16 ka Mount St. Helens ash shows these many Cheney-Palouse floods were the same as had backflooded lower-level Walla Walla and Yakima valleys.

At least 14 floods invaded high Priest valley. Pine Coulee exposes at least 12 flood beds near the upper limit of Missoula flooding into the Cheney-Palouse. Moses Coulee, whose high intake is hard to flood, passed at least 5 gigantic ones. At least 62 floods backflooded lower Yakima and Walla Walla valleys; at least 15 of them need at least 500 km<sup>3</sup> of water hydraulically ponded behind kilometer-wide Wallula Gap. From Columbia gorge at least 17 floods swept far up John Day valley. At least 22 mighty floods swept from broad Portland basin over Lake Oswego trough into Tualatin valley. At least 40 débâcles via Portland basin backflooded tens of kilometers up Willamette valley.

Thickening Purcell Trench ice dammed early Lakes Missoula that released giant floods once every few to several decades. Farther west advancing Okanogan ice closed three huge floodways before recession reopened one. This changing geography shifted routings and discharges of successive floods down different distributaries. As Purcell Trench ice then dwindled over centuries, it held in smaller glacial Lakes Missoula that released smaller floods more often.

Earlier 1-D hydraulic modeling suggested 2500-km<sup>3</sup> glacial Lake Missoula sufficed under different routing patterns to flood several main channels of the Scabland and Columbia valley. New 2-D models governed by shallow-water-flow equations largely concur that successive Missoula débâcles under changing geographic conditions flooded high scabland tracts. Stratigraphy, geomorphology, and modeling all together show that Missoula megafloods under the different settings swept the Channeled Scabland and Columbia valley nearly up to the limits of field evidence. Channels blocked in succession gave different channels peak discharges during different floods. No one Missoula flood, no matter how immense, could inundate all floodways at once up to the limit of evidence.

**O-3003**

## **Chronology of Pleistocene ice-dammed lake outburst floods in the Altai Mountains, Siberia - first new data**

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### **Abstract**

In the late Pleistocene, some of the largest floods in the world took place in the Siberian Altai Mountains. In the headwaters of the River Ob, advanced valley glaciers blocked the course of the River Chuya and formed ice-dammed lakes that repeatedly drained by catastrophic outburst floods. As discussed below, previous reconstructions resulted in more or less consistent scenarios of the timing and dynamics of the regional Pleistocene glaciation being the main trigger of the events. Methodological and technological progress in dating techniques have improved knowledge of the temporal dynamics but also increased the uncertainty due to an increasing number of contradictory data. This uncertainty has led some to doubt some previous findings of the chronology of the glaciation and related outburst floods in the Russian Altai Mountains. By the application of state-of-the-art techniques for different dating methods by experts in the field we want to improve the knowledge of the temporal and spatial dynamics of the outburst floods as indicators of the glaciation in the area, which might be seen as a key location for Central Asia.

**O-3004**

## **Pleistocene megafloods in an incised-valley system. The lower Ebro River**

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### **Abstract**

The Móra Basin is a small marginal sedimentary basin located near the south-eastern margin of the Ebro Basin formed during the Paleogene Alpine Compression in the domain of the Catalan Coastal Ranges. The Low Ebro River flows through the Móra Basin from north to south. Both the entrance to the basin and the outlet incise into Mesozoic carbonates which have originated two gorges, El Pas de l'Ase in the north and L'Estret de Barrufemes in the south. Every of both channel constrictions produces a significant backwater effect. The Comte Stream flows into the Ebro River from the left just before L'Estret de Barrufemes. At this point, the Ebro Delta is about 50 km far.

Just before the narrowing of L'Estret de Barrufemes there exist at least five Ebro River terraces. The aim is on the two lower units which are into the lower valley of the Comte Stream. Unit Two is made up of fluvial multistorey clast-supported, polygenic rounded conglomerates, and sandstones. The lower Comte Stream, near its mouth, incises into this unit which is at this point 17 m thick. Upstream, this unit forms the stream channel floor. It is incised and unconformably overlain by a multistorey layer 15 m thick of gravels and sands from the Unit One, preserved in the stream riverbank. The Unit stacks over the Unit Two. An outcrop of both units reaches until 3.5 km upstream from the Comte Stream mouth and near 40 m over the current Ebro River. At this point, slackwater deposits of cross-laminated sands and sandstones from both units finish the fluvial sediments into the Comte Stream channel.

The hydraulic behaviour in the Comte Stream mouth, influenced by flood waves of the Ebro River arriving at L'Estret de Barrufemes and their related deposits are the core matter of the research. The interpretation of the Comte Stream deposits is made on the basis of sequence stratigraphy. It comprises the analysis of deposits properties and textural features and their vertical and lateral relations. Therefore, on the one hand, the different units have been characterised to deduce fluid dynamics and sediment transport processes, and on the other hand, stratigraphical relations between units have been established. The analysis focuses on the two lower units which are those which flowed into the current Comte Stream channel but not dismissing the older fluvial units. It is significant to emphasise that the Lower Ebro River in the Móra Basin is an incised fluvial system influenced by marine base-level changes and the megaflood deposits were placed in a setting of the rising base level.

O-3005

## Morpho-stratigraphic characteristics and Late Quaternary environmental evolution of the Salado–Juramento fluvial megafan, Chaco Plain, Argentina

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### Abstract

Morpho-sedimentary data of one of the largest fluvial fans of South America, the Salado-Juramento megafan (ca.185,000 km<sup>2</sup>), are presented. It is one of the six megafans of the Chaco aggradational plain, representing part of the foreland basin along the eastern flank of the Central Andes. The applied methods combine assessment of landforms and processes and geomorphological mapping from remote sensing images analysis and field data. The lack of exposed stratigraphy across the flat megafan surface and the sub-environments complexity conducted to a program of research boreholes. Sedimentological analyses of cores were performed by laser diffractometry, optical microscopy and DRX; also geochemical data and OSL datings were obtained. The surface of the Andean basin of the formative transverse river of the megafan is 38,000 km<sup>2</sup>. The river undergoes large seasonal fluctuations in discharge (from ca. 30 to 2,000 m<sup>3</sup>/s) that result from monsoonal precipitation (South American Monsoon System), with high sediment yields favouring an avulsive dynamic. The longitudinal profile of the megafan is upward concave, with gentle slopes (0.18–0.01°) and maximum width and length of 150 km and 650 km respectively. Aggradation and progradation have been conditioned by flexural and tectonic controls regulating the interaction between the megafan and its axial trunk river (Paraná). The defined nine morpho-sedimentary units of the megafan and the ten sub-units of its distal zone represent the complexity of subenvironment interactions produced by different processes. Fan-shaped depositional lobes and a radiating network of palaeochannel belts are typical landforms. Flexure and dynamic topography favoured subsidence, avulsion and accumulation, with high potential of preservation of swamp, channel, pond, soil, and loessic facies in the distal zone of the megafan. A Late Quaternary wetland (ca.29,000 km<sup>2</sup>) occupies this zone preserving high-resolution palaeoenvironmental data. Shallow cores and a 30 m depth borehole (29°10'28"S and 61°11'57"W) conducted to stratigraphic correlations. The representative Pleistocene sequence (19.5 to 6.5 m) is formed by clayey silts accumulated in temporary to permanent swamps with an interbedded hydric paleosoil. A sandy palaeochannel of the megafan was drilled on top of the wetland (6.5 to 5.5 m), covered by a loessic deposit (5.5 to 1.5 m). Late Holocene swamp sediments compose the upper part of the sequence. The palaeowetland deposits are lying on Plio-Pleistocene fluvial sands deposited by the Paraná system (30 to 19.5 m). First geochronological data and regional correlation indicate that Chaco megafans would have reached their maximum development during the MIS 3 and the first part of the MIS 2, and experienced aridity in the LGM. The recent expansion of deforestation and agricultural land on the megafan increased its vulnerability to flooding events. Megafan evolution information is the key to support socio-economic decisions on aquifer exploitation, land uses and infrastructure planning.

O-3006

## Catastrophic Flood Events During Late Pleistocene-Holocene in the Tropical Narmada River Basin, Western India

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### Abstract

High-energy catastrophic flood events are recorded in response to the abrupt deglacial intensification of the monsoon. Information on long term frequency, magnitude and causes of large floods is necessary for estimation of future floods. The occurrence of floods in the rivers of western India is related to monsoon rainfall intensity and cyclonic activity. The study highlights the geologic record of high-energy discharges in the bedrock reaches of the Narmada River basin. The flood deposits are preserved as huge gravel bars, now incised by small tributaries arising from the nearby drainage divides. The area comprises highly dissected Deccan Trap basalt with plugs of Carbonatite and numerous NE-SW trending lineaments and fractures. Gravel sequences ranging from 5-30m are seen exposed on either side of the tributary, the Banganga. The sequence comprises clast supported gravel (Gcm) overlain by couplets of coarse sand (Sp, Sh) and gravel (Gp, Gh) capped by a thin calcretized fine silt layer. Overlying this are units of coarse massive gravel (Gm), thick calcretized silt, upward graded gravel - sand unit and horizontally stratified sand-gravel couplets (Sh, Gh). The clasts are largely sub angular to sub rounded and up to 50cm in intermediate axis in the basal part of the sequence indicative of short distance transport. The sediment facies assemblage suggests that the deposition of gravel occurred due to hyperconcentrated flood flows followed by vertical accretion of sand deposits during low flow conditions. The rhythmic layering in the upper sequence suggests episodic flooding and rapid recession. The thickness of these units is seen to vary; the maximum being in the central part of the basin as compared to the upper and lower reach. OSL chronology on the silt units that cap the gravel sequences from the central part have provided ages of  $12\pm 1$  ka,  $7.5\pm 1$  ka,  $3.5\pm 0.3$  ka suggesting three distinct episodes of sediment deposition under high-energy discharge conditions. Since the Banganga river itself is short (~10km in length), narrow, with limited catchment and remains dry during non-monsoon months, it is unlikely that such huge pile of sediments could have been transported and deposited by the present-day stream. However, Narmada is a large river and has records for high magnitude flooding characteristics. The post-glacial high energy discharge in the Narmada River could have scoured pathways along the lineaments that run almost perpendicular to the channel in the tectonically active basalt terrain. These scours were then filled with sediments during the spill over during large scale flooding events related to intensified monsoon ~12, 7.5 and 3.5 ka and later on incised by the Banganga River.

O-3007

## A 10,000-year flood record of Sant Maurici Lake, Central Pyrenees

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### Abstract

Studies of high-mountain lakes contribute to high-resolution information about the catchment flood dynamics. These catchments respond sensibly to hydrological extreme events because of altitudinal environmental and climatic gradient. Local mountain communities are vulnerable to hydrological extreme events such as flash floods, debris flows and flooding of the valley bottom.

The aim of this study is to identify hydrological extreme events and their provenance through the geochemical and sedimentological imprint of flood layers of the Sant Maurici Lake (42°34'54" N, 1°0'15" E, 0.22 km<sup>2</sup>, 1924 m a.s.l.) located in Escrita Valley, on the southern slope of the Central Pyrenees. The catchment surface is 15.91 km<sup>2</sup> and the highest elevation is 2950 m a.s.l. at the Subenuix Peak. This study is part of a regional project that focuses on the reconstruction of the climatic variability in the Pyrenees during the Holocene. With the paleoflood data inferred from the Sant Maurici sediments, we expand the information provided by other nearby paleoclimate studies (e.g. lakes Estanya, Enol, Bassa de la Mora).

An 865 cm-long core was retrieved from the Sant Maurici Lake, which covers ~12,000 years. Sedimentological and geochemical analysis include lithology, color, elemental composition, XRF and smear slide observation. Three index are used in order to identify hydrological extreme events:  $(Sr + Rb + Zr) / Ca$ ;  $(Sr + Rb + Zr) / Ti$ ; and  $(Ca + Zr) / Ti$ . The second index  $((Sr + Rb + Zr) / Ti)$  allows us to identify both, the siliciclastic and carbonate flood layers, which were deposited during 10.000 – 10.500 cal years BP (Preboreal) and 3600 – 4000 cal years BP (Subboreal). These two flood episodes show a similar duration ~ 350 years, both separated by ~ 6000 years hiatus and ~45 years mean return periods. We attribute these pulses of increased flooding and deposition in the San Maurici Lake to pulses of storm activity which were reported by several paleoenvironmental studies (fluvial, lacustrine, marine sequences) focused on the Iberian Peninsula and NW Mediterranean Sea. These stormy episodes (~ 1500-year cycle) are related to the displacements of the Westerlies Stream. To conclude, regional changes in the atmospheric circulation system affected environmental conditions of the Sant Maurici catchment.

O-3008

## An unconsidered source of Tokyo earthquakes and Pacific Ocean tsunamis

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### Abstract

The assessment of seismic hazards along subduction zone coastlines provides important information regarding the frequency and magnitude of earthquakes and tsunamis that can be expected to impact coastal communities in the future. Unlike many subduction zone coastlines that involve one tectonic plate subducting under another, seismic hazard assessments in the Tokyo Region are complicated due to the presence of a nearby triple junction, where one continental (CON) and two oceanic plates (PHS, PAC) collide. The CON/PHS and CON/PAC boundaries are recognized earthquake sources. However, until now, historical and geological evidence of a PHS/PAC earthquake has been lacking. Here we show that two unusually large tsunamis are evidenced by sandy deposits preserved along ~50 km of coastline in the Tokyo Region. The oldest of them, deposited about 1,000 years ago, contains evidence consistent with tsunami deposits reported elsewhere in Japan (e.g., marine foraminifera, rip-up clasts, pebbles, erosional base) and represents a previously unknown prehistoric earthquake. In computer simulations, this earthquake deposited sand that extended too far inland to represent earthquakes originating from the CON/PHS and CON/PAC boundaries. Rather, the greater inland penetration requires interplate thrusting along the PHS/PAC boundary, a previously unconsidered source for earthquakes. This previously unconsidered source has the potential to generate tsunamis that could result in damaging consequences for the Tokyo Region as well as other Pacific Ocean coastlines.

**O-3009**

## **Subduction zone paleoseismology in northeast Japan**

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### **Abstract**

After 2011 Tohoku disaster, the Japanese government decided to incorporate not only written record-based but also geology-based paleoseismology into long-term forecast of subduction zone earthquakes. In this presentation, I review the recent progress of subduction zone paleoseismology in northeast Japan (Hokkaido and Tohoku regions) and how they have been applied for the long-term forecast.

Along the Pacific coast of eastern Hokkaido, a historically unknown tsunami, so-called “17th-century tsunami”, was revealed by Nanayama et al (2003). Nanayama’s report modeled its source as having both offshores of Tokachi (western Hokkaido) and Nemuro (eastern Hokkaido). Such multi-segment earthquakes were initially considered to recur every 500 years, but the intervals later were reevaluated by Sawai et al. (2009) to vary ranging from 200 to 800 years. The most recent long-term forecast published in 2017 by the government incorporated the variation of the recurrence intervals and recalculated occurrence potentials for subduction zone earthquakes in southern Kuril trench.

In Tohoku region, paleotsunami research began using lacustrine deposits along the coastal area of Japan Sea in the 1980s. After that, in early 1990s, research groups of Tohoku University and Tohoku Electric Power Company identified a tsunami deposit associated with 869 Jogan tsunami, one of the oldest historical tsunamis in Japan. However, National Seismic Hazard Maps for Japan (2005) did not include this tsunami because its source had not been modeled yet. Building on their works, Geological Survey of Japan later proceeded further geological research and modeled its source as having an offshore Sendai source, with a moment magnitude ( $M_w$ ) of greater than 8.4-8.6, using numerical computer simulations. The government was scheduled to apply this estimation for long-term forecast for subduction zone earthquakes in Japan trench, but the serious disaster occurred about one month before their disclosure.

O-3010

## Megathrust earthquakes at subduction boundaries: Their isotopic signature in remobilized sediment

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### Abstract

The 2004 Sumatra (Mw9.3) and the 2011 Tohoku-Oki (Mw9.0) megathrust earthquakes and associated tsunamis were close to the upper size limit for such events and had devastating societal consequences. These events are rare so that few are known e.g., M9.4 Alaska 1964, M9.6 Chile 1960, Cascadia 1700 AD. A major objective of submarine paleoseismology is to characterize location, time, and size of large tsunamigenic megathrust earthquakes from their sedimentary record.

Submarine studies of recent well-resolved earthquakes provide precious ground truth, especially post-2011 surveys of the Japan Trench. Short-lived radioisotopes including those from the Fukushima nuclear reactor (excess  $x\text{s}^{210}\text{Pb}$ ,  $^{137}\text{Cs}$  and  $^{134}\text{Cs}$ ) and Sr, Nd and Pb isotopes have permitted to document the thickness and spatial distribution of the sediment remobilized in the 2011 event and by prior earthquakes. Three main sediment transport facies were recognized turbidites, mass-flows (debris flows, slides and slumps) and “homogenites”. Homogenites have been associated with earthquakes in other tectonics settings and have also been documented for the 2011 Tohoku event. In the Japan Trench, “homogenites” are acoustically transparent and they are isotopically homogeneous.

During the *R/V Natsushima* 13-02, 13-19 and *R/V Sonne* 251 expeditions we obtained up to 10m long sediment cores, multibeam bathymetry and subbottom PARASOUND profiles from the upper forearc slope, from a prominent quasi-continuous terrace on the forearc slope and from the Trench. The 2011 sedimentation event is unusually thick and widely distributed from 600 to 8000 m of water depth. The sediment remobilized during the 2011 event is characterized by a large enrichment in  $x\text{s}^{210}\text{Pb}$ . Revealing that sediment remobilization was restricted to the upper few centimeters To accumulate ~2m thick deposits such as those recovered from the Japan Trench, surficial sediment remobilization had to occur over large areas. Up to 7m thick acoustically homogeneous deposits in other trench cores likely resulted from M~9 paleoearthquakes. The Sr, Nd and Pb isotopic ratios within these acoustically transparent deposits have a narrow range in composition. A similar process, as that of the 2011 event, in which surficial sediment derived from large areas of the seafloor was remobilized seems necessary for such thick and isotopically homogeneous deposits to accumulate. In contrast, the Sr, Nd and Pb ratios of smaller, younger and older turbidites reflects a wide range in isotopic composition as expected from diverse sources. Turbidites and “homogenites” recovered from the Japan Trench also reveal along-trench variability in isotope ratios that can be used to identify sediment sources and thus areas of strong shaking close to earthquake ruptures. These combined results may potentially reveal not only the occurrence of mega-quakes but also the segmentation of the boundary.

O-3011

## Earthquake-triggered remobilization of surficial slope sediments: Advancing turbidite paleoseismology in the marine and lacustrine realm

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### Abstract

Turbidite paleoseismology aims for improved understanding of earthquake recurrence by studying records of earthquake-induced turbidites in marine or lacustrine basins. However, good process understanding of turbidity currents and turbidites is crucial to reliably evaluate the records' quality and compatibility with other paleoseismological archives. Most studies up to now have assumed submarine landslides and subsequent flow transformation into turbidity currents as the main sediment remobilization process. This raised doubt considering the continuity and sensitivity of turbidite records as landslides only form after critical sediment mass accumulation on an inclined potential sliding surface.

Recent research on turbidite records of Chilean lakes and the Japan Trench suggested the existence of a different remobilization process: earthquake-induced removal of the upper few centimeters at the sediment-water interface (i.e. surficial remobilization) as opposed to sliding of thick (meter-scale) sediment packages. This process may provide for continuous earthquake records as surficial remobilization is less dependent on critical 'recharging' of slope sediment before seismic shaking. Our study is the first to directly investigate the slope where the process takes place.

Here we present first evidence of surficial remobilization on the slopes of the Japan Trench and two Chilean lakes. Our data shows centimeter-scale gaps in slope sequences of both settings, which can be linked to the strongest historical earthquakes of the two regions. Therefore, we suggest surficial remobilization plays a significant role in sediment transportation upon seismic shaking. Also, several individual slope cores contain multiple gaps indicating that evidence of surficial remobilization can be preserved within slope sequences. Moreover, we find surficial remobilization-related gaps from slope gradients  $>2.2^\circ$ , whereas no gaps are observed on flatter slopes. Our data suggests a linear relationship between total remobilization per site and slope angle (maximum  $4.3^\circ$ ). Both findings point towards gravitational downslope stress as a controlling factor on surficial remobilization depth. Furthermore, gaps could only be observed from  $M_w$  8 in the Japan Trench suggesting that a minimum shaking duration, as this is directly related to magnitude, is needed for surficial remobilization to occur. The study of 25 more Chilean lake cores will further constrain the effect of different slope and seismological characteristics.

Sediment in both Chilean lakes and Japan Trench mainly consists of diatoms making their geotechnical characteristics comparable. Therefore, the Chilean lakes function as a natural laboratory where data acquisition is cost-effective and where well-laminated unbioturbated background sediment allows for precise stratigraphic correlation. Observation of surficial remobilization gaps on the Japan Trench slopes suggests global significance of the process.

**O-3012**

## **A disturbance from the 1700 AD earthquake identified by radiocarbon dating from Lower Squaw Lake, Oregon, USA**

Ann Morey

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### **Abstract**

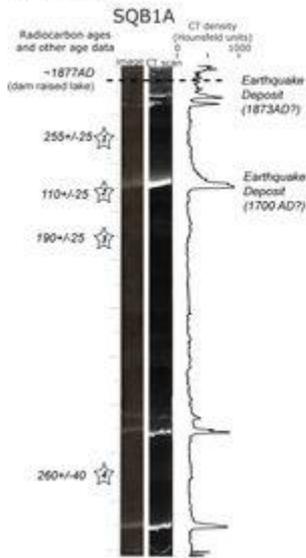
Accurate identification and dating of earthquake deposits are essential for the development of chronologies, models of fault behavior and stress linkages, and to calculate probabilistic assessments used to inform hazard maps. Cascadia lakes are increasingly being used for paleoseismic investigations because they are sensitive recorders of disturbances and can produce continuous records that span the Holocene. This is particularly important in Cascadia because there are no instrumental or written records of megathrust earthquakes given the most recent event occurred in 1700 AD. Identifying a deposit that can be confidently attributed to the ~M9 1700 AD Cascadia earthquake in lake sediments is important because the deposit characteristics can be used to identify similar deposits from past earthquakes downcore.

To determine if Cascadia earthquake deposits can be uniquely identified in sediments from Lower Squaw Lake, OR, I compared the historic portion of the record to the sequence of historic events, including the ~M9 1700 AD Cascadia and ~M7 1873 AD intraplate earthquakes. Initial deposit attribution was based on timing and relative position, then deposits were described and compared. Deposits attributed to intraplate and subduction earthquakes were different from each other but have the same structure: an initial unit composed of lake-margin, failure-prone schist becoming increasingly organic-rich upward, followed by a fine-grained, watershed-sourced unit suspected to result from liquefaction of the lake's large, coarse-grained subaerial delta. This silt unit grades upward into a long, organic-rich tail. Deposits attributed to floods did not have organic tails. The organic tail is composed primarily of lake phytoplankton, diatoms, bacteria and degraded organic matter, suspected to have formed as a result of flocculation which resulted from the mixing of fine particles and electrolytes released during liquefaction with lake water.

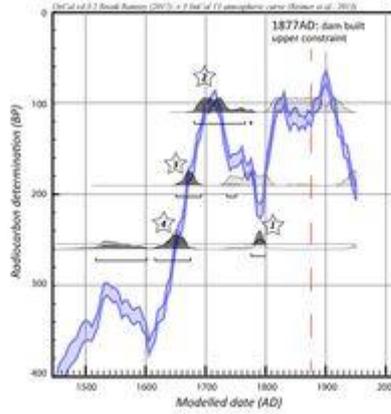
A sample taken from the organic tail of the lower portion of the deposit attributed to the 1700 AD earthquake was dated at  $110 \pm 25$  RCY BP, similar to simulated radiocarbon distributions for a calendar age of 1700 AD (OxCal Program, version 4.3; C. Bronk Ramsey, 2017). Simple calibration produced two possible ranges: 1682-1736 cal AD and 1805-1935 cal AD, typical for this unusual section of the radiocarbon production curve. A radiocarbon age from a detrital sample between the deposit attributed to the 1700 AD earthquake and the tailed deposit attributed to the 1873 AD earthquake make the younger range impossible. A detrital sample from below the deposit attributed to the 1700 AD earthquake constrains the sequence from below. The figure below shows the results of a depositional sequence which constrains the timing of the deposit to ~1680-1740 AD. This is strong evidence that this deposit was formed in direct response to the 1700 AD Cascadia earthquake.



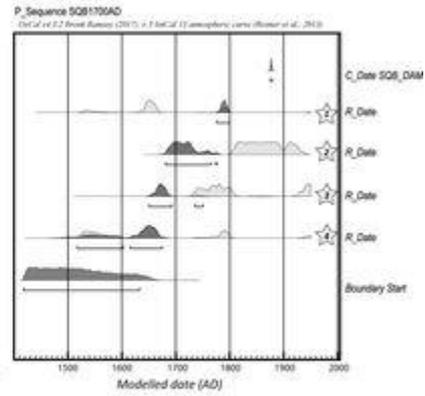
A. Model Data



B. Modeled distributions on RC curve:



C. Modeled distributions in stratigraphic order: (evenly spaced along vertical axis)



O-3013

## Intra- and inter-site reconstructions of coseismic subsidence during the great 1700 CE earthquake in southwest Washington USA

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### Abstract

Coseismic subsidence was estimated during the great 1700 CE earthquake at the Cascadia subduction zone (CSZ) using a foraminiferal-based Bayesian transfer function. To test intra-site reproducibility subsidence was reconstructed in three cores within 25 to 600 m at two sites; one in eastern Willapa Bay, WA and one in western Grays Harbor, WA. Estimates of paleommarsh elevation prior to the earthquake differed by 10s cm, likely representative of the variations in marsh surface elevation seen in modern salt marshes at the sites today. At both locations, reconstructed subsidence estimates ranged from ~0.50 to 1.00 m, although the difference in intra-site subsidence estimates were not statistically significant at the 95% level. The similarity (<0.20 m difference) in intra-site subsidence supports the transfer function technique in reconstructing subsidence within a single marsh location, to some extent irrespective of paleommarsh elevation differences and location within the saltmarsh. Further, the addition of quantitative subsidence estimates at Grays Harbor partially fills a spatial gap in the central part of the CSZ that runs from southern Washington through Vancouver Island, British Columbia. Overlapping inter-site subsidence estimates between eastern Willapa Bay and western Grays Harbor, which are ~40 km apart in the strike direction, provides no evidence of plate segmentation between the two locations which agrees with the present earthquake rupture models.

The current distribution of quantitative coseismic subsidence estimates for the 1700 CE earthquake are unable to limit the width of rupture as the majority of sites are located directly at the coast. As a result of this limited distribution and in the absence of additional evidence, the earthquake modeling community uses the 450 C isotherm as the down-dip rupture boundary. Here, we attempt to address this limitation by using subsidence estimates from an additional site (eastern Grays Harbor), ~30 km down-dip of the western Grays Harbor site. A statistically-significant difference in coseismic subsidence estimates between western and eastern Grays Harbor may provide insight on rupture width at this location. Greater (lesser) subsidence at eastern Grays Harbor than western Grays Harbor may indicate a wider (narrower) rupture, although further estimates would be required.

**O-3014**

## **Pioneering multi-proxy palaeotsunami research along the Pacific Coast of Ecuador**

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### **Abstract**

The complex environmental, vegetative, geological, geographical, and tectonic setting of Northern South America can set the stage for an elaborate and heterogeneous compilation of different marine extreme event signatures within the coastal sedimentary record. The Pacific Coast of Ecuador, between Esmeraldas and the Bay of Guayaquil has been the focus of the first multi-disciplinary palaeotsunami investigations ever conducted in the country since 2016, targeting multiple sedimentary environments from fluvial-dominated plains to sandy beaches, in both natural settings and urban areas.

Important historical earthquakes have been recorded in Ecuador since 1896, all triggered by  $M_w > 6.9$  earthquakes associated to the Nazca Subduction Zone, each producing extensive and critical damage to both the natural environment and human-made structures. Even though some of them have triggered tsunamis, very few have been evidenced geologically as not all tsunami-generated sediments are preserved due to the complex depositional settings encountered along this coastline.

The aim of this on-going investigation is to identify marine extreme event signatures in different types of sedimentary environments using a multi-proxy approach, including detailed lithostratigraphic descriptions, particle size analyses, petrophysics, mineralogy (i.e., heavy mineral assemblage characterization), analysis of morphoscopic features of sediment grains, bio-stratigraphy, dating by means of both  $^{14}\text{C}$  and Optically Stimulated Luminescence (OSL) and luminescence signal analyses. For the latter, two novel approaches were implemented to help distinguish between tsunami and storm events: a) measurement of bulk samples using a Portable OSL Reader (PPSL) to create luminescence profiles in order to elucidate variances in stratigraphic continuity; and b) Single Grain Over-Dispersion (SG-OD) OSL analyses which allow to characterise the degree of sedimentary chaos within a deposit.

Presence of multiple potential tsunami and possible storm deposits was found throughout the numerous large trenches excavated and on exposed coastal/fluvial outcrops found along the coast, varying in thickness and sedimentological features depending on the environmental setting. On-going luminescence analyses (both PPSL and OSL) seem to be a key identification proxy to distinguish between palaeostorm and palaeotsunami units, besides the more conventional analytical techniques, also allowing to narrow the time-window for the chronology of the different events found along this coast.

**O-3015**

## **Late Quaternary environments in the Nile Basin**

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### **Abstract**

Late Quaternary climates in the upper Nile Basin have fluctuated between two extremes: cold and dry or warm and wet. Episodes of very high Nile flow coincide with intervals of sapropel accumulation in the E Mediterranean, the most recent having ages of 81 ka (S3), 55 ka (S2) and 13.5-6.5 ka (S1). Between 75 ka and 15 ka the regional climate was mostly dry (apart from moist phases at 55-50 ka and, perhaps, 38-30 ka) with active dunes encroaching on the Nile. In the Ethiopian headwaters of the Atbara and Blue Nile, <sup>36</sup>Cl exposure ages for glacial moraines range from 70 to 15 ka, after which the ice melted as the climate grew warmer.

In the Red Sea Hills of Egypt and the Sinai Peninsula, moist air masses from the Mediterranean extended as far south as latitude 24°N between 31.2 ka and 22.5 ka, which is when lakes in the Blue and White Nile headwaters of Ethiopia and Uganda were drying out.

During the Last Glacial Maximum (24-18 ka), temperatures in the Ethiopian Nile headwaters were 4-8°C lower than today. Periglacial processes were active down to 3000 m, slopes were unstable, and the tree line was 800-1200 m lower than today. The Blue Nile was then a highly seasonal river with a bed-load of sand and gravel, much of which was deposited by the main Nile in northern Sudan and southern Egypt. The ecotone between savanna and desert extended 300-500 km further south and the Atbara ceased to flow for much of the year. The abrupt return of the summer monsoon at 14.5 ka caused the hitherto closed lake basins in the Ugandan headwaters of the White Nile to fill and overflow, creating a shallow seasonal lake up to 25 km wide and over 400 km long south of the Blue and White Nile confluence of that time.

The Blue Nile and Atbara provide most of the sediment and flood discharge, but the White Nile provides most of the water during the time of minimum annual flow. When flow in the White Nile was cut off, as it was during 25-15 ka, winter floods from the Red Sea Hills would have helped sustain Nile flow.

Until 14.5 ka, sand-bearing Blue Nile distributary channels radiated across the surface of the Gezira alluvial fan to join the White Nile up to 120 km south of its present confluence. Later Blue Nile incision beheaded these channels, reduced seasonal flooding, and caused desiccation of the wetlands along the Nile and its major tributaries. Episodic late Pleistocene channel incision along the main Nile converted former flood plains into alluvial terraces suitable for prehistoric occupation.

O-3016

## Continental records for the 'African Humid Period': lake sediment archives from the Ounianga Basin and the Tibesti Mountains, N Chad

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### Abstract

Triggered by orbital forcing via increased summer insolation, an intensified and northward shifted African/Indian monsoon resulted in a re-greened early and middle Holocene Sahara. During this phase – often named 'African Humid Period' – a wooded savannah is documented for the Central Sahara at least up to 19°N. Since the mid-Holocene, as a response to monsoonal weakening, the Sahara has turned into today's largest hot desert. The timing, magnitude and progression of the ecological responses to this shift – especially the de-greening of the Sahara – are discussed contrarily.

The volcanic Tibesti Mountains and their forelands in Northern Chad are a key region for palaeoclimate research due to their inner-continental position and diversity of ecological habitats. We present records from ecologically related, but topographically different settings in elevated craters and in the lowland oases of the Ounianga Basin.

Lake Yoa provides a unique continuous, high-resolution and well-dated sedimentary record for the Tibesti's eastern foreland since the onset of lacustrine deposition around 10,500 cal BP. The distinct dominance of grasses and sporadic occurrence of dry-adapted Sudanian elements in the basal pollen spectra indicate an already established thorn savannah pointing to a prior onset of humid conditions. The successive spread of more humidity demanding, deciduous Sudanian trees about 1000 years after the lake formation suggest a continued slow wetting in the Central Saharan plains, culminating in an extensive savannah with abundant Combretaceae – a tropical plant family with a recent distribution in the Sahel and southwards.

During the 5<sup>th</sup> millennium cal BP a distinct ecosystem change from a deciduous Combretaceae savannah to a thorn savannah is documented within a few hundred years, possibly triggered by trespassing climatic thresholds, whilst the main biomass-producers display a gradual change. The grass proportion decreased slowly over several millennia, while the goosefoot proportion – dominating the desert vegetation together with grasses – increased successively.

<sup>14</sup>C dating of micro-charcoals and pollen concentrates reveal an onset of lake formation in the Tibesti Mountains around 9500 cal BP, distinctly later in comparison to the surrounding plains, probably a consequence of the exceptional hydrological settings of the crater lakes. Pollen-analytical results show the persistence of sagebrush-grass-formation vegetation during the 'African Humid Period', indicating a less pronounced vegetation change in the high mountains.



Our results indicate a stepwise re-greening and de-greening of the Central Sahara. The mid-Holocene rather sudden, definitive retreat of a Combretaceae savannah is followed by a gradual decline of vegetation cover as indicated by the slow decrease of grasses – thus not connected to prompt aridification with vast vegetation-free areas.

O-3017

## Local environmental context of the Howiesons Poort sequence at Klipdrift Shelter, South Africa

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### Abstract

The Late Pleistocene Middle Stone Age (MSA) in southern Africa displays variations in technological and cultural mechanisms and shifts in anthropogenic ecological niches. An essential question is the role of climatic and vegetation changes as potential catalysts for human adaptability, changing mobility patterns and increased cultural complexity. To what extent did global and regional climatic fluctuations affect local vegetation and precipitation patterns, and could potential local variations have influenced human settlement and subsistence strategies?

Past local vegetation and climate can be reconstructed by analyses of micromammal species that become incorporated into archaeological sediments. Their suitability as palaeoenvironmental indicators is a result of small home ranges, precise ecological requirements and being primary consumers in the food chain. In this study, micromammals recovered from the Howiesons Poort (HP) sequence at Klipdrift Shelter (KDS), located on the southern Cape coast of South Africa, have been analysed to provide proxy data for palaeoenvironmental reconstruction. The HP is a prominent techno-cultural period characterised by blade-based industries and complex material culture (i.e. geometric engravings on ostrich eggshell and worked ochre). At KDS, the HP dates to c. 51-64 000 years ago, corresponding with Marine Isotope Stages (MIS) 4 to 3. Anthropogenic material from the sequence includes HP typified stone tools, modified ochre pieces, engraved ostrich eggshell, *in situ* hearths, and consumption of both terrestrial and marine fauna. Our study aims to provide an environmental context for human utilisation of the shelter while addressing the need for site specific testing of potential (a)synchronous changes in behavioural-environmental proxies.

Taxonomic identification of 20 micromammal species from 19 layers have ensured reconstruction of a detailed palaeoenvironmental sequence. Taphonomic analysis also sheds light on post-depositional processes and provides information regarding non-human and human site utilisation. The results of biodiversity indices, taxonomic composition and habitat weighting create a detailed picture of local environmental conditions during MIS 4 to 3 and contributes new insights to the palaeoenvironmental conditions at the Cape coast.

O-3018

## Zoogeomorphic agency and geoarchaeological interpretation of the dust increase over North Africa at the termination of the African Humid Period

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### Abstract

Several investigations suggest that the termination of the African Humid Period is marked in North Africa by increased dust fluxes to the Atlantic Ocean. The rapid rise of dust supply to the sea as preserved in offshore core records around 5 ka BP is generally interpreted as the consequence of a rapid diminishment of the monsoon system and immediate aridification. However, the study of new zoogeomorphological features discovered in dryland landscapes of Northern Africa reflect early human-animal agency acting since prehistory on surface processes, and enable further interpretations regarding the origin of African continental dust fluxes to oceans. Studying the geoarchaeological record of ancient domestication of cattle, sheep, and goats, we recognize that activities related to animal husbandry (transhumance, pastoralism, and herding) were disturbances that significantly affected surface processes like erosion and dust mobilization, as well as reduced vegetation and ecosystems productivity. We argue that the spread of human activities and intensive husbandry of cattle and caprines in this region significantly influenced the geomorphic stability, ecosystem and landscape sustainability in a comparable manner of overuse observed in present-day arid and marginal environments, where pastoral overgrazing pressure increases erosion processes and enhances dust mobilization. We thus reinterpret the increased dust emission from North Africa at the end of the African Humid Period as due to human/animal induced soil erosion and dust mobilization in the context of a drying environment. We suggest that human/animal activities have amplified dust generation from the North African continental interior since ~7 ka BP. This strong evidence of prehistoric human impacts on surface processes in North Africa supports arguments for an early beginning of the Anthropocene.

O-3019

## Northeast Africa and the Eastern Desert of Egypt with its relevance for Modern Human dispersal in the Late Pleistocene

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### Abstract

Northeast Africa is one of the key regions for understanding human dispersal “Out-of-Africa”. Only this region provides a full terrestrial route along the natural bottleneck of the African continent and into southwest Asia. During the late Pleistocene, Northeast Africa has experienced fundamental environmental changes. However, in this area little is known on how humans were affected by these changes as could be deduced from the analyses of complementary archaeological and environmental archives. Instead, palaeoenvironmental information often derived from marine records or global climate models, representing an over-regional climate reconstruction without any direct correlation to archaeological sites. Interdisciplinary geoarchaeological research of the Collaborative Research Centre 806 “Our Way to Europe” at the limestone hogback of Gebel Duwi in the Eastern Desert of Egypt, where the sites of Sodmein Cave, Sodmein Playa and Saquia Cave are located, fills this gap with new results from on- and off site investigations, linking palaeoenvironmental information with archaeological evidence of human presence to the overall landscape setting. This is achieved by three methodological approaches, delivering the following key results.

First, geomorphic mapping at Gebel Duwi by the use of high-resolution satellite imagery and digital elevation models integrated with field investigations at Gebel Duwi shows the coexistence of young and active geomorphic features directly next to presumably old wadi terraces with stable surfaces, which are often covered with Middle Stone Age artefacts. Based on this landscape mosaic, the integration of information from open-air surface sites and the comprehensive stratigraphy of human occupation debris in Sodmein Cave serves as a spatial-temporal background to investigate human occupation in this area.

Second, first optically stimulated luminescence (OSL) age estimates from the archaeological stratigraphy Sodmein Cave range from late MIS 5 to early MIS 4. Th/U based dating of speleothem growth at the nearby Saquia Cave indicate for the first time wetter climatic conditions derived from a single terrestrial archive during all interstadials of MIS 5 in Northeast Africa. This seems to confirm the presumption that humans have been present during multiple wet-phases of the Last Interglacial in the Eastern Desert and thus strengthen the importance of this area, apart from the Nile Valley, as an important region on the northern migration route of modern humans.

Finally, a GIS-based PalaeoMap of the Last Interglacial environment of Egypt sums up palaeo-climate, ecozones, water availability and appropriate raw material sources as primary needs of hunter-gatherer societies on an over-regional scale and thus expands the regional field investigations to the overall context of Northeast Africa. This multi-scale research approach allows us to integrate socio-environmental interactions from distinct site regions in the Eastern Desert to the overall context of Egypt and derive its relevance for modern human dispersal Out-of-Africa.

O-3020

## Late Pleistocene palaeoenvironment in southwest Ethiopia – insights from geoarchaeological investigations at different spatial scales

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### Abstract

The reconstruction of palaeoenvironmental changes requires multidisciplinary investigations, using different scales of consideration. Geoarchaeological research allows using these different angles - from geoscientific analyses to archaeological observations. The interdisciplinary project A1 “Out of Africa - Late Pleistocene Rock Shelter Stratigraphies and Palaeoenvironments in Northeastern Africa”, as part of the Collaborative Research Center 806 “Our Way to Europe”, focuses on the usage of various research approaches to reconstruct Late Pleistocene rock shelter stratigraphies and the palaeoenvironment at sites in Northeastern Africa.

The southwestern Ethiopian Highlands, one of the projects research areas, holds valuable archaeological sites. According to the Mountain Refugium Hypothesis, prehistoric hunter-gatherer might have frequented these high elevated areas trying to cope with environmental stress. Rock shelters like Mochena Borago and the Sodicho Rockshelter, at Mt. Damota and Mt. Sodicho, preserved complex and heterogeneous sediment stratigraphies with comprehensive archaeological sequences of the Late Pleistocene. The poster displays initial results of research in the area, mainly focusing on geoarchaeological work at the Sodicho Rockshelter. Research topics, e.g. site formation or the preservation of archaeological remains, can be addressed by using different scales of investigation. The methodological approach comprises a local scale, using high resolution Pléiades 1A and ASTER GDEM\* satellite images as a tool for landscape analyses. A selection of sedimentological and geochemical field and lab analyses are applied to clarify site stratigraphy. The smallest scale of investigation is done by micromorphological observations to record microscopic changes in fabric and characteristic features.

The first results suggest, that the actual area is influenced by highly dynamic hydrological systems of radial and dendritic drainage networks with temporal swamp formation. Open-air sites and obsidian raw material outcrops are threatened by active gully erosion. A better preservation is given in the rock shelters, such as Sodicho. Several occupation sequences, with Later Stone Age lithic assemblages, alternate with thick volcanic ash layers. Environmental changes are indicated not only by the abrupt volcanic fallout but also a sterile clayish horizon – referring to the African Humid Period. In the future the obtained geoarchaeological data will help to improve the knowledge of human-environmental interactions in Northeastern Africa.

O-3021

## Environmental change in the Afro-alpine zone: a 16,000-year diatom record from the Bale Mountains, Ethiopia.

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### Abstract

Palaeoenvironmental records from high-altitude sites in eastern Africa are few in number relative to the numerous records from the rift valley, so knowledge of Late Pleistocene-Holocene environmental dynamics at higher altitudes is somewhat limited. Here we present a 16,000-year diatom and XRF-derived geochemistry record from Garba Guracha (3950 masl), a ~5 m-deep cirque lake in the Bale Mountains, Ethiopia. Key research questions include: i) Can we identify environmental changes equivalent to those known from lower altitude sites? ii) How does the diatom stratigraphy record changes in the lake and its catchment, and how are these changes related to climatic variations?

Diatom productivity was low during the Pleistocene-Holocene transition, the assemblage being dominated by shallow-water, ice-tolerant taxa. These conditions continued during the African Humid Period (11,700 - 4,250 cal. BP), but with increased organic productivity. Dominant taxa were the facultatively planktonic Fragilarioid species (*Staurosirella pinnata* and *Staurosira construens* var. *venter*). After ~4,500 BP the diatom assemblage changed to dominance by *Pseudostaurosira pseudoconstruens*, apparently in response to a reduction in woody *Erica* vegetation cover in the catchment, and drier climate. Benthic and aerophilous taxa also increased during this period, with a further increase in the last 150 years, probably reflecting reduced lake depth and increased aquatic macrophytes. Overall, the Garba Guracha record shows more subtle responses to Holocene climatic change than records from low-altitude sites.

**O-3022**

## **Heavy metal contamination of Northern Norwegian Younger Stone Age Seafood c. 4300 - 1900 BCE.**

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### **Abstract**

Prehistoric human seafood is generally considered safe and healthy. The analysis of a c. 2400 year deep time-line (c. 4300 – 1900 BCE) of the heavy metal toxins cadmium, lead and mercury in the Younger Stone Age human food chain in Arctic northern Norway suggests that this was not always the case. Investigations of the Atlantic cod (*Gadus morhua*) and harp seal (*Phoca groenlandica*) bone component of the marine food dominated diet indicate, at times, highly elevated levels of cadmium and lead and, to some extent, mercury. On average, those levels of cadmium and lead contamination were three to four times higher than today's recommended limits. The levels of mercury were generally below the presents recommended limit but still of considerable magnitude. This shows that human marine food in the Younger Stone Age of northern Norway, although almost certainly unknown to the prehistoric societies, was surprisingly unhealthy if not unsafe and may have had detrimental effects on individuals and society alike. This paper presents the data, methodology and results followed by a discussion of probable, global climate change driven, causes for the contamination including changes in temperature, sea-level change, erosion and melting permafrost.

O-3023

## A paleoenvironmental perspective on human-environment interactions during the Iron Age in the Lofoten Islands, Norway

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### Abstract

In the North Atlantic region, early human settlements were established in marginal agricultural environments and were susceptible to various environmental stressors. The Lofoten Islands have had an important role in the history of this region, particularly during the Iron Age (500 BC-AD 1050), when Lofoten developed from pioneering agricultural settlements to a prominent node of power and trade under Viking chieftains. Iron Age developments in Lofoten were concurrent with significant natural environmental changes, including variations in climate and sea level, which likely influenced early settlements. Our project involves an integrated archaeological and paleoenvironmental investigation of human-environment interactions on the island Vestvågøy. We are developing sedimentary records from isolation basins to reconstruct relative sea-level history, and from lakes in the main agricultural valleys to reconstruct early human-landscape impacts. These data are coupled with archaeological evidence that we have compiled from published literature as well as local cultural history archives. Here we present data from several sedimentary records that span the late Holocene from Vestvågøy. Reconstructions from two isolation basins show sea-level lowered ~4 m over the last 4.1 ka and provide perspectives on how coastal environments and harbor locations changed, particularly during the Viking Age (AD 800-1050) when maritime activity increased. We also infer spatial changes in landscape impacts based on the analysis of bulk organic geochemical data, pollen, and molecular biomarkers. Preliminary data indicate significant changes c. 2.5 ka, likely coinciding with early agricultural settlements, and after which the number and types of archaeological sites discovered increases. Overall, this project contributes a better understanding of how people have interacted with the environment in Lofoten in the past and how humans and landscapes have evolved through time.

**O-3024**

## **Long-term settlement on islands of SW Norway**

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### **Abstract**

Development-led archaeological excavations are the main providers of information about synchronic prehistoric human practices. In applying a cross-disciplinary approach combining archeological and paleoecological research strategies, new knowledge about the dynamic relations between humans and a changing environment, as well as a more profound understanding of long-term landscape change is achievable.

The settlement history and landscape development of the mainland of southwestern Norway is well documented by discrete archaeological, geological and palaeobotanical records, while there have been fewer studies in the island region. Recent archaeological excavations connected with the planning of a new coastal highway, bridging islands of the outer Boknafjord region, has however given access to new information about landscape and settlement. The archaeological objects and sedimentary records of the outer islands reveal a settlement history going back until at least the Middle Mesolithic. The sites were probably part of a settlement pattern based on logistic mobility, taking advantage of the variability in natural resources. The botanical analyses of an organic structure sealed under a raised beach, possibly remains of a human construction like a bark mat, and radiocarbon dated to the Middle Mesolithic period show the presence of mixed forest on the island during that time. High terrestrial biodiversity may have been an important attribute to the marine resources, and a reason why these coastal sites eventually were chosen for more permanent settlement. Although scarce availability of soil substrate on the islands, a farming practice with animal husbandry and cereal cultivation is evidenced from the Late Neolithic onwards until present day, comparable with the more well suited agricultural districts on the mainland.

O-3025

## Impact of climate and anthropogenic factors on vegetation history: an ancient DNA based vegetation reconstruction from Varanger, northern Norway

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### Abstract

Mortensnes (*Ceavccagead̥ge* in Sami) is a well-investigated archaeological site in northern Norway. It is also close to the eastern colonization corridor of Northern Norway, both in botanical and human terms, and is expected to provide a signal of early human interaction with vegetation in the past. Using sedimentary ancient DNA from Nordvitatnet at Mortensnes, we reconstructed temporal changes in the plant species composition of vegetation in this area for the first time. We also analyzed the sediments for loss on ignition (LOI), and other non-biological proxies. The sediment chronology covers the entire Holocene and part of the late Pleistocene. We identified about 40% of the taxa each to species and genus level, and about 20% of the taxa to tribe, subfamily, and family levels. Our results show a relatively species poor Late Glacial and Younger Dryas period, dominated by arctic taxa like *Dryas*, *Papaver*, and *Saxifraga oppositifolia*. The total plant species richness increased rapidly in the early Holocene, concurrent with increasing LOI, indicating a generally higher biological productivity. Nitrogen demanding species such as *Anthriscus sylvestris*, *Chamerion angustifolium*, and *Filipendula ulmaria* likely indicating anthropogenic activity in the vicinity of the lake, appear from around 11 000 cal. BP, the same time as the oldest dated archeological records from Mortensnes. The occurrence of pioneer species indicative of past climatic episodes suggests that the historical climate strongly affected vegetation in northern Norway, particularly during Late Glacial-early Holocene transition. During the Holocene, several ruderals and human activities appear concurrently suggesting anthropogenic factors as an important driver of vegetation change despite the anticipated low human impact in this region. Linkages in time between these compositional changes in vegetation and archeological events will be made in order to explore possible interactions between humans and vegetation development.

O-3026

## Late Holocene insect faunas and human impact in Greenland

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### Abstract

The impact of hunter gatherers on their environments has been the topic of lengthy debates and palaeoecological investigations with the emphasis on understanding specific signals which tie back to particular activities. In Greenland human impact of hunter gatherers in relation to a changing climate has been less studied, although there has been much discussion of the role of climate in the demise of Norse farming communities and the disappearance of pre-Inuit hunting groups. Palaeoecological research on hunter gatherers in Greenland has tended to concentrate on bone assemblages with limited research on other aspects of the flora and fauna. There has been some research on fossil insect assemblages from pre-Inuit (Saqqaaq) and Thule Inuit Greenlandic sites but there is need for more detailed study, expanding the groups identified to provide further information about the taphonomy and interpretation of the relevant assemblages. A large number of samples from Saqqaaq Qeqertasussuk at Disko Bay from around 4400 BP spanning around a thousand years are discussed in relation to previous work from the site and the cultural record of site use and abandonment. In addition, comparative results from a Thule Inuit midden near Nuuk at Kangeq dating from the 14<sup>th</sup> century onwards provide information from a period which overlaps with the demise of Norse farms in the inner fjords of the Western Settlement. Presence and abundance of taxa are considered as they may relate as much to seasonal activities by the hunters as to taphonomic processes. Results provide information for seasonal use and different modes of exploitation of materials. Data from different periods of occupation are examined and compared in order to understand better hunter gatherer subsistence, changes over time and abandonment. These hunter gatherer sites are discussed in the context of natural Greenlandic insect faunas examining human impact as a driver of change. A comparison with assemblages associated with Norse pastoralists indicates the different nature of human impact on their environments and provides information on the ecological footprints of different groups, which may have broader relevance in terms of understanding the development of man made environments. A number of species of insect are common to both hunter gatherer and Norse farming communities but several disappear with their unwitting hosts in the late Norse period and not all are re-introduced with renewed European occupation, farming and enforced sedentism in the last three centuries.

O-3027

## The role of fire in scrub clearance during the Norse *landnám*, Greenland

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### Abstract

The Norse *landnám* (Old Norse: 'land-taking') of Greenland began around AD 985 with the supposed arrival of 14 ships from Iceland. At the outset of colonisation, a potential obstacle to the establishment of Norse farmsteads was the birch-willow scrub that covered substantial areas of southern Greenland. Typically, pollen diagrams demonstrate that clearance of the scrub vegetation began at *landnám* and that this process was completed shortly thereafter. Burning has often been advocated as the main method of clearance used by the Norse settlers. This idea largely developed from the evidence of a small number early studies conducted in the Western Settlement. These reported visible charcoal horizons positioned stratigraphically prior to the palynological signal for human activity. A more substantial number of pollen and microscopic charcoal profiles are now available from different sedimentary contexts across southern Greenland. Many of these include detailed palaeoenvironmental records with high temporal resolution which can now be presented collectively, allowing a thorough and critical examination of hypotheses relating to the use of fire in Greenland by the Norse settlers.

Relative and accumulation rate (influx) microscopic charcoal data from the Eastern and Western Settlements of Greenland encapsulate not only the critical *landnám* horizon and the settlement period (~AD 1000-1400), but also provide information for the preceding centuries and those following the abandonment of the colony. Thus they provide baselines for the accumulation of microscopic charcoal particles in a sub-Arctic environment over substantive periods when there was no demonstrable regional human presence. The results show that elevated microscopic charcoal influx to lakes and mires was not restricted to the immediate years following *landnám*. High charcoal accumulation rates were sustained throughout the four centuries of settlement, over much of which time the pollen records indicate that scrub coverage had been reduced to a minimum. The data suggest that the case for widespread clearance of scrub vegetation by the Norse in Greenland through burning has perhaps been overstated. It would seem that a substantial proportion of the microscopic charcoal seen in sedimentary records was more likely to be derived domestically from fires used in heating and cooking.

O-3028

## Reconstructing landscape change at Cerro Benitez, Patagonia (52°S): new insights for megafaunal extinctions and human occupation.

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### Abstract

During the Last Glacial Maximum, a coterminous Patagonian ice sheet extended from ~38° to 55°S which would have posed a considerable geographical barrier to the colonization of the region by early hunter-gatherers. During the Late glacial, warmer climatic conditions drove rapid landscape changes characterized by retreating glaciers and the spread of vegetation that strongly reflected the regional east-west precipitation gradient and latitudinal movements in the southern westerly winds (SWWs). The region of Cerro Benitez, Ultima Esperanza, Chile (52°S) was successfully colonized by a rich fauna, including *Mylodon*, *Hippidion*, *Lama gracilis* and other camelids and carnivores such as *Smilodon* and *Panthera*. Archaeological evidence for sites of early occupation by *Homo sapiens* along the Andes is limited but a key site in southern Patagonia where human occupation has been extensively recorded is within a cave system on the flanks of Cerro Benitez. Human occupation has been established at Cueva del Medio at c. 12.6 ka, with signals of ephemeral human interaction with *Hippidion* and camelids.

To better understand the changing landscape during the Late glacial and the Holocene an 11m core was retrieved from a basin mire on Cerro Benitez. The record suggests deglaciation from the area sometime before c. 18 ka followed by relatively stable open grassland conditions that would have favoured a food chain dependent on large herbivores. A brief period of expansion of southern beech (*Nothofagus*) woodland at c. 13.8 ka suggests a response to more humid-temperate conditions before the contraction of tree cover during a return to colder conditions coeval with the Antarctic Cold Reversal and the apparent cessation in human occupation of Cerro Benitez. The rapid expansion of southern Beech forest at c. 12.1 ka indicates the onset of Holocene-like conditions and a dramatic change in resources and their accessibility provided by the landscape. The increase in southern beech forest and greater fire activity also coincided with the disappearance of the mylodonts. It is probable that the rapid loss of open grazing led to the local extinction of the large herbivores. During the Holocene the forest cover fluctuated, probably in response to latitudinal shifts in the focus and intensity of the SWWs. The early Holocene human occupation of the region may have been the result of exploration by a new community of hunter-gatherers adapting to the increasingly forested environment around Cerro Benitez. They targeted small rockshelters for habitation, diversified their diet by adding some coastal and forest subsistence resources and made a more informed use of the regional lithic raw material sources. Cueva del Medio itself was only revisited by hunter-gatherers c. 4.5 ka contemporary with an opening of the forest cover.

O-3029

## Simulating the mid-Holocene 'Green' Sahara and the potential relationship with future precipitation change

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### Abstract

The early to mid-Holocene in North Africa is a fascinating example of a fundamental natural environmental change. During this time much of the present-day Sahara was transformed by an expansion of vegetation and lakes. This transition was caused by a substantial increase in precipitation that resulted from the change in insolation that resulted from variations in Earth's orbit through time. However, simulations with a range of climate models have repeatedly failed to reproduce an adequate precipitation response for the mid-Holocene, raising questions about their underlying skill, and reinforcing concerns about the currently wide uncertainties on precipitation in future projections.

In this work we use a Bayesian methodology to optimise one of these general circulation models HadCM3. Simulations of the mid-Holocene with this model produce a relatively weak precipitation response over North Africa, with a minimal expansion of grass plant functional types. Following our optimisation which is based on a 150-member perturbed parameter ensemble, HadCM3 is able to reproduce the precipitation increase inferred from pollen samples for the mid-Holocene without any significant degradation of the present-day model simulation skill. We also investigate the role of moisture stress in shaping the coupled dynamic vegetation response. Based on an ensemble of present-day and mid-Holocene simulations, we find that a modest improvement in the simulation of present day arid region vegetation dynamics, also improves the vegetation response during the mid-Holocene.

Finally, we employ a statistical emulator to compare the simulations of the mid-Holocene with an equivalent ensemble of future-like simulations in which atmospheric CO<sub>2</sub> is doubled. We use these to identify how an improved simulation of North Africa in the mid-Holocene impacts the uncertainty distribution on precipitation in the 'future-like' state. We discuss processes that may contribute to the realism of this.

O-3030

## How blue was the 'Green Sahara'? Reviewing Saharan megalakes evidence for wetter environments

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### Abstract

The proposed paleoclimatic change in the Sahara based on shallow lakes and discharge deposits, flowing streams, and minor vegetation changes, is dwarfed by the suggested presence of very large (mega) lakes, ranging in surface area from 3000-350,000 km<sup>2</sup> at 15-35°N. We review the physical and biological evidence for these proposed megalakes, especially during the African Humid Period (11-5 ka). We point to the lack of evidence supporting the existence of such megalakes, including the absence of paleoshorelines, and of near-shore remodeling of adjacent ancient alluvial fans and bajadas. Outside the core of the Sahara, there is ample evidence in support of the existence of the vast Megalake Chad (10-18°N) during the African Humid Period. However, this lake system drains large areas of the tropics 5-10°N that experiences 1000-1500 mm yr<sup>-1</sup> of rainfall even today. An approximate shift of the rain belt by 5 degrees to the north would have increased dramatically the area of the watershed that experiences such precipitation amounts. A simple hydrologic model of the proposed megalakes areas requires mean annual rainfall 1000 mm yr<sup>-1</sup> or much more, and therefore, a northward displacement of the tropical rain belts by ≥1000 km. Such a profound shift is not supported by a range of other paleoclimate proxies nor by modeling efforts, therefore challenging the existence of such megalakes in the Sahara. In our view, published evidence for perennial water bodies in the Sahara is more consistent with the presence of isolated wetlands, discharging springs, and small shallow lakes (<50 km<sup>2</sup>), and hence no conjecture on tropical paleoclimate in the Sahara during the African Humid Period can be supported. In conclusion, pale-green, discontinuous, patchy wetter environments did exist in the Sahara, but their exact spatial distribution and magnitude should be reevaluated.

O-3031

## Modern Sr isotope hydrology as a basis for interpreting the 15 kyr paleo-record of Lake Chew Bahir, south Ethiopia

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### Abstract

Eastern African hydroclimate became significantly drier in the mid-Holocene at the termination of the African Humid Period (AHP; ~15 to 5 ka). This aridification resulted in the desiccation of many lakes and may have pressured hunter-gather societies to move towards concentrated pastoralist settlements at the shores of the few remaining lake areas or river valleys. During the AHP, Lake Chew Bahir, in the East African Rift System, was presumably expansive with a paleo-shoreline ~30 m higher than present day, and likely served as an important freshwater source and refugia. Today it is a predominantly dry playa mudflat with ephemeral swamps in the deltaic areas. Strontium (Sr) isotope ratios (<sup>87</sup>Sr/<sup>86</sup>Sr) preserved in carbonate-rich lacustrine strata provide regionally-specific records of past variability in weathering and regional drainage patterns. During humid episodes, the Chew Bahir catchment expands northwards to include the Chamo and Abaya catchments. As these catchment are dominated by younger volcanic lithology, with low Sr isotopic ratios, additional water inflow from here can potentially change the overall Sr isotope ratio of the lake water in Chew Bahir in a measurable way.

This study aims to reconstruct the hydrobalance of paleolake Chew Bahir using a three-step approach. We first establish the Sr isotope ratio of the input end members by sampling modern waters from the Chew Bahir and adjacent catchments, including groundwater, lakes, springs and rivers. We then analyse the Sr isotope ratios of microfossils from the time period of the most recent AHP lake level high-stand from three short cores (CB05, CB06 and CB03) along a transect from the centre to the western margin of the Chew Bahir basin. Finally, we use the paleo Sr isotope record over the last 15 ka to develop an isotopically-enabled hydrobalance model to quantify past lake levels. Over the last ~15 ka <sup>87</sup>Sr/<sup>86</sup>Sr ranges from 0.7059 to 0.7066, with higher values during the start of the AHP, decreasing towards the termination. This suggests a larger input of water entering paleolake Chew Bahir from the northerly catchments and paleo-connectivity of these lake systems during humid periods. This study provides valuable data for reconstructing millennial-scale change in hydrobalance and freshwater availability, in a highly-sensitive climate region, over a key time period for the transition from hunter-gather societies to pastoralism.

O-3032

## Quaternary dune generations on northern Fuerteventura

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### Abstract

Aside the long lasting research history concerning the origin of the Canarian archipelago, also the carbonate sands aroused interest since the first investigations by Humboldt in 1779. Especially the Eastern Canary Islands (Lanzarote, La Graciosa and Fuerteventura) show huge deposits of dune generations (the oldest are dated to >450 ka) intercalated by reddish layers. Generally, these archives consist of I. carbonate sands, II. dust deposits and III. material of volcanic origin (tephra, lapilli and basaltic debris). The studied sequences reveal a recurring pattern, starting with a) deposition of carbonate sands, followed above by b) deposition of dust accompanied by weak soil forming processes, lowering the sediments resistivity against c) water induced relocation, finalising one sequence.

The supply of carbonate sands depends on sea level changes. We assume highest sand supply to occur right after sea-level maxima during periods of falling sea level (Fig. 1). Whereas during periods of rising sea level the sand supply is decreased to the benefit of dust imprint. The southward shifting of the Westerlies during glacials goes ahead with extending ice volume (and falling sea level, by implication). Consequently, during sea level low stands, the Canarian archipelago is effected by more moisture conditions induced by the increased influence of the Westerlies. These conditions favour the deposition of dust, enable weak soil forming processes and initiate water induced relocation.

For some decades, features of reddened silty layers were interpreted as results of strong soil formation. In contrary, our analytical findings support the assumption that these reddish layers are mainly related to aggrading iron loaded dust deposits since the in situ soil forming processes seem to be restricted to slight de- and recalcification processes and some oxidation of iron and manganese.

Finally, we want to focus on the site-specificity within these archives and the influence of the local volcanism completing the complexity of the investigated dune archives, making them both challenging but so much interesting in the same way.

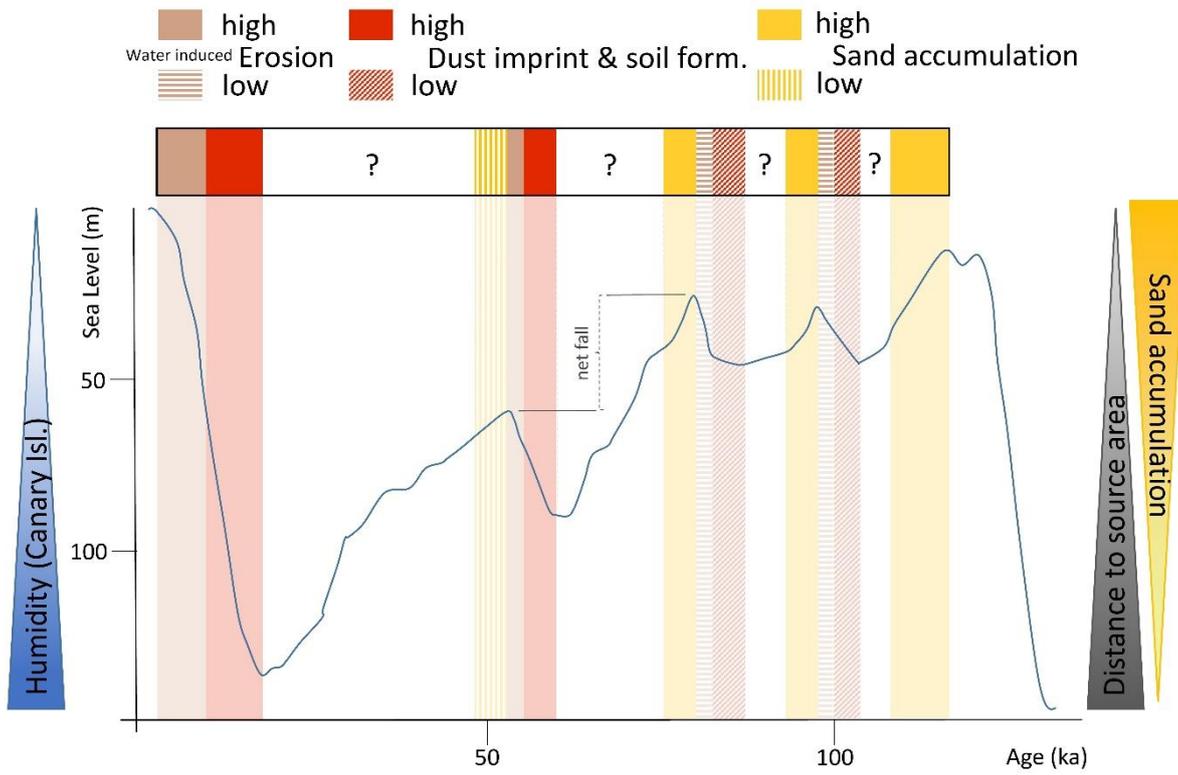


Fig. 1 Conceptual approach of process relation to sea level fluctuation.

O-3033

## Modelling late Quaternary surface hydrology changes and climate feedbacks over African drylands

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### Abstract

Historical and Quaternary palaeoenvironmental archives from northern and southern Africa indicate phases of extreme wet/dry conditions of much greater amplitude than the variability seen in recent observations. Such variability of hydroclimate has also been strongly linked to ancient human adaptation and migration. The most well documented wet phase is the African Humid Period (AHP; ~14,000 to 6000 years ago), during which North Africa experienced expansion of wetlands, river systems, and lakes. This occurred as a response to orbitally driven changes in the seasonality of insolation, leading to strengthened summer monsoons. Similar wetter conditions have been documented at various times for southern Africa, including the expansion of mega-lake Makgadikgadi. Recent studies suggest that African wet-dry phases may have resulted from small changes in the magnitude of hydroclimate variability and/or more persistent conditions. African dryland regions have been found to have some of the strongest land-atmosphere coupling strengths in the world, where surface hydrology feedbacks significantly amplify small changes in precipitation. Yet, interactive feedbacks with variable lakes/wetlands are missing from most climate models.

Here, we investigate simulating changes to surface hydrology over African dryland regions during the late Quaternary, and whether including feedbacks with lakes/wetlands enables improved simulations of large swings in palaeohydroclimate. We will present results from two components of the study. Firstly, idealised AHP climates (based on palaeoclimate data) were used to drive the JULES land surface model, a statistical overbank inundation model, and a surface hydrological model to simulate river discharge, wetland inundation and inland lakes. The distribution of inland water bodies at the AHP and present-day were compared to palaeo and modern hydrological data. Secondly, we incorporated surface water area changes into the new UK climate model, HadGEM3.1, both as prescribed changes during the AHP, and subsequently interactively using the land surface/hydrology models. We will compare simulations of the AHP with and without interactive inland water bodies to examine the impacts of the introduced feedbacks.

O-3034

## Revisiting the palaeohydrology of the Nama Karoo – late Pleistocene lake high stands and associated archaeology in the South African interior

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### Abstract

In the 1970s and 1980s several late Pleistocene palaeo-lakes were proposed to have existed within the South African interior. In particular, the ~44 km<sup>2</sup> Alexandersfontein pan, south of Kimberley, in the central interior summer rainfall region, was identified as providing evidence for major lake phases at 19 and 17-13 ka. The presence of Middle Stone Age (MSA) and Later Stone Age (LSA) artefacts within stratified deposits, rather than as surface lags, was also noted. In the context of a broader study considering geomorphic evidence for palaeohydrological change across the interior of South Africa, we present new results from Alexandersfontein, as well as from two large pans, Swartkolkvloer and Grootvloer, which are part of the Fish and Sak River catchments to the west. Our aims are to: 1) provide much more robust constraints on the timings of palaeohydrological change and, where possible, first age constraints on stratified archaeological materials; 2) provide more detailed descriptions of the character of the archaeological materials (and their contexts) across these sites. The dating programme encompasses new radiocarbon dating, the application of single grain luminescence dating, and preliminary attempts to apply cosmogenic dating and U-Series methods.

At Alexandersfontein radiocarbon dating of lacustrine clays exposed at the northern margin of the site implies the existence of a late Pleistocene high stand ~14 m above the modern pan at ~32,100 cal yr BP. OSL ages indicate the overlying colluvial sediments are all younger than 10-12 ka. A key locale identified within the Alexandersfontein system is the Mauritsfontein site, where recent aeolian sands (luminescence age ~2.7 ka) overly a sequence of lacustrine silts and a well-developed calcrete, which can be traced across the site. The latter contains *in-situ* MSA lithics and is the subject of U-series dating analyses. At Swartkolkvloer an impressive double shoreline system (at +5 and +10 m) dates to between ~27,400 and ~40,500 cal yr, BP, while at the southern margins of Grootvloer (to the north), freshwater mussels have now been dated to ~20,600 cal yr BP.

Additional radiocarbon, luminescence and U-Series results from all of these sites will be presented. The results thus far imply the existence of several substantial (potentially >120 km<sup>2</sup> in the case of Swartkolkvloer) lake systems during late MIS 3 and during MIS 2. This is broadly consistent with recently identified evidence for more humid conditions during late MIS 3/early MIS 2 elsewhere in the western interior. The potential causes will be considered. Of particular significance is the identification of stratified MSA lithics. Given that this is a rare occurrence in the interior, where the archaeological record is largely surficial, these sites also present opportunities to provide numerical age constraints on human occupation(s) of this region.

O-3035

## Re-visiting Williams Point at Kati Thanda–Lake Eyre as a recorder of long-term climate change in Australia’s arid interior

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### Abstract

Williams Point is an iconic late Quaternary sedimentary sequence exposed at the margin of Madigan Gulf at Kati Thanda – Lake Eyre, Australia's largest lake. The 15 m high cliff outcrop is capped by ~ 5 m of the Williams Point Aeolian Unit (WPAU), which overlies a thin (< 0.5 m) beach/shoreline facies, and 5 – 6 m of fluvio-lacustrine facies. Previous researchers (Magee et al., 1995; Magee et al., 2004) have used this sedimentary sequence as critical evidence of hydrological change throughout the last glacial cycle over a large proportion of Australia’s arid interior. We present a revised chronology using single-grain optically stimulated luminescence within a Bayesian modelling framework. We evaluate the evidence of prolonged pedogenesis in the upper parts of the fluvio-lacustrine facies and we re-examine the WPAU, which contains abundant eggshell of large flightless birds (*Dromaius novaehollandiae* and the extinct putative *Genyornis newtoni*).

Our new data highlights that the lacustrine facies at the base of the cliff (interpreted to represent shallow, but oscillating lake water levels) were deposited  $130 \pm 16$  ka to  $113 \pm 20$  ka. An unconformity separates the overlying fluvio-lacustrine phase with all eight samples indicating fluvio-lacustrine deposition at  $85.9 \pm 3.3$  ka. An erosional unconformity separates this unit from the overlying Coxiella beach facies which itself dates to  $70.4 \pm 4.4$  ka ( $n = 2$  samples). This beach facies is interpreted to represent a regression shoreline with a water level ~ 12 m deep. The overlying WPAU dates to  $48.1 \pm 6.1$  ka ( $n = 3$  samples), slightly younger than previously identified. Importantly the WPAU has formed at the same time (within errors) of the last megalake phase of Lake Eyre at  $48 \pm 2$  ka (Cohen et al., 2015). The topographic position of the WPAU and the new chronology demands that this gypsiferous aeolian unit has formed as Lake Eyre has receded as it underwent a hydrological transformation. This would suggest that the putative *Genyornis newtoni* has indeed become extinct at a time period of extreme hydrological change. These results bring a fresh perspective to a site that has had a big influence on previous views of the Quaternary history of Australia’s arid zone.

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O-3036

## Proximal – marine distal tephra links of Santorini explosive volcanism for the past 200 kyrs

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### Abstract

Santorini volcano (Eastern Mediterranean Sea) has been violently explosive active over the last ca. 360 kyrs, producing thick pumice and scoriae deposits in the proximal area from twelve major Plinian and numerous interplinian eruptions. However, tephra chronological information is sparse and the distal tephra record is incomplete mainly due to the lack of glass chemical data sets that enable proximal-distal tephra correlations and the difficulty of obtaining reliable numeric age dates from proximal deposits. This gap in knowledge has several implications for both volcanological and palaeoenvironmental studies. On the one hand, eruption frequencies, magma volumes and tephra dispersal directions of this high-risk volcano are difficult to estimate; on the other hand, the present uncertainties in tephra assignments yield serious constraints for the independent dating of palaeoclimate records in the Eastern Mediterranean region.

In this study, we present new proximal geochemical glass data of all major and some minor Santorini eruptions. We use this dataset in order to establish precise correlations with numerous visible and non-visible (crypto) tephra layers of Santorini provenance in three marine sediments cores from the SE Aegean Sea. Cores M40/4-65 (KL49), LC21 and M40/4-67 (KL51) form a 250 km medial-distal to distal transect SE of Santorini and span the last ca. 80 kyr, 160 kyr and 200 kyr, respectively. Their chronologies have been established by combining tephrochronology and new age estimates of sapropel boundaries via orbital chronology (KL49, KL51) as well as alignment of foraminiferal oxygen-isotope data with the Soreq speleothem  $\delta^{18}\text{O}$  curve calibrated via U/Th disequilibrium dating (LC21; Grant et al., 2012). These age models enable the precise dating of marine tephra layers and, through geochemical correlation with proximal Santorini deposits, provide more reliable time constraints of all Plinian and some interplinian Santorini eruptive events than previously obtained numeric ages of proximal deposits (e.g., Druitt et al., 1999).

Our new tephrostratigraphic record from the SE Aegean Sea furthermore allows for a more detailed reconstruction of tephra dispersal directions for the last 200 kyrs of Santorini volcanic activity. Both the proximal and marine tephra glass chemical and chronostratigraphical datasets provide a basis for future distal tephra correlations that can help to facilitate the correlation of marine and terrestrial palaeoclimate proxy data in the Eastern Mediterranean region.

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O-3037

## Tephrostratigraphic insights from Lake Ioannina, North West Greece

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### Abstract

The palaeoenvironmental record of Lake Ioannina (NW Greece) is an important archive of Quaternary climate and ecological change in the Mediterranean region. The pollen record from Ioannina is argued to contain a clearer representation of vegetation response to millennial-scale climate variability than other eastern Mediterranean records, due to the persistence of tree populations in nearby refugia, allowing a rapid ecological response to abrupt changes in climate (Tzedakis, 2002). Developing an independent chronology for the site to allow the study of these millennial-scale changes, particularly the comparison of their timing and impacts to those identified in other regional records, has proved challenging. These challenges arise from low organic content of the material and older ages associated with radiocarbon dating of sediments from karstic environments, where the underlying geology adds 'old', inert carbon to the system. Tephrochronology offers a key means of building age-depth-models for such sites.

Here we present the findings of tephrostratigraphic investigations of the 38 metre I-08 core from Lake Ioannina, which spans the last ~50 kyrs BP. Both visible and crypto-tephra horizons have been detected in the core. Geochemical analysis has been used to identify tephra layers associated with explosive volcanism at Italian volcanic sources, including Campi Flegrei, Pantelleria and the Aeolian islands. The identification of multiple layers associated with the eruption of Campi Flegrei following the 38 ka BP Campanian Ignimbrite super-eruption provides an exciting challenge and raises important questions about the detection of reworked material both prior to and following tephra layer deposition in the lake. These tephra horizons provide a chronology for the I-08 core, as well as facilitating the direct correlation of this record with other Mediterranean pollen records such as Lago Grande di Monticchio (S Italy), Lake Ohrid (Albania), and Tenaghi Philippon (NE Greece).

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O-3038

## New major element analyses of proximal tephras from São Miguel confirm a link between the Azores and mainland Europe

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### Abstract

The Azores archipelago is one of the most active volcanic areas in the North Atlantic region. Approximately 30 eruptions have been reported over the last 600 years with some major VEI5 eruptions further back in time, e.g. the Fogo A eruption, 5600 cal yr BP. The geochemical composition of associated tephra-derived glass, however, is not well characterized. An Azorean origin of cryptotephra found in distal areas such as North Africa, the British Isles and Greenland has been suggested, but proximal data from the Azores are scarce and the correlations have been tentative at best. These tephra have a trachytic composition which excludes an Icelandic origin. Johansson et al. (2017) presented major element analyses of proximal tephra-derived glass from five Holocene eruptions on the Azores Islands. There is a striking geochemical similarity between trachytic tephra from volcanoes on the São Miguel island and cryptotephra found on Ireland (e.g. Chambers et al., 2004; Reilly & Mitchell, 2015), and especially with eruptives from the Furnas volcano. New EPMA analyses of samples taken in 2018 confirm and strengthen the link between Furnas and Irish cryptotephra, e.g. between the Furnas AD 1440 eruption and the Irish MOR-T2 tephra (e.g. Chambers et al., 2004). We also suggest a correlation between a previously unsourced tephra found in a Swedish bog with an eruption of the Sete Cidades volcano ca 3600 cal BP. We conclude that trachytic tephra erupted from explosive eruptions on São Miguel have a potential to contribute to the construction of a European-wide tephrostratigraphic framework.

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O-3039

## South West England: A Holocene tephrostratigraphical treasure trove

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### Abstract

Volcanic ash is useful for helping us understand records of past environmental change. It provides us with independent marker layers in sediment from which the timing of key environmental and climatic changes can be assessed and geographically disparate sites in different settings can be linked (oceans, peat bogs, lakes, ice cores). It also provides us with a means by which to test the robustness of other chronological techniques and can help us refine age estimates obtained using methods such as radiocarbon dating. In the historical time frame, many ash layers have uncertainties of only a year or less, and throughout the Holocene many can provide ages on sequences with less than +/-100 year uncertainty. Cryptotephra was first identified in the UK in Caithness, Northern Scotland (Dugmore, 1989), with the recognition of Icelandic ash within peat. The subsequent 30 years have seen a significant rise in the number of researchers employing this technique and as a result of methodological and analytical advances we are now able to characterise very low concentrations of ash in sequences in areas remote from volcanic centres.

The application of tephra analysis to the peatlands of southwest England represents a much more recent spatial extension of the technique. Hall and Pilcher (2002) first reported that there are 'extremely sparse tephra layers on Dartmoor'; however, at that time, they were unable to characterise them. This was followed up by Matthews (2008) who's work on Roman Lode, Exmoor identified and characterised 3 ash layers (Hekla 1947, Hekla 1510 and OMH-185) covering the period back to c. 2700 cal yrs BP. Subsequently, Fyfe et al. (2016) identified five distinct ash layers on Dartmoor, and Watson et al., (2017) reported on the identification and chemical characterisation of two ash layers on Bodmin Moor, Cornwall (likely the AD 860 A and B ash layers), demonstrating that far-travelled ash is able to reach this region of the UK.

Here we report a more in-depth study of tephra in peat sequences on Exmoor and Dartmoor which was borne out of the Exmoor Mires partnership (<http://www.exmoormires.org.uk>). This has identified considerably more volcanic ash layers in the south west extending back to over 9000 cal yrs BP and originating from a number of volcanic centres. This provides us with an exciting opportunity to study the timing of key environmental changes in southwest England and also to assess how these compare to other parts of the UK, Ireland and Northern Europe.

O-3040

## Initiating cryptotephra research in Iceland

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### Abstract

Icelandic tephrochronology is the result of a long line of research and consists of geochemically well characterized and well dated tephra horizons. However, there is no one site in Iceland which would hold a complete record of all the silicic major tephra marker layers, which traditionally form the core of the chronology. Because the extent (of the dispersal area) of a visible tephra layer is determined both by the intensity and the length of the eruption as well as the prevailing wind directions during the eruption, most of the marker layers in Iceland are visible only within a certain sector extending away from the source volcano. Additionally, the tephra preservation potential may vary through time in any one site due to changing environmental conditions, which contributes to gaps in the tephra stratigraphy of a single site. Some amount of tephra grains is, however, expected to be deposited over a larger area and to be preserved as a cryptotephra layer.

We therefore suggest that initiating cryptotephra research in Iceland would increase the chances of constructing a more complete tephra stratigraphy for any single site, as well as help to strengthen the dialogue between tephrochronological frameworks of Iceland and distal areas. For an example, the cryptotephra findings in Northern Europe indicate that surprisingly many silicic tephra layers may yet be missing from the Icelandic tephrochronology. These tephras could possibly be present as cryptotephra layers in Iceland as well.

The focus of our research is in improving the early Holocene tephrochronology of North, East and Northeast Iceland by using both visible and cryptotephra layers. We conducted a systematic cryptotephra search in six sites by taking the following steps: 1) continuous high-resolution subsampling of peat cores and organic-rich soil sections 2) sieving accompanied by density separation where necessary 4) electron probe microanalysis of tephra geochemistry 5) constructing tephra stratigraphy for each site and 6) establishing between-site correlations of tephra layers by using both major element biplots and correlation coefficients.

Our preliminary results reveal the presence of at least six separate geochemically confirmed cryptotephra deposits between the Hekla 5 and the Saksunarvatn tephras in the inspected soil and peat sequences. For example, the silicic Fosen/Reitsvík tephra (ca. 10,200 BP) which was detected as a visible layer in just one of our sites, forms a cryptotephra layer in the five others, and can therefore be used as a secure tie-point between all our sites. So far our results suggest that cryptotephra method works well in the Icelandic conditions, at least in the organic-rich soils and peatlands, and holds great promise for future tephrochronology projects.

**O-3041**

## **Establishing (crypto-)tephrostratigraphic frameworks: a case study of the Last Glacial-Interglacial Transition in the British Isles (c. 16-8 ka BP)**

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### **Abstract**

The use of cryptotephra deposits as time-synchronous markers has become an important tool in the investigation of Quaternary records. When reliably identified, cryptotephra offer improved chronological control for records in which they can be traced, in turn helping to build a better understanding of the spatial and temporal complexities of environmental, geological and archaeological change. However, the use of cryptotephra for this purpose can be hampered by issues relating to: i) stratigraphic integrity; ii) chemical composition; and iii) chronological precision. Here we present the collective results of cryptotephra investigations conducted on more than 50 sites in the British Isles which span the Last Glacial-Interglacial Transition (LGIT; c. 16-8 ka BP). This collective evidence represents one of the most detailed studies of tephra deposition for this interval anywhere in the world, revealing that as many as 26 tephra fall deposits may be represented, with the great majority originating from the Icelandic province. These tephra are ranked as to their potential to serve as isochronous tie lines, based on the robustness of available evidence with respect to stratigraphic consistency, glass analytical data and chronological control. Currently, 15 of the 26 candidates are considered useful isochronous markers, while the data obtained from the remaining 11 are considered insufficiently robust. The issues encountered in the development of this framework are not unique and we hope that the approach applied here will find relevance in the wider tephra community. We also present preliminary results from on-going research that aims to extend and improve this tephrostratigraphical framework for the LGIT interval in the British Isles.

O-3042

## The Greenland tephra repository: uncovering the source and timing of distant eruptions

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### Abstract

Polar ice-cores have long been recognised for their value as repositories of volcanic activity. Unsurprisingly, tephra deposits from local eruptions dominate these records. However, improvements in micro-sampling and analytical techniques have uncovered a range of cryptotephra erupted from exceptionally distant eruptive sources. For instance, in the Greenland ice-cores, tephras from five different volcanic regions (Japan, Kamchatka, Cascades, Alaska and Iceland) have been identified during a short mid-Holocene window. This highlights the pivotal position of the Greenland ice-cores to capture deposition from the convergence of several far-travelled ash clouds. Their position in the ice provides high-precision age estimates from known eruptions such as Hekla 4, KS-2, Mazama and Mashu (-f-j), which can be employed as chronological constraints for other proxy records where these deposits are also preserved. Moreover, major and trace element signatures afford an opportunity to explore the distinct nature of tephra compositions originating from different tectonic settings. This is especially important for constraining the origin of unidentified sulphur peaks in ice-cores and optimise our quest to identify tephras from low-latitude eruptions. We present our micro-analytical approach to analyse small, fine-grained ash particles extracted from the ice and scrutinise the process of pinpointing eruptive sources.

**O-3043**

**The geomorphology, controls and dynamics of southern African dust sources.**

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**Abstract**

This presentation examines the landforms of southern Africa associated with contemporary dust emissions. These sources include dunes, soils, rivers and pans from across Botswana, Namibia and South Africa. Emissions are examined considering sand/silt and clay composition and include abrasion and saltation processes. Supply settings and availability dynamics are determined by both climatic and anthropogenic factors and are varied in both space and time. Particular focus is placed on the dunes of the Kalahari, Namibian west coast dunes, coastal sabkhas, rivers and gravel plains, inland playas of the Namib and Kalahari, large ephemeral basins of Etosha and the Makgadikgadi as well as South Africa's Arenosols.

**O-3044**

## **Intersections between wind regimes, topography and sediment supply: Perspectives from Central Asian dunes and dust**

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### **Abstract**

The widespread aeolian deposits of the Central Asian steppes and piedmonts offer great potential to better understand the dynamics of, and interactions between, the major northern hemispheric climate subsystems of Eurasia over Quaternary timescales. However, there is a problem with established assumptions linking climate processes with dust generation and aeolian deposition in the arid Central Asian context. Emerging datasets from the Tien Shan piedmont suggest that 1) hypotheses assuming a connection between increased loess accumulation and cold glacial conditions do not hold for this region, and 2) mass accumulation rates, and the timing of peak dust flux, are highly variable from one site to another. These results raise questions as to the nature of the relationship between loess accumulation, aeolian flux and palaeoclimate.

Here we investigate the relationship between wind regimes and the distribution, morphology and timing of dunes and dust in the Ili Basin, spanning southeast Kazakhstan and western China. Our findings, based on GIS and geomorphic mapping, wind trajectory reconstruction, geochemical provenancing and loess chronostratigraphy, indicate that:

- Dominant wind strength and aeolian transport capacity varies strongly across the basin, most likely in response to the obstructing influence of the Tien Shan mountain ranges;
- Ripples overlying linear dunes in the central basin directly correspond to short-term wind-storm events;
- Linear dunes preserve variable orientation across the basin, reflecting variability in the vector of dominant sand-shifting winds, over timescales where sand supply was plentiful;
- Dust sources for loess deposits vary across the basin depending on wind regime and supply, indicating more dominant local supply in the east, and increasing distal contributions to the west;
- The timing of loess accumulation varies substantially across the basin; there is no uniform, contemporaneous draping of dust along the piedmont.

Our integrated approach provides more nuanced information about aeolian processes in relation to wind regimes not otherwise available from site-specific case studies, and highlights a need to interrogate climate-driven models for aeolian deposits.

O-3045

## Loess, dust, parna: unravelling the conceptual continuum in Australasia for improved paleoenvironmental reconstruction in the Quaternary.

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### Abstract

There are a variety of both mechanisms and geomorphic processes which generate, sort and concentrate silt-sized grains: entrainment by wind, then deposition by aeolian processes follow. This can occur in semi-arid to temperate to periglacial geomorphic units. Loess is an accepted term in New Zealand for aeolian, silt-sized deposits of glacial origin. In Australia, a varied terminology ranging from parna, to dust to lithogenic fluxes are all employed to describe aeolian silt sized deposits, generally accepted to be sourced from semi-arid environments.

This range of terminology can be a source of confusion and has likely arisen from historical constructs during the development of loess research world-wide. But what we do know is that aeolian sediments and their associated soils in both Australia and New Zealand encompass a wide range of particle size, mineralogy and geochemistry. This reflects differences in the dust source of the contributing regional geomorphic units, dynamics of dust emission from the differing geomorphic units as well as post sedimentary changes to the dust deposits (pedogenesis) driven by gradients of aridity and weathering.

We aim to demonstrate that despite these differences, loess, dust, parna also exist on a continuum, influenced by gradients of aridity, weathering and particle size. We will do this by deconstructing some specific examples in Australia and New Zealand. We compared the different provenance, formation pathways, mineralogy and geochemistry for these sediments using a range of techniques including optical micromorphology, granulometric analysis and QEMSCAN<sup>®</sup> analysis.

In Australia (southern NSW), microfabric analysis demonstrated a continuum of pedogenesis of the associated parna soils along gradients of aridity and weathering. In New Zealand, the transport pathway for the loess mantled landscape in the Manawatu district (North Island) is generally accepted, but the morphological and chemical difference between the soils developed on the drier terraces (Tokomaru) compared to those on the moister terraces (Dannevirke) is still not fully understood. On comparing the mineralogy and geochemistry, the dust / parna in Australia is dominated by quartz and clay, and little plagioclase feldspar. While in New Zealand (Manawatu), the grain size distribution of the two soils are very similar. The Dannevirke soil mineralogy is dominated by kaolinite and chlorite while the Tokomaru soils have a greater proportion of weatherable mineral grains.

We discuss the results in terms of the conceptual differences in the transport pathways and pedogenesis of loess and how this can inform our ability to reconstruct Quaternary paleoenvironments, and ultimately contribute to improved numerical models of the dust cycle.

O-3046

## New Zealand as a potential source of mineral dust to the atmosphere and ocean during glacials

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### Abstract

The geochemical composition of sediments and dust can be used to trace their provenance, thereby providing insights into a range of Earth surface processes. During past glacial climates, much of New Zealand was blanketed by temperate erosive glacier systems, which produced significant volumes of sediment. To trace the extent of subsequent aeolian and oceanic transport of this material, and thus its potential impact on climate and ecological systems, we characterized the geochemical composition of sediments. We present geochemical analyses, including Sr-Nd-Pb isotopes and major/trace elements, of more than 20 fine-grained (<5  $\mu\text{m}$  diameter) sediments from the major dust- and sediment-producing regions of the South Island. We find that sediment composition strongly reflects local lithology. The central South Island, including the Canterbury Plains and Mackenzie Basin, has a relatively homogenous isotopic composition, with  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7095\text{-}0.7165$ ,  $\epsilon\text{Nd} = -6.5$  to  $-4.0$ ,  $^{208}\text{Pb}/^{207}\text{Pb} = 2.470\text{-}2.485$ , and  $^{206}\text{Pb}/^{207}\text{Pb} = 1.198\text{-}1.215$ . The southern South Island, including Southland and Otago, has an isotopically younger and more variable composition, reflecting the presence of Paleozoic volcanic complexes. Here  $^{87}\text{Sr}/^{86}\text{Sr} = 0.7041\text{-}0.7140$ ,  $\epsilon\text{Nd} = -4.0$  to  $+5.3$ ,  $^{208}\text{Pb}/^{207}\text{Pb} = 2.463\text{-}2.483$ , and  $^{206}\text{Pb}/^{207}\text{Pb} = 1.196\text{-}1.208$ . We make comprehensive comparisons to available isotopic data from other Southern Hemisphere mid-latitude dust sources, finding that while isotopic fields often overlap, the combination of Sr, Nd, and Pb isotopes offers improved ability to discriminate between potential source areas. We estimate the expansion of glacial outwash plains based on a sea level lowering of 130 m at the Last Glacial Maximum (LGM), and find that the Canterbury Plains likely covered an estimated 38,500  $\text{km}^2$  while the Southland/Otago Plains may have extended to 50,500  $\text{km}^2$ . Considering New Zealand's extreme uplift and erosion rates ( $\sim 10$  m  $\text{kyr}^{-1}$ ), we suggest that the South Island, though limited in extent compared to larger Southern Hemisphere landmasses, may have served as an important dust source to the high-latitude atmosphere and ocean during glacial periods.

**O-3047**

## **Automated static image analysis technique to identify Saharan dust particles within unconsolidated eolianites on Fuerteventura**

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### **Abstract**

The identification of windblown dust in regions located relatively far from major dust source areas is an intriguing problem of sedimentary studies. The identification of external mineral particles is rather challenging, however, in certain cases the geological-geomorphological environment provide suitable conditions. The island of Fuerteventura is free from quartz and just bears basaltic rocks and carbonate sands originating from the shallow shelf. Therewith the islands dune sequences are placed best to serve as a natural laboratory for our investigations of quartz-rich, silt-sized Saharan dust deposits.

An automated static image analysis method completed with Raman spectroscopy was applied in this study to identify and separate Saharan mineral particles from Upper Pleistocene sedimentary units.

The captured high-resolution grayscale images of ~50,000 individual mineral particles per samples allowed us to apply different independent approaches. Beside bulk grain size and grain shape characterization, (a) sedimentary subpopulation partition by parametric curve-fitting, (b) Raman spectroscopy based quartz particle identification, and (c) grayscale intensity mean values of particles (relatively high values were used as a proxy for quartz grains due to the finding of a strong correlation between light transmissivity of grains and chemical identity) were used.

The presented set of methods provided new data on the granulometric character, the depositional mechanisms and the admixture of dust material to sandy units. Joint applications of several size, shape and grayscale intensity values and mathematical techniques allowed the separation of quartz grains from other mineral particles.

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O-3048

## Loess deposition and remobilization in an ice-marginal landscape

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### Abstract

Considerable loess research has focused on systems of silt generation and eolian transport, and their ties to paleoclimate. In our study area in western Wisconsin, USA, just outside the Last-glacial margin, most of the silt was derived from broad outwash valleys and transported on westerly winds, often assisted by saltating sand. Normally, such systems lead to continuous blankets of loess downwind from the source area. Across the hilly, sandstone landscapes of western Wisconsin, this initial phase of loess deposition probably began shortly before the last glacial maximum and continued through the early period of glacial recession, ca. 23-18 ka. Across this ice-marginal landscape, much of this loess was deposited on ground rife with permafrost. We will argue that the landscape underlying this initial loess deposit was later destabilized by thawing permafrost, leading to widespread slumping and mass movement of loess across steep hillslopes, exposing loess deposits to strong winds and saltating sands. Our data will show that this combination of events and circumstances led to widespread landscape instability, facilitating reentrainment of this "initial" loess during a secondary period of silt transport. Much of this loess, which we refer to as "secondary" loess, was deposited at sites farther downwind. Because of the hilly topography and assumedly strong winds at this time, transport and deposition of much of this secondary loess was strongly influenced by the bedrock topography. Thick deposits of secondary loess, often burying "primary" loess below, formed in protected sites on the lee (SE) sides of the highest hills. These deposits approach thicknesses of 7 m. Conversely, the northwest-facing hillsides were windswept and are today loess-free. Ventifacts are commonplace on this landscape, attesting to a period of strong winds and widespread erosion. The result of these eolian depositional-erosional events is a loess cover that is highly spatially variable, and in places, of two distinct ages.

We report on stratigraphic data from one of the thickest loess sites in the region, where >5 m of loess cap a hilltop. Western and northwestern flanks of this hill are loess-free. Our down-core data on texture and geochemistry, as well as OSL ages, clearly indicate a stack of younger, sandier loess overlying a siltier, older unit. The broader implications of this loess "stack," all of it entirely postglacial in age, will be the focus of this paper.

O-3049

## A tale of two dune fields: dust emission processes from White Sands, New Mexico and Monahans, Texas, USA

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### Abstract

Research focusing on dust emissions from eolian dunes has recently increased as researchers recognize the importance of improving global emissions estimates and detailed characterization of dust sources. The well-sorted nature of eolian sand has precluded dunes from being considered as major sources of dust because most dune fields contain a very low percentage of dust-sized material. However, dust emission potential of dune fields can be quite variable on a landform scale, related to grain size distribution, mineralogy, and processes contributing to grain abrasion during saltation transport. We used the Portable in situ Wind Erosion Lab (PI-SWERL) to measure the PM-10 dust emission potential from a variety of geomorphic units comprising two dune fields: the White Sands dune field in New Mexico, dominated by gypsum, and the Monahans dune field in West Texas, dominated by quartz. These dune fields contain landforms with variable sedimentologic properties, including large active dunes, protodunes and sand sheets, stabilized and vegetated dunes, and fine-grained interdunes. Deflation of playa at White Sands leads to low-relief protodunes to well-developed dunes. The eolian sand is well sorted and contains <1.5% fines. The Monahans dunes are sourced from the Pecos River and transition from low relief vegetated sand sheets with >10% fines, to vegetated parabolic dunes, to active and partially stabilized dunes containing <3% fines at the dune field core. PI-SWERL tests reveal that Monahans sand sheet would be a prolific dust emitter if the vegetation was destabilized ( $1.21 \text{ mg m}^{-2} \text{ s}^{-1}$  PM-10). Vegetated parabolic dunes are moderately emissive ( $0.31 \text{ mg m}^{-2} \text{ s}^{-1}$ ), while active dunes have relatively low dust fluxes ( $0.03 \text{ mg m}^{-2} \text{ s}^{-1}$ ). White Sands dunes are moderately emissive ( $0.36 \text{ mg m}^{-2} \text{ s}^{-1}$ ), with fluxes comparable to vegetated parabolic dunes of the Monahans. Dust emissions from the Monahans sand sheets and parabolic dunes are largely driven by the liberation of resident fines during saltation. Dust emissions from the dune field core are likely driven by abrasion of sand that removes grain coatings, as well as minor chipping and spalling. White Sands dust emissions are likely driven by significant chipping and spalling of soft gypsum grains that become more equant downwind. Active dunes likely contribute to high ambient dust concentrations in desert environments, but with persistent drought or landscape disturbance by the growing oil and gas industry in West Texas, sand sheets could become significant dust producers in the future. White Sands occasionally generates large dust storms that cause visibility and respiratory problems for nearby populations. Conditions during the 1930s Dust Bowl drought may have resulted in wide-scale deposition of White Sands-derived dust. Our results indicate that dust emissions from dune fields can be highly variable, highlighting the importance of landscape-scale properties in dust emission estimates.

O-3050

## Pleistocene –Holocene depositional rhythms in clastic successions of the Caspian Sea under climatic control

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### Abstract

The Lower Pleistocene (Absheron stage), Middle Pleistocene (Khazar stage) exposures on the Absheron Peninsula, and Holocene sediments from the Kura river delta located in the western flank of the South Caspian depression have been studied via integration of different geological and analytical methods -sedimentology, paleontology, isotope and trace elements geochemistry. Lithologically Pleistocene sediments are represented by shelly sandstones, coarse- to medium - grained sandstones, silts and silty shales. Holocene succession is dominantly composed of muddy sediments with some sand intervals. The Caspian Sea level fluctuations were recorded in the Pleistocene succession as depositional environment changes within shoreface -offshore settings, and in Holocene sediments – in facies variations within deltaic- fluvial environment.

A high resolution time series geochemical analyses of carbon and oxygen isotopes and

elemental ratios (Mg/Ca and Sr/Ca) in ostracod shell carbonate demonstrate a close correlation between Caspian Sea level fluctuations, climatic variations, and faunal assemblages, depositional environment changes.

The shallowing and decrease of salinity of the basin on the Plio-Pleistocene boundary caused the formation of a poor and stressed faunal complex in the Early Absheronian time. Subsequent the mid-Absheronian transgression accompanied with the increased of salinity created favorable conditions for flourishing of fauna. In Holocene Kura river delta retreat and realignment brought salinity variations in the 10-12‰ range, and rapid changes in the hydraulic conditions. Consequently, fresh and brackish water species dominance was recorded.

Based on the  $d^{18}O$ ,  $d^{13}C$  and Ca/Mg, Sr/Ba ratio variations we can testify to significant climatic and basin salinity variations during Pleistocene-Holocene that provided us by unique opportunity for characterizations of short-term climatic cyclicality in this geological interval that was, probably, the major Caspian lake-level control, governing depositional processes in the basin. We can report tens of climatically driven small scale depositional rhythms in the Caspian Quaternary succession. Thus, the Caspian Sea level drop and accumulation of the low stand sediments took place during cool stage of the climatic cycles. In contrast, deposition of high stand sediments was more common during warm stages.

O-3051

## Absolute chronology of Caspian sea Late Quaternary basins

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### Abstract

The stratigraphy and palaeogeography of the Northern Eurasian Pleistocene is recorded in Caspian Sea sediments. They contain a unique record of major regional and continental phenomena (e.g. glacial-interglacial cycles of the Russian plain, the Caucasus and Central Asia, and links to the oceans during marine high-stands), as well as of global climate change. To fully understand this record there is an urgent need for an accurate numerically-based chronology for the marine history. During the Late Quaternary dramatic changes in relative sea-level are known to have occurred in the Caspian Sea. However, all previous attempts at resolving the uncertainty associated with the timing of these transgressive/regressive events using standard dating methods have produced inconclusive or controversial results. For the last 5 years series of reference sections of Caspian sea Late Quaternary in Lower Volga valley (Kosika, Raigorod, Cherny Yar, Srednyaya Akhtuba, Leninsk, Batayevka, Seroglazka, Bykovo, Selitrennoye), Manych Depression (cores from central and eastern parts of the depression), Dagestan coast (Turali section, Darvagchai-zaliv Paleolithic site), Mangyshlak peninsula, Gorgan river valley, Kerch and Taman peninsula (Tuzla and Eltigen sections), Western Turkmenistan (Cheleken peninsula) were dated using radiocarbon and OSL. High-resolution luminescence dating results correlated with biostratigraphical chart based on Caspian sea Didacna Eichwald mollusks and radiocarbon dating allowed to re-evaluate the existing understanding of the chronology of Caspian Sea transgressions. We will present newest results based on more than 200 OSL dates from main Late Quaternary stratigraphic layers, describing main palaeogeographic events: Novocaspien, Early and Late Khvalynian; Hyrcanian and Late Khazarian transgressions; Atelian, Mangyshlak and Enotaevka regressions.

O-3052

## Variability of the chocolate clays deposition during the Late Pleistocene in the Lower Volga Region

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### Abstract

Chocolate clays are one of the most common facies of the Lower Khvalynian deposits in the Lower Volga River valley. They were deposited during the Early Khvalynian transgression of the Caspian Sea. These clays consist mainly of clay with lenses sand and silt that contains mollusc shells.

Here we present the results of 69 radiocarbon ages of chocolate clays derived from mollusc shells (*Didacna*, *Monodacna* and *Dreissena* species). Radiocarbon ages were calibrated to calendar years using the CALIB 7.0.4. (IntCal13) program (Stuiver and Reimer, 1993). The materials were collected from the key sections (Svetly Yar, Raigorod, Sr. Akhtuba, Cherny Yar, Tsagan-Aman, Kopanovka, Enotaevka, etc.) in the Lower Volga region.

Radiocarbon dates of chocolate clays reveal ages between 20-11 cal ka BP. 28 of these ages lie between 14,1-13,5 cal ka BP. The ages at the base of the chocolate clays are 16-14,5 cal ka BP and at the top are 14-12,5 cal ka BP. Few dates correspond to 11 and 20 cal ka BP. The radiocarbon ages of the bottom part of the chocolate clays in the southern key sections are 16,5-14,8 cal ka BP, meanwhile in the Northern sections they are 14,1-13,8 cal ka BP.

The results suggest that the sand layers with mollusc shells in the bottom of the chocolate clays were deposited between 16,2-14,7 ka BP, which correspond to the Oldest Dryas cold event, while during 14,5-14,1 ka BP chocolate clays with massive structure were accumulated. This time corresponds to the Bølling warm period. The ages of upper and middle sand horizons that contain molluscs *Didacna ebersini*, *Dreissena polymorpha* are estimated between 14,1-13,8 ka BP, which correspond to the Older Dryas cold event. Deposits of sandy clay sediments that contain molluscs of *Dreissena polymorpha* reveal the ages of 13,8-12,8 ka BP and correspond to Allerød warm period.

The results show that the variability of the litho-facial composition of the Early Khvalynian region sediments in the Lower Volga could potentially depend on the Late Pleistocene climatic regimes. The abundance of molluscs prevailed during the cold events when sandy layers were deposited. In the Bølling warm period when massive chocolate clays were deposited the molluscs disappeared.

### Acknowledgements

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O-3053

## Correlation of the paleogeographic events in the Caspian sea and on the East European Plain during the glacial epoch

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### Abstract

The problem of correlation between transgressive-regressive oscillations in the Caspian and glacial events on the Russian Plain is of great importance in Pleistocene paleogeography. It has been thoroughly studied previously by a number of researchers, but at the present moment, there is no unequivocal opinion on the problem. This work presents new data obtained by the authors during the last years. They allow us to specify relationships of events in the Caspian Sea and on the Plain. The authors have carried out analyses of the sections from the Lower Volga Region and boreholes cores from the northern Caspian Sea. The complex studying included lithologic, faunistic, palynological and geochronological analyses. Paleogeographic evidence on glacial events on the Plain is based on published sources. The conclusion is made the events during the last glacial epoch (MIS 4-2) left their distinguishable imprint on the Caspian Sea environment evolution. During MIS 4 and the first part of MIS 3 the Atelian regression developed in the Caspian Sea. The dating obtained for the Atelian deposits testifies to the formation of them from 68 to 45 ky. The horizons of the soil (MIS 5) is broken by frost cracks and wedges that are filled with the Atelian sediments. Palynological materials indicate periglacial vegetation in the basis of the Atelian deposits and moderately warm in their upper part. The early stage of the Khvalynian transgression of the Caspian Sea developed during the second half of MIS 3. The radiocarbon dates (31.5-28.5 ky) of deposits are comparable with the OSL dates. Judging from the shell composition the water temperature was moderately warm. Pollen data confirm it. It was the interstadial epoch. The level rising was interrupted during maximum cooling and aridization at MIS 2 and resumed when the ice sheet was decaying. The events known as warm phases of Bølling and Allerød promoted the ice sheet melting along with thawing of permafrost, the latter having been widespread in the Volga drainage basin. All the above contributed to the Khvalynian transgression. The 'chocolate' clays were accumulated in the Volga estuary and in depressions in the Pre-Khvalynian relief. Phases of a cooling known as the Oldest, Older and Younger Dryas marked by a decrease in the runoff volume from the Caspian drainage basin are correlatable with regressive stages in the Khvalynian basin history. The best pronounced of them corresponded to the Younger Dryas. The Khvalynian came to its end at the first sharp warming that resulted in the rise of the Caspian level. The Mangyshlakian regression is dated to the Holocene and was essentially a response to the increase in the climate continentality. The work is supported by the Russian Foundation for Basic Research (Grant 18-00-00470).

O-3054

## The Late Pleistocene history of the Manych Strait (new data)

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### Abstract

Manych-strait connected Black sea and Caspian Sea in Pleistocene is a great event in the history of the Ponto-Caspian region. The strait located within such geological structure as Manych Depression which is extended sublatitudinally from the west coast of Northern Caspian to the north-west of the Azov sea. The existence of the Manych-strait is essentially for the stratigraphy and paleogeography. There were several stages when marine waters spilled over from Black sea to Caspian and alternatively. Due to the alternation of sedimentary layers it is possible to correlate pleistocene deposits and paleogeographic events. Nowadays there are a lot of materials and data about the history of Manych-strait. In the profile are distinguished interbedding marine deposits with lacustrine and alluvial formations and subaerial deposit on top. The main question is the paleogeographical reconstruction and chronological timeframe of main events of Late Quaternary. We try to solve this problem using our new data and elaborating available information.

The preliminary scheme of the sequence of paleogeographic events in Pleistocene is complied. The beginning of Late Pleistocene is marked by the penetration of marine water deep within the Manych Depression during the Black Sea interglacial transgression (Karangat Trangression, MIS 5e). The character trait of marine water through this period is relatively high salinity (18-20 ‰), that favors the development of Black Sea mollusks. During the transition to the glacial epoch (MIS 5d-a) the marine waters oh Karangat bay had begun retreated back into the Black Sea basin. In the end of this stage there was a strait called Hirkanian, which had desalted brackish waters (8-10‰) of the Caspian sea. The marine epoch in the central part of the Manych depression changed to the durable lacustrine phase of development in the second half of Late Pleistocene (MIS 4-3), Burtass lake existed there. In the beginning of its existence it was flowing through (it so because of the major of fresh- and calmwater mollusks in the base of the layer).

During the continental stage there was an active erosion damage of the burtass deposits. Through this period were formed specific landscape forms – extended ridges – which finally formed in the epoch of degradation of the last glaciation and Khvalynian water removing to the Black Sea basin. After the closing of the Khvalynian strait began the continental epoch, through this time there were forming the subaerial stage, which is continuous nowadays.

Research was supported by the Russian Science Foundation, project 16-17-10103.

**O-3055**

## **New data on stratigraphy of late Holocene deposits of the Sea of Azov (Eastern Europe)**

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### **Abstract**

Over the last 15 years we were studying bottom sediments and coastal outcrops of the Azov Sea. A regular sample of cores in different parts of the sea implemented, as well as drilling on the coast. The combination of lithologic, seismoacoustic, micropaleontological (spore-pollen, diatom) data with radiocarbon dating made it possible to clarify several aspects of the Holocene history of this internal marine basin.

The summary of radiocarbon dating from 25 cores with the results of micropaleontological analysis made it possible to clarify the age and thickness of bottom sediments of the Azov Sea. It has been established that the upper 2-3 m of the sedimentary thickness are consisted of by deposits of the New Azovian age (last 3.1 thousand years) usually. A decrease of their thickness (less than 1 m) is noted in the east of the open sea area, as well as in the central and eastern parts of the Taganrog Bay.

The time intervals of transgressive-regressive phases' existence were corrected; several stages of sea level rise and fall were traced, which affected at the change of diatoms' species composition. These stages do not coincide with the Black Sea basin ones, and reflect regional features and relative isolation of the Azov Sea from the Black and Caspian Seas. It was shown that changes of the Azov Sea level occur with a delay compared with regional landscape-climatic phases. The obtained data confirm the interrelation of sea and land processes occurring in the Azov Sea basin: general humidization in the region preceded the transgressive phases, and the regressive ones, on the contrary, are associated with aridization of the climate. The results of the diatom analysis confirm the existence of the Fanagorian and Korsunian regressions, as well as the Nymphaean transgression. The humidization of the climate at the beginning of the Subboreal period coincides with the transgressive phase. The initial stages of the New Chernomorian and Nymphaean transgressions also coincide in time with the period of humidification of the climate.

It is shown that the water area of the Taganrog Bay was significantly expanded by intensive abrasion processes, which proceeded at the general background of transgressive sea level rise in the Late Holocene. As a result, over the past few thousand years, the size of the bay, its depth, the configuration of the shores changed, the outlines and location of the Don River Delta were transformed. At the stage of the Fanagorian regression, the dried seabed was actively denudated. It has been established that the accumulative bodies of the sand tails at the southern coast of the Taganrog Bay have been formed over the past 5,000 years.

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O-3056

## Caspian sea Late Khvalynian transgression and its role in development of human population during Epipaleolithic in Western Turkmenistan

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### Abstract

During Quaternary period, unstable sea-level regime of the Caspian Sea resulted in vast transgressions and deep regressions which played an important role as a natural barrier and influenced past migration routes of human populations. Because of its central geographic location, the area also channeled culture, technology, and other forms of exchange between adjoining regions from the first modern human occupation into Eurasia and up to the present day.

Unfortunately, not all areas of Caspian region are studied evenly, and at the present time the ancient human history of the Eastern Caspian is very poorly understood. Previous investigations of the prehistory of the region were conducted in the middle of 20th century by A.P.Okladnikov (Okladnikov, 1953) and later by G.E.Markov (Markov, 1966), and published in Russian. These studies suffer from the absence of absolute chronology and the results of modern multidisciplinary analysis. The reexamination of old Okladnikov's collections is ongoing and focusses on the multilayer rockshelter sites named Dam-Dam-Cheshme 1, Dam-Dam-Cheshme 2 and Jebel, which are located in the Great Balkhan (Uly Balkan) region, and two other sites located in the Krasnovodsk peninsula – Kuba-Sengir and Kaylu.

In 2018, we conducted an archaeological survey at Krasnovodsk peninsula in Turkmenistan, during which we identified the exact location of Kuba-Sengir and Kaylu sites and described their geomorphological position and collected samples for luminescence dating.

The latest data on the age of the largest Late Quaternary Khvalynian transgression of the Caspian Sea (Yanina, 2017) allow us to reconstruct the paleogeographic situation in the region. About 13-15 thousand years ago, the level of the Caspian reached maximum of +46-48 m, i.e. 76 meters above the modern level. During that time, the seawater filled located to the south-east Western-Turkmen lowland with, forming a deep gulf and penetrated along the Uzboy valley for 100-120 km to the east, while flooding and extending the Kemal lowland (Fedorov, 1978). Located on the altitude of +60 meters Cuba-Sengir cape site was outside the flooding zone and could be populated for a longer time. The waters of the Caspian Sea at this time approached as close as possible, and the shell material from the beach close to the site could be a source for production of the beads. This fact is also indicated in the numerous finds of fish bones, including sturgeon. It is unlikely that the ancient population used shells from deposits of older Caspian transgressions, since the horizons containing them are located substantially lower.

Results of science work will be cartographic materials of the levels dynamic of the Caspian Sea and revealing the influence of the levels evolution of the Caspian Sea on archaeological objects in the Holocene.

This work was supported by RFBR grants 18-00-00470 and 18-00-00660.



O-3057

## Source-to-sink processes and their response to hydroclimatic variability in tropical Lake Towuti, Indonesia

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### Abstract

Humid tropical landscapes are subject to intense weathering and erosion, which strongly influence sediment mobilisation and deposition. Over longer timescales, these processes are altered by climatic and environmental changes, as well as other factors, e.g. tectonics, giving rise to complex, dynamic landscapes. In this setting, we aimed to understand how hydroclimate and geomorphology altered the style and intensity of erosion and sediment composition in a tropical lake and its tectonically active catchment. Lake Towuti (2.75°S, 121.5°E) is one of the oldest and deepest lakes in Indonesia, with uninterrupted lacustrine sedimentation over several glacial-interglacial cycles. We present results from a source-to-sink analysis of Lake Towuti's modern catchment, and apply this understanding of modern processes to a 100-m-long, continuous lacustrine sediment record, spanning the last ~1 million years.

We find that the overall composition of modern sediments across the lake is strongly influenced by tectonic disturbance of river courses, which enhances bedrock abrasion and promotes slope instabilities in some of the river catchments. The two large and most tectonically influenced rivers Mahalona and Loeha, together with material from the lateritic catchment soils, are identified as the three dominant sediment sources to coring location TDP-Site 1. Geotechnical analyses from Lake Towuti's catchment show that the lower laterite horizons have lowest stability and can function as slide planes to mobilise the entire soil package during mass movement events. Across the 100-m-long Pleistocene sediment record, variability in sediment composition reflects the interplay between these three sources, which in turn can be related to hydroclimatic variability in the region. In addition, long-term tectonic basin evolution, post-sedimentary sediment alteration, and changes in lake productivity are important factors that shape sediment composition through time. Preliminary results of the high-resolution geochemical sediment record suggest that hydroclimate at Lake Towuti is sensitive to changes in orbital parameters, as well as higher-frequency climate variability.

The detailed study of the modern catchment and associated processes provides an important contribution to defining the baseline status and variability of ecosystems and landscapes in Central Sulawesi in the recent past and on glacial-interglacial time scales. In combination with the long sediment record, this enables a comprehensive reconstruction of changes in depositional environments and hydroclimate from the Southeast Asian humid tropics through large parts of the Pleistocene.

O-3058

## Forest-fire-climate dynamism in the lowland tropics of Wallacea over 30,000 years

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### Abstract

The lowland tropics of Wallacea in south-east Asia represent some of the most diverse, biogeographically significant forests globally. Long-term ecological data for this region are, however, scarce, making it difficult to predict vegetation response to future drivers of change, including an increase in the intensity and frequency of precipitation extremes. Emerging palaeoclimatic data suggest that marine isotope stage 2 (MIS 2) within Wallacea was significantly drier and more seasonal than either MIS 3 or the Holocene, and that the Holocene was characterised by a series of lower-amplitude hydroclimatic shifts. Examining floristic response to these shifts can provide insight into the acclimation thresholds of forest taxa to hydroclimatic drivers of different magnitudes, and illuminate the dynamism of the tropical landscape over millennia.

This research presents palynological records from two sites within lowland Sulawesi, Indonesia – Lake Lantoa (16,500 yrs BP to the present) and Lake Towuti (30,000 yrs BP to the present) – that, respectively, capture local and regional floristic change from that start of MIS 2 to the present. Our results show that closed forest has persisted in the local and regional landscape over the assessed time period in spite of being subject to drier climates and heightened fire activity prior to the Holocene. However, there are notable intra-forest compositional shifts evident in the records in response to glacial scale climatic forcing and changing patterns of landscape disturbance (including burning). These include contraction of tropical coniferous forest between 31,000 and 17,000 yrs BP in response to heightened seasonality, the replacement of seasonal forest taxa with rainforest species with increased humidity (at the Bølling-Allerød interstadial and the MIS 2-Holocene boundary), and a slight return of seasonal/ secondary forest types in response to late-Holocene anthropogenic activity. These findings demonstrate the stability of the tropical forest biome in Wallacea to key drivers of change, but highlight intraforest compositional dynamism in the landscape in response to these drivers.

O-3059

## The origin of variability present at Lynch's Crater, northeastern Queensland (Australia), across the period 40 - 10 ka

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### Abstract

The presence and timing of Heinrich (H) events have been well-established in the north Atlantic region (H1, H2, H4 and H5) and associated with rapid temperature, precipitation and ocean circulation changes due to iceberg discharge events linked to the Hudson Strait/Hudson Bay region while the more minor H3 and H6 are associated with European ice-sheets. In the Southern Hemisphere and the tropics it has been suggested that warming and/or wetter conditions likely due to the southward movement of the ITCZ are associated with Heinrich events. Studies undertaken at Lynch's Crater, northeastern Queensland have resulted in conflicting conclusions of conditions present during Heinrich events with the suggestion that the presence of inorganic phases indicate wet H events (Muller et al. 2008) while Turney et al. (2004) suggest that H events coincide with 'warm' (dry) ENSO activity based on sediment humification and the Cyperaceae/Poaceae pollen ratio. A more recent high resolution palaeoecological study shows across the period 40 – 10 ka conditions are highly variable and that both 'wet' and 'dry' conditions coincide with H events. It is suggested that local insolation and the degree of continentality (Australia and New Guinea being one landmass), which may impact the circulation of ocean surface currents such as the Indonesian Throughflow and the extent of the Indo-Pacific Warm Pool, may be influential in the determination of the extent of the southward migration of the ITCZ and therefore whether 'wet' or 'dry' conditions coincide with H events.

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O-3060

## Atlantic forest and fire dynamics during the last two glacial-interglacial cycles (Colônia, Brazil)

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### Abstract

Located in the eastern part of Brazil, the Atlantic forest is one of the most diverse forests of the world, encompassing high levels of endemism along a latitudinal gradient from 3°S to 30°S. Pollen Analysis of the last 120 kyr BP has shown that the Atlantic forest was sensitive to glacial-interglacial cycles reflected in changes in forest composition together with contraction and expansion phases. However, the drivers for these changes are still poorly known. Yet, long-term datasets are very useful to observe how the succession of different cycles impacted the Atlantic forest, which can lead to predicting future responses of ecosystems to drastic climatic changes.

In Southeastern Brazil, where the Colônia crater is located, the influence of the Atlantic Ocean, polar air masses, and monsoon circulation make the area a unique place for regional and global paleoclimatic research. Here we present new pollen, diatoms, biomarkers, charcoal and geochemical results from the sediment core CO14 (14 meters length) retrieved from the bog. Pollen interpretations are based on the presence of the cold-moist related taxa (*Araucaria*, *Ilex*, *Podocarpus*), and warm moist related taxa (Anacardiaceae, Euphorbiaceae, *Myrsine*, Myrtaceae) indicators. The sediment and geochemistry analyses showed that the site was previously a lake until ca.120kcal yr BP when it was progressively filled in. Our results reveal that during the last 160 kyr BP, the Atlantic forest responded differently to the last 2 glacial periods. High frequencies of arboreal vegetation were detected during MIS6, MIS5, MIS3 and MIS1 stages and high fire activity was found during MIS6, MIS4, and MIS3. During cold and dry periods such as MIS4, MIS3b and MIS2 an open landscape was covering the area. The interplays between monsoon and polar air system dominances are inferred to explain the different responses of the tropical forest to global changes.

O-3061

## Late Quaternary tropical forest dynamics as response to climate variability and human impact in northern Madagascar

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### Abstract

Madagascar is well known as a biological hotspot with a unique flora and fauna regarded as ones of the earth's biologically richest, but also most endangered terrestrial ecoregions. Assessing its future development under changing climate, but also increasing human impact, requires a profound understanding of its natural dynamics over long timescales. Related to past climatic variability studies on vegetation dynamics in Madagascar are rather scarce. Thus, this new project, launched in 2018, is focusing on forest resilience to climatic and anthropogenic impact. In this context, we aim to provide high-resolution reconstructions of past vegetation and climate changes, based on a multi-proxy approach applied to multiple lowland and mountain sites in northern Madagascar. Preliminary results from the investigation of several lacustrine sediment records, continuously covering the past 25 ka cal BP, reveal distinct vegetation dynamics, which can be linked to climatic variability. At ca. 15 ka cal BP a remarkable increase in sediment accumulation rate, increased minerogenic input, coarser particles together with enhanced organic carbon content most likely reflect the onset of the African Humid Period in Madagascar. Contemporaneously, reduced charcoal and montane rain forest occurrence suggest moister conditions with forest expansion from mountain to lowland environments. Moist conditions were intensified during the Early Holocene until ca. 5 ka cal BP. Thereafter, distinctly increase in charcoal indicate drier conditions in northern Madagascar, most likely caused by insolation driven shifts in the southern position of the Intertropical Convergence Zone and monsoon duration in northern Madagascar. Further, our records clearly indicate human impact on the vegetation during the past ca. 1000 years (commonly regarded as one of the trigger for the megafauna extinction) through a tremendous increase of charcoal. Our studies in northern Madagascar will increase the understanding of past vegetation dynamics in tropical regions and especially help to distinguish between climatic and anthropogenic drivers for ecosystem changes in this highly vulnerable region.

O-3062

## The changing tropical landscape in the Lake Victoria Basin, East Africa

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### Abstract

The impacts of human activities and climate change in the Lake Victoria Basin (LVB) was assessed using Remote Sensing Technologies, DNA analysis of fish populations and water quality analysis techniques. In the LVB, wetlands are part and parcel of many water bodies where they are hydrologically and ecologically linked through the supply of water, nutrients and organic matter. In the upper reaches of the LVB, many wetlands have been formed by spring water draining into valley bottoms where the gradient is low and hence water accumulates, supporting characteristic biota. Other wetlands are formed as a result of shallow water table in depressions, though most of these are seasonal and their area fluctuates depending on the prevailing weather conditions. Tropical wetlands are known to be very productive, providing water and primary productivity upon which large numbers of plants and animal species depend for survival. They are also important locations of plant genetic diversity and support large numbers of bird, mammal, reptile, amphibian, fish and invertebrate species. However, the human population explosion in the LVB, coupled with unsustainable exploitation, have led to a decline in wetland goods, particularly fisheries. Human activities in the LVB have accelerated the rate of ecological change and increased threats to the existing natural resources. A substantial natural resource base is thought to be one of the many reasons that led European powers to scramble for Africa during the 18-20th century, where economic ventures was the main agenda. The explorers found that the entire catchment of Lake Victoria was already a vibrant civilization center with structured indigenous governance systems to regulate the utilization of resources around the lake. Today, Lake Victoria, the world's second largest fresh-water lake, stands as the most critical economic resource that links its three riparian countries of Kenya, Tanzania and Uganda, as well as Rwanda and Burundi, which form its drainage basin. The lake and its basin is the single most valuable shared natural resource in the region and the lifeline to the downstream countries of Sudan, South Sudan and Egypt. This paper examines the impact of human activities and climate change on the LVB changing landscape based on remote sensing and GIS analysis combined with DNA and water analysis. The quality of the effluent generated by the industries found within the study sites and their effects on downstream discharge was also determined. The physical and chemical analysis of water quality revealed high levels of phosphates and nitrates along the agricultural zones of River Nzoia Basin. The satellite images revealed that in all the three study sites land vegetation cover has continuously reduced in size. The extent of ecological change and increased threats to the existing natural resources in the LVB is discussed.

**O-3063**

## **Island life – the biogeography of South Pacific chironomids**

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### **Abstract**

Little is currently known about the biogeography and biodiversity of chironomid faunas from islands in the South Pacific. There are various theories regarding the distributions of insect faunas across these widely spaced islands, including dispersal associated through human colonisation. Chironomids are typically abundant fossils from lake sediments and provide valuable palaeoenvironmental information, and hence analyses of their distribution (in space and time) in South Pacific islands will likely yield important data regarding biogeographic processes and past environmental change. There are no known surveys of chironomids from the freshwater lakes of the South Pacific.

This project is focused on assessing chironomid communities from Holocene lake sediment sequences in Vanuatu, Samoa, and the Cook Islands, an increasing distance gradient from major biological centres such as Australia, New Zealand and Indonesia. The island locations will allow us to assess the biogeography and diversity of chironomid communities in space and time, including the potential impact of human colonisation. Furthermore, independent palaeoclimate and vegetation proxies exist for some of the sequences, allowing us to test the response of chironomids in the South Pacific to major hydroclimate and vegetation change. Initial results indicate that both hydroclimate and human colonisation are important factors in controlling chironomid communities, and these will be discussed in depth during the presentation.

O-3064

## Environmental change through the last glacial cycle at Fraser Island, subtropical Australia

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### Abstract

Recent programs to extract detailed and longer records of Australia's Pleistocene environments have produced a number of efforts to analyse long sedimentary sequences in the subtropical sand islands of Australia's east coast. Echo Lake is a perched fen within ancient dune sands on Fraser Island at 25° S that provides a record of precipitation change over ~100 ka. A 12 metre core into the (now) ephemeral swamp revealed lacustrine sedimentation in a period of higher precipitation, followed by a transition to swamp sedimentation as water levels fell. The chronology, based on <sup>14</sup>C and OSL ages, suggests parts of the record may be interrupted or lost owing to drying or burning of the surface. Here we present an updated OSL chronology together with pollen analysis and ITRAX-XRF proxies for palaeoenvironmental change over the last glacial cycle in subtropical Australia.

O-3065

## Palaeochannels of Australia's Riverine Plain - Reconstructing past environments and vegetation across the Last Glacial Maximum and Holocene.

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### Abstract

A series of palaeochannel facies throughout the Riverine plain of southeastern Australia reflect environmental conditions spanning the Late Pleistocene and Holocene. The Gum Creek (41-29 ka) and Yanco (29-18 ka) palaeochannels both provide evidence of significant late Pleistocene fluvial activity, likely connected to increased spring snow melt from the south east Alpine region. This paper attempts to broaden the palaeoenvironmental record of these palaeochannels via investigations of the finer silt sediments that both underlie and cap the coarser-grained channel sands. New OSL ages for the overlying silty channel fill from four separate sedimentary cores/sites indicates that the rate of sediment infill/accumulation varies between sites.  $\delta^{13}\text{C}$  analysis in conjunction with pollen and elemental investigations suggests that the vegetation landform mosaic also varied through space and time.  $\delta^{13}\text{C}_{\text{TOC}}$  data is predominantly a C3 vegetation signature ranging between -28‰ and -22‰. However, C4 vegetation calculations, taking into account the effects of SOM decomposition and the varying accumulation rates between sites, point to a pulse in C4 vegetation across the Riverine Plain post LGM fluvial activity. In turn, there is an increased dominance in C3 trees and grasses in the mid to late Holocene. A shift in *Eucalyptus/Poaceae* ratios from <1 to >2 in the upper 200cm of the Gum Creek facies sediments supports a shift from a landscape with greater grassland representation to a more closed wooded mosaic. In contrast, the pollen within the sediments of the Yanco palaeochannels, although limited in numbers, identifies a consistent contribution from *Poaceae* (70%) between the surface and 200cm depth, despite the C4 estimations from  $\delta^{13}\text{C}$ , also indicating a distinct shift to C3. We interpret this particular Yanco site as representing a consistently open vegetation mosaic through the Holocene with a shift from C4 to C3 grasses, and no major increase in wooded vegetation. Elemental ratios derived from XRF analysis of bulk sediments imply fluctuating environmental conditions during the deposition of the upper and lower silt units, with a distinct period of wetter conditions around 2ka cal BP, which followed fluctuating wetting and drying phases. A lack of pollen and low TOC (<0.05%) values in the older silt units below the channel sands makes understanding changes in the vegetation mosaic more challenging. Despite this,  $\delta^{13}\text{C}$  for both TOC and TIC indicate a dominance of C3 vegetation prior to the commencement of fluvial activity.

O-3066

## An Integrated study of aeolian, lacustrine and fluvial geoarchives in the Murray-Darling Basin, Australia; reconstructing LGM hydro-climate variability

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### Abstract

In this study we present new records for Australia's Murray Darling Basin (MDB), a vast (>1 million km<sup>2</sup>), predominately semi-arid basin. These new records obtained by the study of mostly unexplored lake-lunette systems chiefly preserve records of LGM palaeoenvironmental change, that is, hydro-climate variability.

Lakes and adjacent lunettes are semi-closed systems where the material composing the lunette is mainly deflated from the lake basin, consequently, in combination lake-lunette records potentially allow a more refined reconstruction of changes in the basin hydrologic conditions through time. Lunettes evolutionary models developed for semiarid areas worldwide have identified discernible sedimentary facies associated with dry and drying conditions as well as lake full phase, e.g. as implied by Bowler's (1973) classic lunettes model. Using this approach, lake-lunette systems can provide extremely valuable palaeohydrologic data, which in isolated systems (fluvially disconnected), have been interpreted as corresponding to major climatic fluctuations.

In the Southern MDB lake-lunette systems are however mostly connected to major river systems. Therefore in this setting, the development of both lunette and lake facies has been highly dependent on fluvial dynamics. This adds complexity when interpreting the palaeoenvironmental significance of these records.

Reconstruction of lakes-lunettes stratigraphy within different systems in the MDB has revealed a high degree of variability in sedimentary facies between sites (and within sites), implying facies assemblages are dependent on i) river dynamics (essentially connectivity) and ii) hydrogeology (groundwater dynamics).

Despite variability in facies between sites, the overall results support a scenario of high discharge for both the Murray and the Darling Rivers, contemporarily to enhanced aeolian activity and therefore lunettes building through the Last Glacial Maximum.

In combination the results of this study imply that boundary conditions influence lunettes facies, however, lunettes accretion phases may be linked to broad-scale hydro-climatic conditions. The possible palaeoenvironmental scenarios developed by the study of lunettes sedimentary sequences include wet conditions in the lower Darling during the LGM, supporting the hypothesis on moisture available from the Coral Sea or a northern migration of Westerlies; on the Murray River, lunettes facies records point towards a more enhanced seasonality although implying the lack of extremely dry conditions throughout the glacial stage.

In addition, the deglacial has resulted in the cessation of lunettes accretion and corresponding dominance of pedogenetic processes within the lunettes, possibly implying reduced winds strength or change in their position and sediment supply limitations extended at broad scale, which might relate to the change from mixed to suspended load systems affecting all major rivers within the basin.



*Bowler, J.M. (1973) Clay dunes: Their occurrence formation and environmental significance. Earth Science Reviews 9, 315-338.*

O-3067

## A high-resolution record of south-eastern Australian hydroclimate between 30,000 - 10,000 years ago: toward a better understanding of the Australian LGM

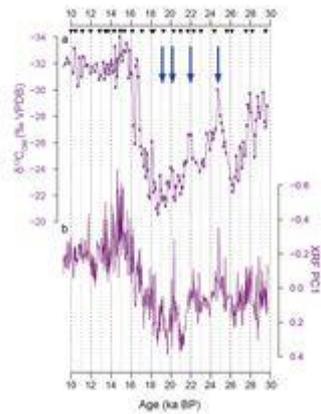
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### Abstract

Global climate variability during the late Quaternary is commonly framed in terms of the ‘bipolar seesaw’ pattern of asynchronous temperature variations in the northern and southern polar latitudes. However, the terrestrial hydrological response to this pattern in south-eastern Australia is not fully understood, as continuous, high-resolution, well-dated proxy records for the hydrological cycle in the region are sparse. Here we present a well-dated, highly resolved record of moisture balance spanning 30000 – 10000 calendar years before present (30 – 10 ka BP), based on x-ray fluorescence and organic carbon isotope ( $\delta^{13}\text{C}_{\text{OM}}$ ) measurements of a sedimentary sequence from Lake Surprise in south-eastern Australia. The data provide a locally coherent record of the hydrological cycle (Fig. 2). Elevated Si (reflecting windblown quartz and clays), and relatively high  $\delta^{13}\text{C}_{\text{OM}}$ , indicate an extended period of relative aridity between 28 – 17.5 ka BP, interrupted by millennial-scale episodes of decreased Si and  $\delta^{13}\text{C}_{\text{OM}}$ , suggesting increased moisture balance. Peak aridity was reached between 21 and 17.5 ka BP, possibly representing the expression of the global Last Glacial Maximum. This was followed by a rapid deglacial shift to low Si and  $\delta^{13}\text{C}_{\text{OM}}$  at 17.5 ka BP, indicative of wetter conditions. We find that these changes are broadly coeval with similarly high-resolution records from south-eastern Australia and New Zealand. We also supplement our high-resolution record with discrete clumped isotope measurements on freshwater gastropods from Blanche Cave, also in south-eastern Australia. Temperatures either side of the Last Glacial Maximum were slightly cooler than those of the modern day, with the hint of a decrease from 40 to 30 ka BP. We did not find gastropods within the 28-17.5 ka BP interval in this cave, but identify this as a period for urgent attention.

Together, our analyses suggest that drivers of the regional hydrological cycle have varied on multi-millennial time scales, in response to major shifts in global atmosphere-ocean dynamics during the last glacial-interglacial transition. Southern Ocean processes were the dominant control on hydroclimate during glacial times, via a strong influence of cold sea surface temperatures on moisture uptake and delivery onshore. Following the last deglaciation, the southward migration of cold Southern Ocean fronts likely resulted in the establishment of conditions more like those of the present day. These conclusions will be tested in future work, focused on quantitative rainfall estimates from clumped isotope of land snail shells.



**Figure 1.** Selected data from the Lake Surprise record: **a)** Bulk sediment carbon isotope ratios ( $\delta^{13}\text{C}_{\text{OM}}$ ), interpreted to reflect plant moisture stress; **b)** First principal component (PC1) of the calibrated scanning XRF dataset, interpreted to reflect aeolian deposition of Si. Arrows indicate periods of increased effective moisture within the relatively arid LGM. Triangles denote  $^{14}\text{C}$  age control points.

O-3068

## Low altitude periglacial activity in south eastern Australia during the late Pleistocene

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### Abstract

Glaciation of Australia during the late Pleistocene was restricted to Tasmania and the Snowy Mountains. Ice occupied the highest areas of mainland Australia briefly four times between ~59,000-16,000 years BP based on exposure dating. Periglacial processes dominated at lower altitudes and produced a wide variety of landforms ranging from large-scale block fields to smaller-scale solifluction deposits at the lowest elevations. These landforms hold considerable potential to shed light on the magnitude of cooling during glacial periods. However, few periglacial deposits in Australia have been dated because of difficulty in finding dateable material. In this paper we present a new study of block deposits in Victoria and of low altitude (~600 m) scree slopes in New South Wales. We review the likely modes of formation of these deposits and their environmental setting. We then present trial ages from cosmogenic nuclide exposure, optically stimulated luminescence, and radiocarbon dating and weathering rind measurements to provide dating information for these deposits. Although each method has advantages and disadvantages, a combined approach provides limiting ages for the periglacial deposits we studied. We find that the apparent ages of formation extend over a longer period than just the last glacial maximum. These ages constrain maximum cooling of south eastern Australia during the last glacial cycle.

O-3069

## Southeast Australian palaeofloras of the late Pleistocene and their implications for glacial palaeoclimate reconstructions

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### Abstract

The climatic extremes of the last glacial period (approximately 100,000 to 12,000 years ago) and particularly the last glacial maximum (approximately 20,000 years ago) are thought to have exerted a significant influence over the current distribution of mesic forest taxa in southeast Australia. However, limited taxonomic resolution afforded by fossil pollen has meant that the nature of glacial biotic communities remains poorly understood.

Pollen-based palaeoclimate reconstructions of southeast Australia have invoked a mostly treeless, 'glacial steppe' environment characterised by cold, dry, windy conditions. But, in contrast with the Northern Hemisphere evidence of continental-scale migration to and from southern refugia during successive Pleistocene glaciations, contemporary patterns of species diversity and endemism suggest that forest taxa persisted widely in southeast Australia, in multiple, localised refugia. Resolving this conflict is the focus of this study.

Based on species-level identifications of plant macrofossils, we will provide precise new insights into the southeast Australian glacial climate and biotic communities. Improvements to the taxonomic resolution of palaeobotanical records will allow for the use of bioclimatic niche models to quantitatively reconstruct palaeoclimate. Porch (2010) demonstrated this concept elegantly, but at Spring Creek, too few beetle taxa available for analysis resulted in an inconclusive finding. By applying this method to the plant macrofossil assemblage from this site, we hope to reconstruct the environmental parameters likely to have predominated at the time. Preliminary results suggest that the climatic tolerances of the late-Pleistocene flora of Spring Creek did not differ substantially from those of the modern-day assemblage.

The results of this study will contribute to a globally significant debate about the role of the Pleistocene glacial-interglacial cycles in the generation and maintenance of terrestrial biodiversity, and also to the increasingly urgent discussion of the degree of sensitivity of iconic Australian plant taxa to changing climate in general.

### References:

Porch N. (2010) Climate space, bioclimatic envelopes and coexistence methods for the reconstruction of past climates: a method using Australian beetles and significance for Quaternary reconstruction. *Quaternary Science Reviews* 29: 633-647.

**O-3070**

## **A review of sea-level history over the last glacial cycle in Australia**

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### **Abstract**

In the Australian region, maximum sea-level was between +2 and +4 m above PMSL during MIS5e. Due to limited tectonic uplift in the Australia region, sedimentary facies of Late Pleistocene interstadials (MIS5c, 5a and MIS 3) rarely crop-out above PMSL. For this reason, there is a dearth of studies that accurately trace the characteristics of sea-level oscillations between the Last Interglacial (*sensu stricto*) and the Last Glacial Maximum (LGM). Previous research does indicate that from the close of the Last Interglacial to the LGM was characterised by oscillating sea levels concentrated in a depth range of 70 to 20 m below PMSL which are superimposed on a general decline in sea-level. The positive oscillation (interstadials) occurred at:

-ca93,000 yr BP (MIS5c) with similar sea-level height above PMSL that have been observed in MIS5e;

-ca83,000 yr BP (MIS5a) with sea-levels ca28 m below PMSL; and

-at three specific times (60,600±300, 50,800±300 and 36,800±2,000 yr BP) during MIS 3 where sea-levels ranged between 85 and 74 m below PMSL.

Early in MIS 2 sea-level fell rapidly to ca-110 m (ca24,000 years ago), before dropping further to the LGM sea-level lowstand of between 120 and 130 m below PMSL between ca20,000-22,000 years ago. In the Australian region, Yokoyama *et al.* (2001), reviewing data from the Joseph Bonaparte Gulf, the Gulf of Carpentaria, the Great Barrier Reef and off the Sydney coast, concluded that around Australia sea levels during the LGM were between -110 and -120 m below PMSL. Melting of the continental ice sheets following the LGM resulted in a rapid rise in sea-level. In response to the rising sea-level associated with the most recent PMT, sediment stored on the inner continental shelf migrated shoreward. The stabilisation of the sea surface and subsequent sea-level highstand promoted the shoreward prograding and the geomorphological evolution of coastal depositional environments.

O-3071

## Gibraltar Outflow and Mediterranean overturning circulation during the last 500 ky

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### Abstract

In order to explore past changes in the Mediterranean Outflow Water (MOW) we analyzed the fine sand content in the sediments together with some geochemical proxies and planktic and benthic stable isotopes at IODP site U1389. This site was recovered in the vicinity of the Strait of Gibraltar along the path of the main core of the MOW. The content of fine sand together with Zr/Al ratios were used to investigate the MOW speed variability along the past 500 ky. The MOW speed variability at this site was mainly driven by changes in the density contrast between the Inflow and Outflow, which was, in turn, governed by changes in the Mediterranean heat and freshwater budgets. Events of enhanced freshwater input to the Mediterranean associated to northward shifts of the Intertropical convergence Zone reduced the density contrast at Gibraltar and weakened the MOW at Gibraltar. Weak MOW events were recorded at times of sapropel deposition in the eastern Mediterranean.

At millennial scale, the MOW intensified at times of Greenland stadials and weakened during interstadials. However, during Heinrich stadials typical three-phase events were observed, with a sandy contourite layer at the bottom and top and a phase of weak MOW in the middle of the stadial, coinciding with the arrival of icebergs to the Gulf of Cadiz. For Heinrich stadial 1 this weak MOW event occurred at the time of the massive release of icebergs from the Laurentian ice sheets. However, the inflow of less saline water to the Mediterranean should have increased not decreased the density contrast between the Inflow and Outflow, especially because freshwater discharge to the Mediterranean from the African monsoons was extremely low. We propose different scenarios to explain these weak MOW events in the middle of Heinrich stadials that were certainly triggered by prominent changes in the Mediterranean heat and freshwater budget.

O-3072

## Post-glacial recolonisation of *Globorotalia truncatulinoides* in the western Mediterranean Sea

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### Abstract

The planktonic foraminifera, *Globorotalia truncatulinoides* is known to have five cryptic species (Types 1-5). Of these, types 2 and 5 are the only genetic types that contain the dextral coiling variant and only type 2 is present in the Mediterranean Sea. Under present day conditions, populations of *G. truncatulinoides* in the western Mediterranean Sea are dominated by the sinistral coiling variant. In particular, the species is abundant during the winter season, where vertical mixing within the water column and subsequent high nutrient availability promote juvenile growth. This research focuses on the quantitative analysis of the coiling variation observed in three western Mediterranean Sea sediment cores taken from the Gulf of Lions and the Balearic and Tyrrhenian basins throughout the Holocene. Sea Surface Temperatures (SSTs) were reconstructed for each core using Artificial Neural Networks (ANN) which suggested that SST was not a controlling factor on coiling direction, as has been previously suggested, but rather ecological conditions relating to water column stability and the presence / depth of a thermocline. Specifically this study identifies a series of post-glacial bioevents associated with the recolonisation of *G. truncatulinoides*. The early to mid-Holocene is characterised by the near absence of *G. truncatulinoides* from the faunal record. It is concluded that the absence of the species is associated with a stratified water column likely the result of post glacial sea level rise and increased river runoff. The onset of a significant increase in the abundance of *G. truncatulinoides* is observed during the mid-Holocene, broadly corresponding with the end of the African Humid Period and a transition to a more semi-arid climate. At this time peak frequencies in the dextral variant was observed across all cores, possibly indicating a weakly stratified water column after a prolonged period of stratification. The onset of modern hydrological conditions coincides with the demise of the dextral variant and subsequent dominance by the sinistral variant at approximately 3 ka. Modern day hydrological conditions in the western Mediterranean Sea support the development of deep vertical mixing, in particular in the north-western basin associated with Western Mediterranean Deep Water formation, providing the means for *G. truncatulinoides* to complete its life cycle thereby contributing to the proliferation of the species.

O-3073

## Western Mediterranean hydro-climatic consequences of Holocene iceberg advances (Bond events)

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### Abstract

Gerard C. Bond established a Holocene series of North Atlantic ice rafted debris events based on quartz and hematite stained grains recovered from subpolar North Atlantic marine cores. These so-called 'Bond events' document nine large-scale and multi-centennial North-Atlantic cooling phases that might be linked to a reduced thermohaline circulation. Regardless of the high prominence of the Holocene North Atlantic ice rafted debris record, there are critical scientific comments on the study: the Holocene Bond curve has not yet been replicated in other marine archives of the North Atlantic and there exist only very few palaeo-climatic studies that indicate all individual Bond events in their own record. Therefore, evidence for consistent hydro-climatic teleconnections between the subpolar North Atlantic and distant regions is not clear. In this context, the Western Mediterranean region reveals key hydro-climatic sites for the reconstruction of a teleconnection with the subpolar North Atlantic. In particular, variability of Western Mediterranean winter precipitation might be the result of atmosphere-ocean coupled processes in the outer-tropical North Atlantic realm.

Based on an improved Holocene  $\delta^{18}\text{O}$  record from Lake Sidi Ali (Middle Atlas, Morocco) we correlate Western Mediterranean precipitation anomalies with North Atlantic Bond events to identify a probable teleconnection between Western Mediterranean winter rains and subpolar North Atlantic cooling phases. Our data show a noticeable positive correlation between Western Mediterranean winter rain minima and Bond events during the Early Holocene and an opposite pattern during the Late Holocene. There is evidence for an enduring hydro-climatic change in the overall Atlantic atmosphere-ocean system and the response to external forcing during the Mid-Holocene.

O-3074

## Hydro-climate variability and linkage to solar forcing in the Western Mediterranean during the last 1000 years, inferred from speleothem records

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### Abstract

The Western Mediterranean has known recurrent drought periods after the 1970s, and climate models anticipate a decrease of annual precipitation by the last 21<sup>st</sup> century. Essential information on climate variability and the involved forcing mechanisms in this region remains however scarce due to the lack of long instrumental datasets. Thus, additional paleoclimate records are highly required. Here, we present three well-dated and high-resolution speleothem  $\delta^{18}\text{O}$  records from different caves in Morocco. The speleothem records are interpreted as proxies of rainfall variability during the last millennium, mainly dominated by the North Atlantic Oscillation (NAO). They reveal substantial decadal to centennial alternations of dry and humid periods, with prevailing dry conditions during the Medieval Climate Anomaly (MCA), wetter conditions during the second half of the Little Ice Age (LIA), and a trend towards dry conditions during the modern period. Interestingly, Low  $\delta^{18}\text{O}$  values, and hence negative phases of NAO that bring precipitation to the Western Mediterranean, are observed during periods of solar minima. This is confirmed by high power and persistent centennial-scale periodicities, similar to the Vries-Suess 200-year solar cycle, that are observed in the speleothem records as well. Hence, we provide proxy-evidence of the linkage between the hydro-climate variability in the Western Mediterranean and insolation through the NAO, consistent with previous model results describing low irradiance as a trigger for southward shifts of precipitation-bearing westerlies during winter.

O-3075

## Environmental change in the Adriatic region over the last 365 kyr from episodic deposition of Modrič Cave (Croatia) speleothems

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### Abstract

The Adriatic Sea, as the northernmost and practically landlocked part of the Mediterranean Sea, is influenced by both Atlantic and Mediterranean air masses, so the isotopic records from coastal cave speleothems are expected to reveal local and regional responses to global climate changes on that bordering region.

In this study we present a 365-kyr long composite isotopic record of three speleothems from Modrič Cave located 120 m from the shoreline on the central part of the eastern Adriatic coast. Results of a 4-year monitoring program of the surface and cave microclimate, rain and drip water stable isotope composition and rain and drip intensities, show cave air temperature variations within 1 °C, a relative humidity of 100%, dripwater O and H stable isotopic composition (range 0.4‰) very well buffered against the seasonal rainfall range (6.8‰). Such conditions enable calcite deposition without strong kinetic isotopic disequilibrium effects, as validated by Hendy tests, and give us confidence that the isotopic signal is faithfully recording climate changes.

All three speleothems (MOD-31, MOD-32, MOD-33) were active, collected from their growth position, so Holocene signals can be traced in all of them. Within their older parts, U-Th dating reveals the following growth periods: MOD-31 from MIS 10 to MIS 7, MOD-32 from MIS 4 to MIS 2, and MOD-33 from MIS 6 to MIS 5. Relatively large  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  ranges (-8.16‰ – -2.97‰ and -13.11‰ – -1.00‰, respectively) indicate significant environmental changes whose comparison with stable isotope time series of adjacent speleothem records and other regional proxies provides the longest eastern Adriatic speleothem-based record.

O-3076

## Millennial-scale coccolithophore paleoproductivity record and water column dynamics in the Alborán Sea (Western Mediterranean-ODP 977) during Marine Isotope Stage 11

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### Abstract

Proxy-based reconstructions of past interglacials is a key to improve the understanding of paleoenvironment and paleoclimate evolution, and in particular for the comparison with the Holocene. A high-resolution coccolithophore analysis along with oxygen and carbonate isotopes and alkenone-derived sea surface temperature (SST) was carried out in the western Mediterranean Site ODP 977 (Alborán Sea) with the aim to reconstruct changes in paleoproductivity and surface dynamics at millennial-scale during the Marine Isotope Stage 11.

*Gephyrocapsa* is the most abundant taxa of the interval with the dominance of small *Gephyrocapsa* (<3mm), revealing high-frequency variations in productivity through the upper photic zone, related to weakening and strengthening of upwelling conditions, as well as changes in the Mediterranean – Atlantic water exchange. During Termination V, the high amplitude warm-up pattern of deglaciation is well expressed by high percentages of “warm water” taxa and temperature proxies. Two contrasted paleoproductivity scenarios highlights during the full interglacial of homogeneous high temperatures MIS 11c, showing independence in the behavior of large part of the coccolithophore assemblage with temperatures after comparison with the alkenone record. The MIS 11 – MIS 10 transition is characterized by the millennial-scale variability. Cold abrupt events identified with the high representation of subpolar subspecies *C. pelagicus* spp. *pelagicus* and high percentages of reworked calcareous nanofossils are correlated with drops in temperature defining two abrupt events. These events are consistent with a decrease in coccolithophore productivity and related to general processes linked to variations in the North Atlantic dynamics.

Short-term oscillations in wind and precipitation controlled by the North Atlantic Oscillations during MIS 11 are here proposed as responsible for this variability in surface water features.

Alternatively, in this study, we paid attention to the identification of several morphotypes/species of *Gephyrocapsa* (“*G. Caribbean*”, *G. oceanica* and *G. muelleriae*) with variable calcification using image analysis techniques. We hypothesized about the relationship between these changes and oceanic processes at the regional and global level.

O-3077

## New insights on Holocene climate dynamics in the southern Mediterranean as deduced from the Sebkhia Kelbia multi-proxy record (Central Tunisia)

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### Abstract

Continuous palaeoecological records are still needed in the southern Mediterranean arid lands in order to fill in the map of Holocene climate change and to improve our understanding of climate dynamics and their geographical discrepancies during the Holocene. In arid regions where suitable sediments are lacking, the Sebkhia Kelbia sequence constitute a unique archive spanning the last 8kyr that allows a detailed, multi-proxy and high-resolution study of landscape and climate dynamics in the semi-arid region of Central Tunisia. Multi-proxy analyses are carried out on a 15 m long core in order to characterize sedimentary environments, paleohydrological changes and associated vegetation landscapes. It includes geochronological, palynological (pollen, non-pollen palynomorph, micro-charcoal) and sedimentological (magnetic susceptibility, loss on ignition, granulometry) analyses.

The sedimentological and palynological results highlight recurrent changes on the sebkhia function and vegetation landscapes associated to the Middle Holocene long-term aridification trend that initiated during the 6<sup>th</sup> millennium BP. Climate aridity trend is documented through sedimentation phases indicating the succession of three paleohydrological systems with first a lake, then a temporary lake and finally a sebkhia. Pollen data, mainly related to the mountainous hinterland, document also this aridification trend with the gradual establishment of the xerophytes Mediterranean taxa (mainly *Olea*, *Pinus*, *Pistacia* and *Juniperus*).

The data provide evidence of Rapid Climate Changes (RCCs) during the Middle and Late Holocene. Comparison with available palaeoecological records both in the Mediterranean and in the Sahara are used to discuss climate dynamics and connection with climate events previously documented further south in the Sahara, such as the end of the African Humid Period (AHP), and other events recorded in the Mediterranean, such as North Atlantic Cooling events. Especially the inedit data from Sebkhia Kelbia emphasize a contrasting climate pattern across the Mediterranean Basin triggered by the differential impact of the North Atlantic Oscillations (NAO) and the Mediterranean Oscillations (MO).

O-3078

## The Diluvium aquarum: geologic evidence and geoarchaeological constrains of extreme floods in Northern Italy during early Middle Ages

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### Abstract

In the Mediterranean region the period following the collapse of the Roman Empire is described by many authors as an interval characterized by important alluvial processes (e.g. floods, river avulsions, alluvial aggradation in the valleys), strongly contrasting with the general geomorphological stability of Roman Age and Late Antiquity. Some important chronicles of early Middle Ages report the occurrence of very high-magnitude floods, often described by ancient historians as *diluvium* (deluge), contributing to create a sort of myth around an out-of-scale event or a longer meteo-climatic phase.

In the framework of the INQUA project “EX-AQUA: Palaeohydrological Extreme Events, evidence and archives” (1623P), a review of the traces of early Medieval floods occurred in Northern Italy was carried out. The study considered new information and previous available data supplied by geomorphological, stratigraphic and geoarchaeological evidence, ancient documents and written sources.

In the investigated area a fast and strong sedimentary phase occurred between 5<sup>th</sup> and 9<sup>th</sup> century AD, leading many large Alpine rivers to avulse. In the system of Tagliamento, thanks to recent geoarchaeological excavations and geochronological analyses, a major extreme event is clearly constrained between the second half of the 6<sup>th</sup> and the first part of the 7<sup>th</sup> century, when the river avulsed and destroyed the ancient city of Concordia Sagittaria. This episode overlaps with the one reported by the Lombard historian Paolo Diacono, dated to 589 AD, which strongly damaged Verona and, downstream of this city, possibly triggered the avulsion phase of Adige River near the so-called “Rotta della Cucca”. Important fluvial changes affected also the Piave and Livenza rivers, while an avulsion channel of Brenta River started to form in the 6<sup>th</sup> century AD.

Notwithstanding, for some minor alluvial systems the detailed chronology supported by archaeological and radiocarbon chronology allows to detect the existence of earlier flooding units, formed since the 2<sup>nd</sup> and 3<sup>rd</sup> century AD. Recent data in the Alpine valley of Adige River, around the city of Trento, point towards the occurrence of some important flood events in the alluvial cones of the major tributary creeks already during the 3<sup>rd</sup> century AD. However, in the same area the floor of Adige valley experienced a vertical aggradation only since the 4<sup>th</sup> and 5<sup>th</sup> century AD, with an enhanced rate of deposition between 6<sup>th</sup> and 10<sup>th</sup> century AD. A rather comparable chronology characterizes part of the alluvial cones of the main Apennine streams flowing towards the Po Plain (e.g. near Modena), which aggraded during early Medieval, but this trend started already in the 3<sup>rd</sup> century AD.

This research supports new data for comparing the palaeoflood record of early Middle Ages with palaeoclimatic proxies, with the aim of distinguishing global forcing factors from regional constrains and anthropogenic disturbances.

O-3079

## Palaeoflood hydrology of the Duero River (Spain and Portugal) during the Late Pleistocene and Holocene

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### Abstract

The Duero River is one of the three major rivers in the Iberian Peninsula, draining an area of 98,073 km<sup>2</sup> (20% in Portugal and 80% in Spain) into the Atlantic Ocean, producing some of the highest peak discharges to be found in European rivers with similar drainage area. The estimation of peak discharges during historic and prehistoric periods and its temporal correlation with climate variability is thus fundamental in flood hazard and dam safety analysis. A palaeoflood study was carried out along a 3 km reach between Vilariño (Spain) and Bemposta (Portugal) at the Natural Park of Los Arribes, a ~200-m deep bedrock gorge cut into Hercynian granite and granodiorite rocks. Slackwater deposits (SWDs) are preserved in thick, high-standing benches in canyon expansions and tributary mouths. Twelve high-resolution stratigraphic profiles were studied, and the deposits dated using optically stimulated luminescence, covering the last 14.4 ka. The most complete record is found at the Duero-Tormes river junction, which comprises five inset SWD benches at elevations between 15 and 25 m above river thalweg (ART). The highest bench (Muga profile) comprises six flood units within four sequences, dated to 13.8ka, 8.4ka, 2.4ka and post-2.4ka. At 23.5 m ART, the Tormes profile recorded 23 flood units organized into four sequences separated by well-developed paleosols, and dated to 11.6ka, 9.5ka, 4.4ka and <1ka. The third inset bench (Cicutina profile; 20 m ART) comprises 19 flood units, whereas in the fourth inset (Tabanera profile; 17.5 m ART), 17 flood units were identified; here the OSL dating is in process. The fifth inset bench (Borbon profile; 14 m ART) was likely deposited during historical and recent flooding, since recent events are known to cover this bench. Sedimentary archive from SWDs was compared to historical flood record from documentary archives in the region. A record of 70 historic floods was compiled over the period 1256-1911, and classified into three categories, catastrophic, extraordinary and ordinary floods. A total of 11 catastrophic floods were identified during the pre-gauged period including the outstanding floods of 1860 and 1909, with estimated discharges at the study area of 7600-7700 m<sup>3</sup>s<sup>-1</sup>. The hydroclimatic analysis of the flood record shows a good temporal correlation between the occurrence of catastrophic floods and the existence of anomalous negative NAO index phase. The Duero's palaeoflood and historical flood records are in good agreement with flood episodes recorded in other Iberian rivers (e.g. Tagus, Guadiana), which highlights the impact of atmosphere-ocean hemispheric coupling conditions on extreme floods in the region. These findings suggest a response, at centennial scale, between climatic factors and the outcome variability in the magnitude and frequency of floods.

O-3080

## A four-dimensional integration of multi-archive datasets to understand historical flood pattern in alpine catchments

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### Abstract

Natural and historical evidence of severe and catastrophic floods that have really occurred, and which are not extrapolated, can be inferred from different types of past flood archives, whether of natural or anthropogenic origin.

In the framework of an innovative research initiative located in the Bernese Alps (Schulte et al., 2019), multi-archive flood series, that include floodplain sediments (4 records), lake sediments (4), documentary data (4), instrumental measurements (4), and lichenometric-dated flood heights (4 profiles), were analyzed to reconstruct accurately flood periods during the past six centuries. Based on this assembled multiple flood data sets of the rivers Hasli-Aare, Lütshine, Kander, Simme, Lombach, and Eistlenbach, Lake Thun, and the pre-alpine Aare river Thun-Bern, i) common flood pulses were determined, ii) records which are out-of-phase were identified, and iii) the sensitivity of the different natural archives were investigated.

The most continuous and accurate series were integrated over the period from AD 1400 to 2005 into a synthetic flood master curve that defines ten dominant flood pulses around AD 1410, 1480, 1570, 1650, 1710, 1760, 1830, 1850, 1870 and 2005. Six flood periods correspond to cooler climate pulses, three to intermediate temperatures, whereas the youngest flood period occurs during the pulse of current Global Warming.

For the ten flood periods, the location and magnitude of all the compiled flood records were plotted in maps that illustrate accurately the spatial pattern of flooding during the last 600 years in an alpine region of 2,117 km<sup>2</sup>. The spatial pattern of the historical flood pulses was analyzed and compared with the most recent floods (e.g. 1999, 2005, 2011) that occurred during the warmest pulse of the recent Global Warming. Furthermore, maps of atmospheric conditions were generated to compare flood behavior in the catchment with the variability of the modeled atmospheric pattern during the flood pulses. Six of ten periods coincide with the positive mode of the Summer North Atlantic Oscillation (SNAO), which is defined by a strong anticyclone blocking between the Scandinavia Peninsula and Great Britain.

Finally, the comprehensive four-dimensional model of paleofloods allows us to understand in depth the extreme riverine flooding phenomena in mountain catchments with regard to their triggering, mechanisms, and forcings at multi-centennial timescales. We suggest that this new methodology can be transferred to other mountain regions.

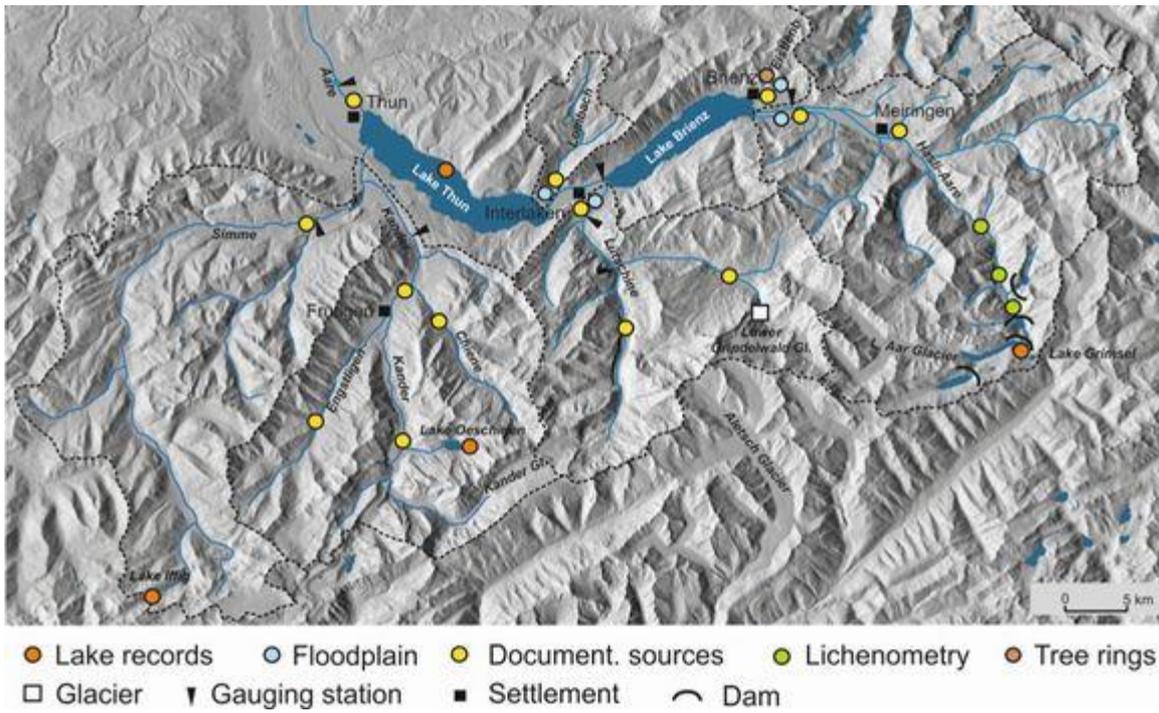


Figure 1. Location of the study area in the Alps. Shaded relief, location and type of flood archives (dots) mentioned in text.

**O-3081**

## **A millennial-scale multi-proxy Palaeoclimate database for a better understanding and prediction of extreme hydroclimatic events in South East Queensland, Australia**

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### **Abstract**

Eastern Australia's hydroclimatic variability is extreme compared to the rest of the world on seasonal to multi-decadal scales. Although this variability is reflected to some extent in the existing instrumental records (e.g. mean annual rainfalls between 650-2850 mm), the relatively short instrumental records (~60-120 years) do not cover the full range of hydroclimatic variability and limit the calculation of robust statistics around the baseline risk of extreme events. However, this hydroclimatic variability is well documented in the paleoclimate proxy records, as potential surrogates for rainfall, streamflow and temperature, which in turn can be correlated with large-scale ocean-atmospheric processes such as El Niño/Southern Oscillation (ENSO) and local hydroclimatology.

Queensland contains the highest proportion of palaeoclimate proxies in Australia, and the contribution of each dataset is considerable, both in resolution and geographic coverage. Furthermore, when combined, their potential is enormous. Each dataset provides an independent control of the key periods of overlap, similarities and drivers of past changes in rainfall and streamflow, helping assess existing and potential future changes in the frequency, duration, magnitude and timing of floods and droughts. Collective analysis of these datasets will also provide a structured and targeted approach to identifying and filling key knowledge gaps.

This study is the first to collate, synthesise and statistically analyse all available proxy climate data for the region and the resulting database will be the most comprehensive dataset of the frequency, duration, magnitude and timing of both flood and drought events during the last 2-3000 years for this region in Australia. This presentation showcases the nature of the existing proxy records and preliminary results of statistical analyses on their spatial correlation across Queensland.

O-3082

## Reconstruction of early historic topography of a large lowland area for palaeo-hydraulic analyses

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### Abstract

Reconstruction of past topography in a palaeo-DEM is useful for a range of geological, geomorphological and archaeological applications. One novel application is palaeoflood analysis using numerical hydraulic modelling, aiming to quantify past flooding patterns and magnitudes. This requires a representation of the past topography as input, with an effective resolution below the model grid size. Here, we present a palaeo-DEM of the Lower Rhine valley (North Rhine-Westphalia, Germany) and delta apex (the Netherlands) for circa 1000 CE. The study area of  $4.5 \cdot 10^3 \text{ km}^3$  is spread over two countries and includes densely populated and industrialized areas. In this presentation, we will focus on the critical steps in construction of the palaeo-DEM, on the completed end product, and on its applications as part of extreme-event palaeo-hydrological investigations.

Two contrasting approaches exist for constructing a palaeo-DEM, namely starting from subsurface data (bottom-up approach; interpolating between scarce data points) and starting from the present-day topography (top-down approach; stripping young morphological features from a modern DEM). Data required for the second approach, most importantly LiDAR DEMs, are relatively easy to collect over large areas. However, correcting a modern DEM to a palaeo-DEM becomes difficult for increasing spatial resolution and periods further back in time.

For our study area, we have developed a protocol for top-down palaeo-DEM construction that can remove considerable anthropogenic overprints and replace young, human-managed river morphology with a representative natural river geomorphology (proximal floodplain topography and channel bathymetry). A key step in our approach was deploying different reconstruction strategies to the area occupied by the post 1000 CE channel belt in the centre of the valley (active zone) and to the rest of the valley floor (inactive zone). The infilling methods for the active zone are a hybrid between top-down and bottom-up approaches, as we used existing geological, geomorphological, and historical geographical data as guidelines (Fig. 1). The workflow we developed can be applied to other lowland fluvial areas at different spatial and temporal scales. The resulting palaeo-DEM is an essential starting point for advanced palaeo-hydraulic analyses.

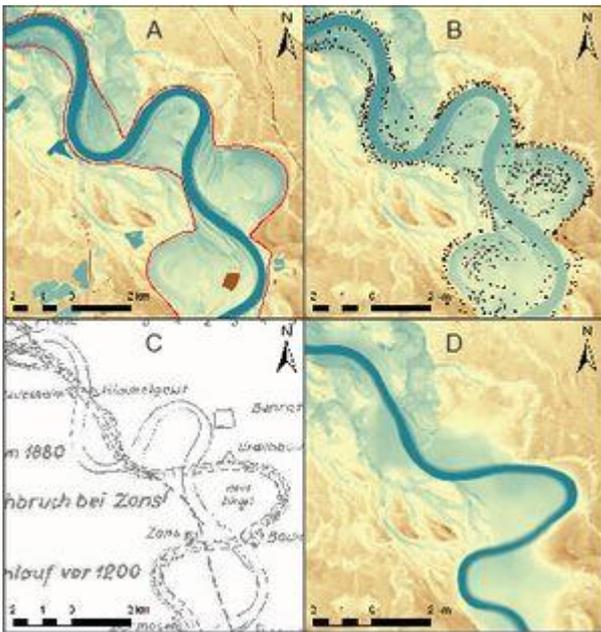


Fig. 1. Reconstruction of floodplain topography upstream of Düsseldorf. A) Present-day LiDAR DEM. Red line indicates active zone boundary based on geological maps. B) Intermediate Palaeo-DEM. Points are placed along and inside the active zone for reconstruction of proximal floodplain. C) Example of an earlier reconstruction of local Rhine river position in medieval times (Scheller, 1965). D) Final palaeo-DEM.

O-3083

## The influence of land-use changes and river management on extreme-floods in the Southeastern Spain. The case of the River Antas

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### Abstract

During the last centuries, the southeastern Iberian Peninsula has undergone significant morphological and land-cover changes. Run-off might have increased and the floods damaged historical infrastructures near the river because of the higher discharges. This study aims to determine the influences of these land-use changes in the dynamics of the fluvial system. The study area is located in the lower catchment of the Antas River (SE Spain), a 5-kilometer stretch that have several historical aqueducts and a weir from the 18<sup>th</sup> Century, which have not been damaged until the last extreme flood (2012). Since the 16<sup>th</sup> Century, land-use was defined by a symbiosis of water resources, irrigation systems, farming and grazing, adapted to the arid environmental conditions of the Southeastern Spain, the driest region of Europe.

Historical flood-series, historical maps and aerial photographs from different periods have been analyzed, in order to recognize extreme flood-events damages, morphological changes, climatic dynamic (temperature) and land use changes in the study area. The historical map (1887 and 1924) shows the difference between the traditional land uses and the current land use. In order to compare those periods, several sets of aerial photos, from 1956 and 1973-1986 (before changes), 1998-2000 (during changes) and 2010-2015 (after changes). In 1956 and 1973-1986 different land uses related with irrigation ditches and old dams in the riverbed were mapped, In addition, the Antas riverbed were used as a pathway of livestock. In the next generation of aerial photographs (1998-2000), not only the land use near the riverbed changed, but also its morphology. As a consequence of the abandonment of this pathways vegetation colonized the river channel and floodplain obstructing the water flow. The old hydraulic structures as two aqueducts and a weir (1867, 1880 and 1544, respectively) survived all historical extreme events (e.g. 1924, 1973, 1989), but not the 2012 flood.

Furthermore, the weirs and irrigation channels detoured in an uncontrolled manner large amount of discharges from the river channel to the irrigation plots, causing massive aggradation and erosion. Since 1973, Magnitude 3 flood-event had not affected the region until 2012-flood event. We suggest, that these severe damage results from synergetic processes: large peak discharge, exceptional land-use changes (destruction of agriculture terrace) and the abandonment of traditional irrigation techniques. Most of these changes have increased the vulnerability and the exposition of population and infrastructures. To sum up, increased flood damage might be related to the poor integrated and environmental management of the ephemeral fluvial system.

O-3085

## The sedimentary record of Alpine lake tsunamis: Assessing an underexplored natural hazard

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### Abstract

Historic chronicles and previous studies document that tsunami waves occur not only in the oceans but also in lakes potentially causing widespread coastal damage and even casualties. With a detailed historic database and its extensive previous limnogeological and paleoseismic research, Central Switzerland offers an outstanding field laboratory to assess the relevant lake-tsunami processes. A multidisciplinary project aims at unraveling the trigger mechanisms, preconditions, processes and impacts of seismic and aseismic subaquatic slope instabilities and related lake tsunamis- a so far underexplored natural hazard. Results are anticipated to be applicable to other lake districts and gained knowledge of underlying processes will contribute to a better general understanding of mass-movement induced tsunami waves in the marine realm. The goals of this research program are thus to understand governing mechanisms of genesis and propagation of tsunamis in lakes by using these continental basins as analogues for their marine counterparts. Through a multidisciplinary approach involving limnogeologists, seismologists, geotechnical specialists, hydraulic engineers and hazard specialists, key concepts and factors relevant for causes and controls of these tsunamis will be developed.

Sublacustrine mass-movements causing these lake tsunamis can be identified in the basal sediments by large volumes of displaced sediments, which provide critical data to model the tsunami propagation including their inundations. Geotechnical properties and geometries of charged slope sediment control threshold conditions at which slope instabilities are triggered. To complete the event catalogue of these events and to verify inundation processes, a series of sediment cores around the lakeshores target the identification of tsunami deposits that witness historic and prehistoric events. For this purpose, various marsh lands and coastal depressions have been cored mostly in shore-perpendicular transects. New lake-sediment-tailored methodologies are currently developed to identify these lacustrine tsunami deposits; key challenges for successful identification of tsunami layers in the lacustrine realm are the impact of lake-level fluctuations on available accommodation space, sediment-availability in the near-shore / on-shore environment, preservation of the associated deposits, the disentangling from flood- and storm-induced detrital layers, anthropogenic impact on coastal morphology and (core-recovery) quality/recovery of cores in these petrophysically highly contrasting lithologies. These challenges can be overcome by a sensitive choice of coring locations and a sophisticated sediment-core analysis, eventually leading to a tsunami-event stratigraphy of the postglacial epoch.

All knowledge gained from studying slope instabilities and from identifying tsunami deposits will be used as input parameters into numerical models of tsunami-wave propagation and inundation yielding a holistic framework for probabilistic tsunami hazard assessment. The results from process understanding, different modeling methods and data developed in the project will provide the baseline for assessing the risks for people, lifelines and structures along lakeshores and coasts.

O-3086

## A 1000-year history of the great tsunamis recorded in emerged sea cave, southern Kanto, Japan

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### Abstract

Locating near the Tokyo metropolitan area, Sagami Trough great earthquake (Great Kanto earthquake) has been a source of care in Japan for the last several decades. The last two events, 1923CE (M7.9) and 1703CE (M8.2), caused severe seismic and tsunami disasters around the Kanto region. However, the older history of the Kanto earthquakes is still unclear. Because the Kanto area had been uncivilized place located far from the capital region in these days, few reliable documents about the Kanto earthquakes are still in existence. Additionally, number of reliable geological evidences are still insufficient to discuss the recurrence history of Kanto earthquakes. Here we report a series of possible tsunami deposits from an emerged sea cave located on the Miura peninsula facing the Sagami Trough. This is the first report of tsunami deposits from Japanese sea caves and improve our knowledge of the frequency and magnitude of large tsunamis around the Kanto region.

The Shiraishi cave is located on the sea cliff of Late Pleistocene marine terrace. Its open width, depth and top board height are about 5 m, 21 m and 10 m, respectively. Excavation researches in the cave revealed the remains of fireplace and tombs at the level of 6.0-6.4 m. Their ages range from the first century BC to 9th century. Covering the ruins, about 1.7 m-thick alternation of mud, sand and gravel layers is distributed in the cave. Main components of these deposits are scoria and mud balls (mainly fragments of loam soil covering the marine terrace) and different from the cave wall geology (Late Miocene tuffaceous sandstone). They are classified into at least five layers with 10 to 60 cm-thick based on the basal erosion surfaces and sedimentary facies. Each layer shows normal or reverse grading, sometimes multiple layered structure. Current ripples and dunes show that these deposits were derived from the outside of the cave. Fossil marine diatoms also characterize these deposits.

Wave heights during the typhoons are not high to inundate the Shiraishi cave. Tsunami height during the 1923 nor 1703 Kanto earthquakes did not reach the cave. It can be still disputable to consider the coseismic uplift (wave cut benches emerged by the 1703CE earthquake is now located around 2.3 m in elevation), plausible sources of the five sediment layers in the Shiraishi cave are large tsunamis.

A total of 10 radiocarbon ages and archaeological evidences roughly placed the five layers 9th to 10th century (lowest layer), 1300-1400CE (second one), 1450-1530CE (third and fourth one) and 1550-1640CE (upper most layer), respectively. Comparing with the historical documents, candidate source of four events are 878 Gangyo, 1293 Einin and 1495 Meio Kanto earthquakes and 1605 Keicho earthquakes, possible Izu-Ogasawara trench earthquake (Ishibashi and Harada., 2013).

O-3087

## Tsunami records from lacustrine environments in Thailand, Chile and Japan: potential and limitations

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### Abstract

Tsunami evidence from coastal lakes and lagoons has not yet been exploited to the same extent as the more conventionally studied terrestrial records from e.g. coastal lowlands. Lakes, however, are often considered superior event archives, as they have more accommodation space for sediments to accumulate in, and preservation potential is better compared to terrestrial records, which are often strongly affected by erosion due to interseismic coastal elevation changes or due to inundation by subsequent tsunamis. Even though these qualities apply to most lake basins, a spectrum of different settings should be regarded, depending on geography, climate, geomorphology and geology of the surroundings, basin morphology, lake origin etc. These factors determine the characteristics and quality of the lake record and the possible presence of tsunami deposits within. A well-considered selection of lakes with different characteristics and in diverse settings along subduction zones in Thailand, Chile and Japan allows to achieve a conceptual understanding of how external factors influence the potential and limitations of lakes as tsunami archives. Characteristics of each site were studied by executing geophysical surveying techniques (reflection-seismics and side-scan sonar), coring (gravity and piston) and core analyses (e.g. CT scans, XRF scans, grain size, <sup>14</sup>C dating, tephrochronology...). This toolbox of methods helps to identify and characterise tsunami deposits and to define which (combination of) proxies are most successful in highlighting marine inundation. The case studies include three small, former tin mining ponds from the last century in Khao Lak, Thailand, two isolated river valleys (Gemelas West and Vichuquén) in Chile that formed due to eustatic regression and dune formation during the Pleistocene, and one big, tidal lake (Hamana) in Japan that is the result of an interaction between Pleistocene incision and complex coastal processes. The Chilean coastline is free of tropical storms and Khao Lak has no history of significant storms, whereas the Lake Hamana area is prone to both tsunamis and typhoons (i.e. extreme wave events). Given the difficulty to distinguish between both types of extreme wave event deposits, this has major implications for Hamana as a tsunami archive. In addition to that, Lake Hamana is directly connected to the ocean and hence experiences a strong influence of relative sea-level changes on deposition and preservation. The Khao Lak ponds, in contrast, are geomorphologically perfectly positioned to serve as tsunami archives. However, their man-made origin strongly limits the record length, only capturing high-resolution deposits of the 2004 Indian Ocean Tsunami. Both lagoons in Chile are capable of successfully recording long (pre)histories of tsunami inundation, but might be infiltrated by other event deposits with a comparable imprint apart from tropical storms (e.g. floods, earthquakes and strong aeolian activity). Identifying appropriate proxies to disentangle the different event signatures is key.

O-3088

## Coupling tsunami field data and numerical modeling to better understand the AD 1755 tsunami

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### Abstract

The application of numerical models of tsunami inundation and related sediment transport have been used recently to better understand the processes involved in tsunami deposition. With reliable and extensive field data these models can provide insights into physical aspects of specific tsunami events and contribute, for instance, to better define its mechanisms.

We applied a coupled field data and numerical modelling approach for the AD 1755's tsunami along the southern Portuguese coast, using Delft3D Flow Mode. Two onshore study sites (Boca do Rio and Salgados) were selected to model tsunami inundation and sedimentary dynamics. In both areas the AD 1755's tsunami deposit, typically, consists of massive or normally-graded, landward thinning layers of shell-rich medium sand with an erosive base within the mud-dominated lowlands. Applying provenance techniques (textural, microtextural and heavy minerals) it was possible to establish the likely sediment sources of this deposit (dune and beach).

This work used geological signatures (both depositional and erosional) of the AD 1755's tsunami to validate tsunami hydrodynamic and sediment transport models from 7 different proposed fault ruptures. These epicentral areas have been previously proposed in literature and include Marquês de Pombal Fault, Gorringe Bank, Cadiz Accretionary Wedge, Horseshoe Fault and 3 different scenarios combining some of these structures with deeper (30-60 km) ones. Results allowed to establish the more likely generation-mechanism and epicentral location based on the best correlation between field and modelled results (tsunami travel time, run-up, erosion depth, volume of sediment and post-event coastal profile). Furthermore, we also tested variations on composition and grain-size and the way it affects the sedimentary imprint laid down by the tsunami event.

Results are promising and suggest that recent advances in numerical modelling can provide useful insights to tsunami geoscience namely by allowing to reconstruct physical parameters and morphodynamic changes caused by tsunami events.

### Acknowledgements

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O-3089

## A multiproxy analysis of extreme wave deposits in a tropical coastal lagoon in Jamaica, West Indies

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### Abstract

The Caribbean Region is vulnerable to natural disasters including earthquakes, tsunamis and tropical cyclones; however, there are few studies of coastal lagoons that attempt to document and distinguish between marine washover layers deposited by storms and those emplaced during a tsunami, which in turn hampers the interpretation and reconstruction of past extreme wave events. Here, we present a 1000-year multiproxy record of extreme washover events deposited within a coastal mangrove lagoon on the south coast of Jamaica. Manatee Bay lagoon is a permanent fresh-brackish water mangrove lagoon separated from the Caribbean Sea by a carbonate beach. Fifteen sediment cores were recovered through ~0.4m of water along five shore-normal transects encompassing ca. 1200 years of sedimentation. The organic and carbonate contents of all cores were determined using LOI and geochemical analyses were performed on the ITRAX  $\mu$ -XRF scanner at Aberystwyth University. The lagoon depositional environment comprises micro-fossil-rich authigenic carbonate lake muds dominated by the brackish-water ostracod *Cyprideis mexicana*. The carbonate muds are separated by organic mangrove deposits which are similarly dominated by *Cyprideis mexicana* but contain an increased abundance of *Heterocypris punctata*, which generally prefers fresh-brackish water conditions. Stratigraphically distinct carbonate beach sand lenses occur within the sediment record. Near-surface sediments from cores across the modern washover fan drape the underlying lagoon muds with a sharp, non-erosional contact and are readily distinguished by abrupt positive excursions in Ca, Sr and Fe and concomitant declines in organic matter, Br and Cl. Washover sediments are dominated by bioclasts of *Halimeda* sp., echinoid spines, sponge spicules, reef benthic foraminifera and molluscan fragments. Evidence of multiple palaeo-washover deposits is contained within 13 of the 15 sediment cores. Fresh-brackish water fossil ostracods and charophytes, typical of the contemporary lagoonal sediments, are notably absent in surface and palaeo-washover deposits. The primary washover deposit that occurs in multiple cores can be cross-correlated across the lagoon by an abrupt positive excursion in Fe. This deposit <sup>14</sup>C-dated at 1810-1925 cal CE encompasses a period of both extreme tectonic and meteorological events most notably the 1907 earthquake, the second most devastating in Jamaica, which generated a tsunami in Kingston Harbour, just 10km east of the study site. However, during this timeframe there were also a series of major hurricanes that passed within 20-35 miles of the lagoon thereby complicating the attribution of this event to any specific cause. The sedimentology, geochemistry and ostracod fauna provide an indication of the extent of marine incursion for different washover events over the ca. 1200 years and their impact on lagoon development, however, it remains unclear as to whether the primary washover deposit has been emplaced by a tsunami or other extreme wave event.

O-3090

## The sedimentary record and numerical simulation of a tsunami associated with the 7.3 ka eruption of the Kikai volcano, Japan

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### Abstract

The 7.3 ka eruption of the Kikai volcano, occurred in a shallow sea area of southern Kyushu, Japan, is one of the largest caldera-forming eruptions in Holocene. A huge tsunami has been generated by a sea-level change caused by caldera collapse and/or an entrance of pyroclastic flow into a shallow sea. Tsunami deposits associated with this eruption have been observed at three distant coastal lowlands (~560 km from the volcano). They are overlain by volcanic ash from the eruption (Kikai Akahoya tephra: K-Ah) and exhibit sharp contacts with the upper tephra and lower muddy sediment in onshore sediment cores. A tsunami deposit overlain by the Koya pyroclastic flow deposit (K-Ky) is also observed at Yakushima and Kuchino-erabujima Islands near the volcano (Geshi et al, 2017; Nanayama and Maeno, 2018). These stratigraphic relationships indicate that the tsunami hit the distant coastal lowlands and the nearby islands immediately before the arrival of the K-Ah fall tephra and the K-Ky pyroclastic flow, respectively. Based on these widely-distributed geological evidences, this study aims to unravel the tsunami size and triggering volcanic phenomena by numerical simulations of both caldera collapse and pyroclastic flow tsunamis.

A tsunami generated by caldera collapse was numerically simulated based on the method proposed by Maeno et al. (2006) and using the non-linear long wave model (JAGURS; Baba et al., 2015). Assuming that a hypothetical volcano (15 km × 10 km) collapsed from 800 m high to 500 m deep in 1 hour, a first wave of the resultant tsunami arrived at the lowlands between 2.5 and 3.5 hours since the caldera collapse started. The amplitude of the simulated tsunami were less than 1 m at all lowlands. A tsunami generated by an entrance of pyroclastic flow was also numerically simulated by a non-linear two-layer model and pyroclastic flow parameters by Maeno and Imamura (2007). A first tsunami arrived at the lowlands approximately 2 hours since the eruption. The tsunami amplitudes are smaller than those generated by caldera collapse. The stratigraphy at the nearby islands suggests that the tsunami was most likely generated by an entrance of pyroclastic flow because caldera collapse probably occurred at the end of the eruptive process, and that its associated tsunami cannot reach the island before the arrival of pyroclastic flow (Geshi et al, 2017; Nanayama and Maeno, 2018). However, the results of this study indicate that the tsunami generated by pyroclastic flow is probably not powerful enough to form a tsunami deposit at the distant locations. Thus, we will give consideration to the possibility that the tsunami was generated by both caldera collapse and an entrance of pyroclastic flow almost at the same time.

O-3092

## Alluvial Fans And Their Relationship To African Humid Period Climate Dynamics

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### Abstract

We investigate the size, timing and impact of African Humid Period (AHPs) flood events along the margins of upland landscapes within the Sahara Desert. AHPs relate to the wobbling of the Earth's axial spin, which alters atmospheric circulation patterns every ~20ka, repeatedly bringing elevated hydrological conditions (~5ka duration) to low-mid latitudes of continental Africa ('Greening' of the Sahara). Insights are provided using alluvial fans, cone-shaped sediment bodies that develop along mountain fronts or at river tributary junctions, hydrologically and sedimentologically linking hillslopes to channels. These landforms possess significant but unrealised large spatial and long temporal potential to inform on climate change sensitive drylands; areas with evidence for early humans and pressures from modern population growth. In this presentation alluvial fan-AHP dynamics are illustrated using examples from the Cape Verde volcanic archipelago (low latitude, offshore west Africa), a terrestrial offshore climatic extension of the Sahara Desert.

Coalescent coastal alluvial fans have developed along the SE volcanic edifice flank margin on Santo Antão island. Fans display an expansive relict surface incised by up to 120m, revealing an up to 100m thick sequence of coarse-grained cobble-boulder dominated fluvial sediments interbedded with a with basaltic lava flows (undated) and tephra (Argon dated = 193 +/-23ka). Fan surface morphology is characterised using 10m TanDEM-X data and targeted field survey with UAV drone mapping. The surface morphology comprises low relief (<3.5m) distributive fluvial bars and channels. Fan surface age-relationships were determined using <sup>3</sup>He cosmogenic exposure dating. Results suggest the fan surface is a composite Late Pleistocene feature formed by spatially and temporally distinct lobes between 1) 80-90ka; 2) 50-60ka and 3) 10-20ka; a chronology coincident with the onset of AHP events. We present a climate-avulsion model in which the elevated hydrological conditions during the onset of AHP events has triggered avulsions of the alluvial fan channel network, switching floodwaters and sediments to different fan surface regions. Furthermore, we quantify the flood magnitude of these AHP-related avulsion events using competence based palaeohydrological methods.

We are expanding research into mainland Africa (e.g. Southern Morocco), using alluvial fans to 1) investigate how and when landscapes responded to AHP events outside of the lowland lake-dune dominated continental interiors of the Sahara; 2) to explore the sensitivity of alluvial fans to AHP events in different latitude and longitude contexts along the NW African continental margin; and 3) to investigate the impact of alluvial fan-AHP flood avulsions in an early human archaeological context.

O-3093

## Large rivers and a green coast: summer and winter precipitation control on North African landscapes over the past 220 kyr

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### Abstract

Changes in past hydrological regimes led to drastic alterations of North African landscapes and shifted ecological boundaries over thousands of kilometres. Understanding how prehistoric human populations reacted to these environmental changes remains a burning issue. However, the lack of continuous archives of North African hydrological variations has hindered our understanding of past climate and human population dynamics.

We present the first continuous and high-resolution climatic record from the Gulf of Sirte (offshore Libya) covering the last 220 kyr that documents fluvial pulses linked to the reactivation of Saharan paleo-rivers as well as coastal runoff. Monsoon-related summer precipitation reached as far north as 25°N during insolation peaks and led to massively increased fluvial runoff from the central Sahara and coincided with the deposition of sapropel layers in the Gulf of Sirte. Intermittent humid periods are detected during MIS6, MIS4 and MIS3, and are inferred to result from enhanced winter precipitation due to an orbitally-forced southward shift of the Mediterranean storm tracks. In addition, our record suggests the occurrence of humid conditions in both southern and northern Libya during MIS5e and MIS7, which may either indicate mega-monsoon events with convective cells reaching as far north as 30°N and/or winter precipitation, both related to periods of high obliquity of the Earth's axis. We argue that the opening of either N-S or E-W green corridors during MIS5 and MIS3-4, respectively, as well as large-amplitude climatic swings during MIS5 and MIS7 played a central role for trans-continental human migration waves and the development of highly developed populations in North Africa.

O-3094

## Sedimentary fillings of mountainous valleys as evidences of climatic and anthropogenic changes around Wakarida's archaeological site (Tigray, northern Ethiopia)

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### Abstract

Well known in West Africa, the *African Humid Period* (AHP) can also be spotted in sedimentary accumulations in East Africa. The earlier deposits (7<sup>th</sup> millennium BCE), found in valleys around the axumite (1<sup>st</sup>-6<sup>th</sup> Century CE) site of Wakarida (northern Tigray, Ethiopia), seem to correspond to wet conditions of the end of the AHP. Ages range from the 7<sup>th</sup> millennium BCE to the 17<sup>th</sup> Century CE and analyses show variations in depositional environments. Gaps in the dating in Wakarida could correspond to drier spells, identified by Dramis et al. (2003) in other Ethiopian places. At the turn of the 3<sup>rd</sup>/2<sup>nd</sup> millennium BCE, the aridification of the climate, pointed by Pietsch and Machado (2014) in Yeha, is sensible through the accumulation of silts, interbedded with gravels. This evolution towards a drier climate has consequences for the vegetation cover and the erodibility of the hillsides. At the end of the AHP, the sediment accumulations are mainly fine-grained, testifying of low competence processes. Nevertheless, coarse beds (with pebbles and gravels) show the occurrence of higher energy events and/or higher sensitivity of the drainage basins to erosive processes. Those can be attributed to climatic changes but they can also be the results of a progressive opening of the vegetation by a growing population. It is not easy to determine whether those changes are the result of climatic, anthropogenic or mixed processes. Sedimentary records dating from the pre-axumite period (800-0 BCE) could indicate the beginning of the clearing of the vegetation by population living in or around the archaeological site, even though no archaeological evidence of cultivation has been found in the excavations. Climatic and anthropogenic processes continue to combine in more recent periods, with two wetter spells leading to sedimentary accumulations in the 8<sup>th</sup> Century BCE and around the 12<sup>th</sup>-14<sup>th</sup> and 15<sup>th</sup>-17<sup>th</sup> Centuries CE. After the 17<sup>th</sup> Century, we lose track of accumulations processes and ablation seems to take place, leading to the erosional forms that we can see nowadays. At present time, the area around Wakarida seems to meet an unprecedented phase of incision and sedimentary crisis, which results in important headward erosion in the valleys' sedimentary fillings and endangers food security in this dry and highly populated area. This chronostratigraphic work has been conducted within a five-kilometre radius study area around the archaeological site and relied on the interpretation and sampling of sixteen sections, laser granulometry and C14 dating of charcoal samples. Working at the scale of small watersheds and multiplying the number of studied sites allows to understand the functioning of the catchment on long time and to identify and integrate some controlling factors like the organisation of the basin or the connectivity between upstream and downstream parts of the valley.

**O-3095**

**Excavations at the Stone Age site of Nyabusora, Tanzania in the context of hominin adaptations to equatorial African landscapes.**

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**Abstract**

This paper presents the results of excavations at the Sangoan site of Nyabusora in northern Tanzania. Excavations in 1959 were conducted by M. Posnansky and the late W. W. Bishop, and in 1961 by M. Posnansky. Hitherto only preliminary reports have been published on this site but new work on the unpublished archive has confirmed the value and future potential of the site both archaeologically and palaeoenvironmentally. The finds, which include lithics and more unusually, bone, take on new significance in light of recent developments in Early and Middle Stone Age (MSA) Archaeology in East Africa. In addition the site provides valuable sedimentological information which has implications for Quaternary landscape change in the Kagera River and Lake Victoria region. Nyabusora is one of several Stone Age sites currently under renewed investigation in the Kagera Catchment by Basell, and is one of only a handful of stratified sites to have yielded Sangoan assemblages. Following a summary of excavations and interpretations of the key finds, future directions for work at Nyabusora will be considered in the broader context of hominin adaptations to equatorial African landscapes.

O-3096

## Fromontane-Afroalpine ecosystems as long-term sensors of environmental change

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### Abstract

The two most important African mountain ecosystems are the Afroalpine and Afromontane ecosystems. Ranging in altitude from 2000 to more than 4500 m asl, they hold distinctive endemic faunas and floras. The best preserved examples are in the Ethiopian highlands but these still face the challenges of current global change, including increasing human action. Their high-altitude ecological communities are very sensitive to environmental fluctuations, being limited to relatively small areas. They are thus often the focus of ecological research, since conservation managers need informed evidence as the basis for management decisions. However little is known of their response to long-term environmental change, which is critical for understanding their likely response to future global change.

Palaeoenvironmental records from the Ethiopian highlands show patterns of increasing temperature and changing regional rainfall since the last glacial that may be linked to vegetation dynamics and human agency. We hypothesize that African mountain ecosystems are sensitive to climate variation and anthropogenic disturbance while being resilient to long-term change. We thus aim to answer the following questions: 1) How have varying moisture patterns affected the Ericaceous belt from the Lateglacial to the present? 2) What are the relationships between climate, vegetation and fire in these ecosystems?

To address these questions, we revisit lake Garba Guracha (GGU, 3950 m asl, Fig 1), presenting a new palaeoecological record of the last 16 kyrs. Our new record includes high-resolution time series of pollen, charcoal, diatoms and stable isotopes ( $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ ), where the latter constitute independent evidence of climate variation. The Lateglacial landscape at GGU was an open, dry, steppe-like environment. The record shows increasing moisture and temperature from 16 ka BP to the mid-Holocene (11-6 ka BP), concurring with the African Humid Period. Vegetation cover responded rapidly to the increasing moisture, with denser Ericaceous vegetation and thicker forest in the lowlands from the Holocene onset. This clear response of the Ericaceous belt to climate change is partially modulated by fire activity, which is dependent on biomass as a limiting factor, establishing a climate-vegetation-fire loop. The coupled climate, heathland, and fire dynamic is punctuated by drought events until 5 ka BP, when a longer, drier period established, lasting to the present and defining a new landscape where human impact became clearly distinctive. We discuss our results in the light of conservation measures for Afromontane and Afroalpine environments.

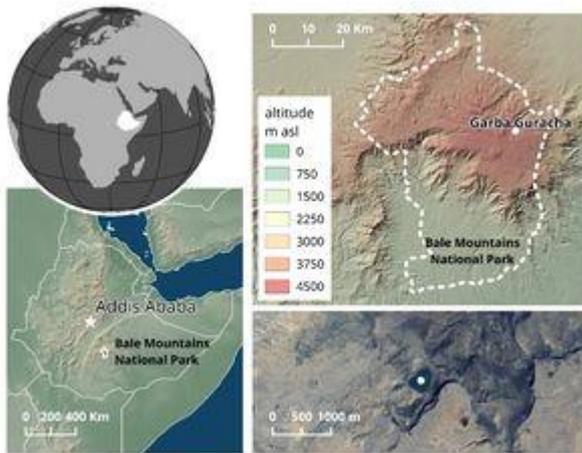


Fig 1: Location of lake Garba Guracha in the Bale Mountains National Park, Ethiopia

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O-3097

## From Iyonda to Bolondo: paleoecological and archaeobotanical signatures of past migrations, climates, and anthropogenic impacts in the Congo Basin.

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### Abstract

Articulating anthropogenic impacts on tropical rain forests within the broader schema of Pleistocene-Holocene climate change remains one of the most challenging research objectives facing Quaternary scientists. Plagued by problems of equifinality and polemic 'climate vs. culture' theoretical frameworks, this body of research can only be advanced through interdisciplinary collaborations focused on building empirically grounded case studies of coupled climatic and cultural change within tropical ecosystems. Records of past vegetation and human activities in the Congo Basin are extraordinarily rare compared with other tropical regions, despite the significance of Congolian Rain Forests within the Earth System and as one of the crucial zones of human adaptation and cultural-ecological coevolution.

Understanding rain forest response to anthropogenic impacts and climatic changes within the Late Holocene offers benefits to our understanding of the rain forest system at large as well as the core dynamics governing anthropogenic impacts. Of particular significance is contextualizing more detailed synchronic observations within diachronic changes over the last two millennia. Radiocarbon dating from excavated sites in the Democratic Republic of Congo indicates that forest settlement spans the last 2,500 years B.P. Excavation of archaeological sites and sampling of associated paleoecological records provides a basis for considering critical questions about anthropogenic impacts and the historical dimensions of modern forests. To what extent do modern anthropogenic impacts reflect past anthropogenic impacts? What can paleoecological archives tell us about the state of modern rain forests and their conservation status? In pursuit of these questions, this project brings together observations from archaeological, archaeobotanical, and paleoecological datasets; permitting consideration of technological and subsistence adaptations within a broader envelope of past vegetation change spanning on-site and off-site records.

Archaeological, archaeobotanical, and paleoecological study at the sites of Iyonda and Bolondo in the Democratic Republic of the Congo records a uniquely detailed Late Holocene record of past cultural and vegetation change on the Congo and Tshuapa rivers. Capturing some of the earliest and latest phases of colonization of the forest zone by prehistoric agriculturalists, these sites provide rare insights into the ecological contexts and outcomes of forest settlement. The presence of *Pennisetum glaucum*, a cultivar of the Sahelian zone, as well as evidence for iron metallurgy at these sites signals regional economic exchange and technological complexity. The evidence from these sites provides direct insights into vegetation change and forest diversity through critical phases of regional climate change and prehistoric settlement. Furthermore, this study makes concrete steps towards identifying and evaluating anthropogenic impacts by bridging archaeological records of human activity and local records of vegetation change.

O-3098

## The climate context of *Homo sapiens* dispersal out of Africa during the last interglacial–glacial: Speleothem records from southeastern Ethiopia

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### Abstract

Ethiopia/northeast Africa has been considered as one of the key sites for the origin of Anatomically Modern Humans (AMH) and possibly the region out of which AMH dispersed. There is a significant debate about the role of climate variability in human evolution and dispersal “Out of Africa”. High-resolution paleoclimate records from this region are therefore required to shed light on this debate. Climate records from speleothem archives using multi-proxy approach (oxygen and carbon isotopes, growth rate and trace element data) from southeastern Ethiopia spanning important time windows between the last interglacial and the late Holocene provide significant input to this effect. The record from the GM1 speleothem which intermittently grew during the last interglacial for instance shows that the earliest human migration during MIS 5e occurred during a major wet event in northeast Africa. Other speleothems from the same region which have been dated to the critical period of 120 - 50 ka are under investigation and pilot proxy records show rather drier conditions during the major episode of human dispersal at ~50 - 75 ka, suggesting a more complex relationship between climate change and human dispersal episodes. Comparison of high resolution but intermittent speleothem records from southeastern Ethiopia with continuous but lower resolution records from the northwestern Ethiopian highlands (the Tana Lake record), southern Ethiopian rift (the Chew Bahir Lake record), archaeological and sedimentological records of the Goda Buticha cave on the southeastern Ethiopian plateau, and marine records from the Gulf of Aden shows the relative significance of regional versus local climate variabilities.

O-3099

## Reconstructing Neolithic to Post-Medieval land-use dynamics and human activity from Lough Catherine, Northern Ireland: a *sedaDNA* and lipid biomarkers approach

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### Abstract

A molecular approach to lake sediments used for artificial islands (crannogs) is here used to reconstruct the environmental record from a natural island in Lough Catherine Northern Ireland. The island, named 'Island McHugh', was excavated in the 1940s-1950s and again in the 1970s. It has yielded artefacts from most periods including; Neolithic worked flint, a Bronze Age sword, worked wood, and charcoal, an early medieval crannog, and lastly a post-Medieval castle. The excavations by in the 1940s revealed a complex stratigraphy which has been re-evaluated as part of the *Celtic Crannogs Project*. A core from just off the island has revealed a complex stratigraphy extending back to the early Neolithic. Extracellular *sedaDNA* from the site shows three principal phases of human activity including both domesticates and synanthropes. In the first phase provisionally dated to the Iron Age open ground and grazing taxa increase with a small increase in arable indicators. There is also the appearance of cattle, pigs and sheep. In the second phase more securely dated to the early Medieval period there is a larger increase in both grazing and arable indicator taxa and a very strong increase in domesticated animals. In the Post-Medieval period horse is present and there is a comprehensive reflection of 18<sup>th</sup> century landscaping. The later two periods (Early Medieval and Post-medieval) are well represented in the excavations but the earlier phase (Iron Age) is not, so we are undertaking a further review of the existing excavation data as well as proposing re-excavation of some, somewhat enigmatic, features. The lipid biomarker evidence is also strong with high faecal stanols from the Iron Age to the Medieval levels. A clear peak at c. 600 BC enables the identification of the source as almost certainly of human origin. The faecal stanols record is shown to mirror the animal *sedaDNA* results. This study illustrates the ability of *sedaDNA* to identify both the impact of human activity on local ecology, but also the causes - from the presence of cultivars to domesticates such as cattle, pig and sheep. The presence of horse only in the Post-Medieval levels suggests stabling of horses at the castle on the island. Taken with the direct evidence of human habitation from the faecal stanols we can see how these techniques could be used to provide an archaeological record of sites that had never been excavated.

O-3100

## Advancing our understanding of prehistoric lake settlements: extracting direct evidence of human occupation using lipid biomarkers from excavation and cores

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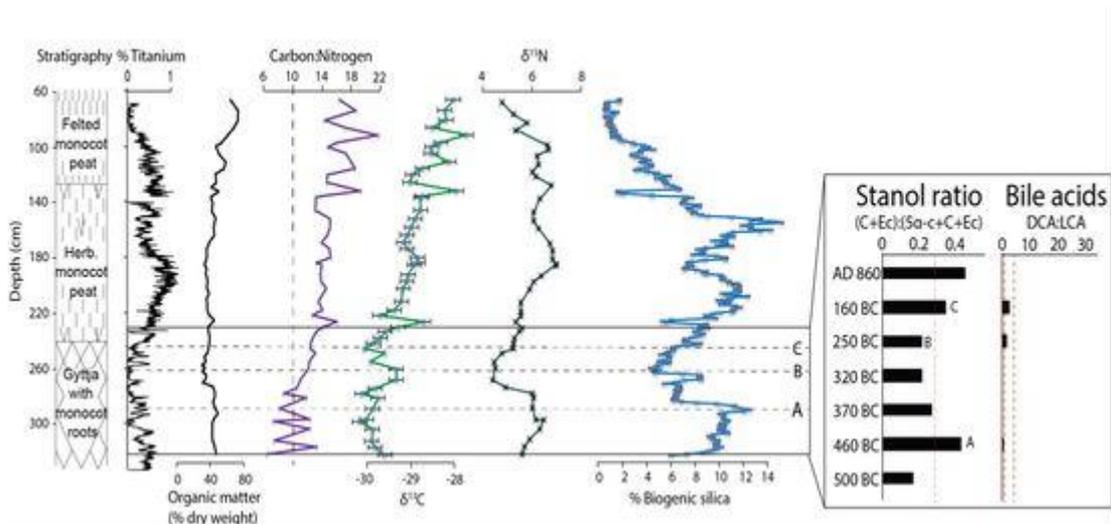
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### Abstract

Both wetland settlements and crannogs (artificial islands) were constructed in Scotland and Ireland from the Iron Age to the Medieval period. Excavations of partially or fully submerged wetland or crannog structures can be logistically and financially challenging, therefore the timing of site occupation and function remains poorly constrained. Analysis of sedimentary archives adjacent to wetland sites and crannog structures can be used as a complementary, and possibly an alternative, approach to excavation. However, currently applied palaeoenvironmental analyses can only provide indirect evidence of human occupancy. Our new research provides direct anthropogenic evidence using steroid biomarkers (stanols and bile acids) contained within wetland sediments. These compounds provide evidence of human and animal faecal matter in a range of depositional contexts, but their application to wetland archaeology has so far been limited.

Steroid analysis was undertaken on sediment archives proximal to two neighbouring Iron Age wetland settlements in southwest Scotland: Black Loch of Myrton and White Loch of Myrton. Evidence of human faecal matter was identified at both sites, demonstrating preservation of faecal steroids within wetland sedimentary environments. The ability of stanols and bile acids to provide direct evidence of human occupation is supported by occupation dates independently obtained from archaeological excavations (Figure 1). Steroid ratios also indicate the presence of ruminants within the settlements, which is confirmed by sedimentary DNA (*sedaDNA*) analyses and supported by palaeoecological reconstructions of faecal matter (from *Coleoptera*) and nutrient-driven changes in aquatic ecology (diatoms and chironomids). The similarities between faecal steroid records and independent lines of chronological and palaeoenvironmental evidence highlights the ability of lipid biomarkers to provide direct evidence of human occupation from wetland sediments, but also demonstrates the ways in which these analyses can be used to characterise occupation phases and advance interpretations of wetland archaeological sites.



**Figure 1:** Sedimentary evidence of Iron Age anthropogenic activity at Black Loch of Myrton, Scotland. Faecal steroid compounds (stanols and bile acids) provide direct evidence of multiple human occupation phases (A-C). The timing of these phases identified within the sedimentary archive corresponds with the archaeological site chronology. Carbon-nitrogen ratios and  $\delta^{13}\text{C}$  values indicate that the site was terrestrialising during the occupation phases.

O-3101

## Investigating human occupation of lakeside settlements using palaeoecological techniques; multi-proxy evidence for Prehistoric lake eutrophication and environmental change

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### Abstract

Humans have always been attracted to lakes as resource hotspots. In the Iron Age to Medieval Period in Ireland and Scotland, this is reflected in the construction of lakeside settlements and artificial islands called crannogs, in thousands of small and largely lowland lakes. Due to the complex nature of these archaeological sites, excavations of wetland structures can be logistically and financially challenging, meaning our ideas concerning prehistoric wetland societies are based on a limited number of sites.

Sedimentary records from very close to archaeological sites offer the opportunity of retrieving information from a range of proxies regarding lakeside settlement usage and environmental impact that would otherwise be difficult to obtain without excavation. It is possible to detect human activities with both high-temporal and high analytical resolution, and these human impacts appear to have had profound effects on and within small lake environments that were typically sensitive to environmental change.

Our research on crannogs and lakeside settlements characterises these prehistoric human-environment interactions using proxies of geochemical and biological signals preserved within both the crannog and wetland/lake sediments. This presentation specifically focuses on palaeoecological proxies e.g., chironomids, diatoms, pollen, beetles and ectoparasites.

Results of the palaeoecological analyses reveal short-lived construction and occupation phases of crannogs from the Iron Age to the Medieval Period. The main effects of human activities on the lake ecosystems are nutrient-driven increases in productivity and shifts in aquatic species to indicate more eutrophic conditions. Site abandonment reduces nutrient inputs and therefore levels of aquatic productivity, as evidenced by decreases in the abundance of siliceous algae. Despite returns to pre-settlement nutrient and productivity levels, indicator species suggest lake ecosystems do not return to their previous ecological state. Results from beetles and ectoparasites highlight a number of taxa typically associated with occupation layers including fly pupal remains, giving an indication of on-site conditions. Detailed investigations using these proxies allow us to understand possible activities undertaken within these prehistoric wetland structures.

O-3102

## Tracking land-use legacies in boreal and alpine landscapes of Sweden using multiproxy analyses of lake sediment records

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### Abstract

Large areas of the boreal and alpine landscapes of Scandinavia are protected today for their (perceived) untrammelled beauty, natural biodiversity and wilderness character. However, although spatially patchy and temporally discontinuous, there is increasing evidence suggesting these landscapes have been culturally imprinted since the retreat of the last ice sheet, but especially over the past millennium. Documenting archaeological sites, such as Sámi stállo settlements in mountain areas or summer forest farms (*fäboddar/säter*) in boreal regions, is a core component in reconstructing the human history of these landscapes, but many of the associated activities such as animal husbandry were widely dispersed in the landscape and would have left little direct physical evidence. From archaeological sites alone it can be difficult to discern not only the full timeline of human occupation but also the extent to which humans may have shaped terrestrial and aquatic ecosystems.

As a complement to traditional field archaeological surveys, analyses of natural archives such as sediments from lakes in close proximity to specific sites offer the potential for a continuous, undisturbed record of past change. Deciphering the imprint of human activities in these records separate from natural climate and environmental changes can be challenging. Here we present data from two pilot studies that combined established techniques in paleolimnology (geochemistry, pollen) with emerging techniques (infrared spectroscopy, pyrolysis-GC/MS, fecal biomarkers, sedDNA) to identify and track the early history of remote summer farming with domestic livestock in the boreal landscape and reindeer husbandry in the alpine landscape. In the boreal lake, pollen analyses suggest a diffuse, discontinuous human presence from 2000 BP with continuous evidence from about 500 BP (the established historical phase), including also PAHs. However, coprostanol increases from 1300 BP, along with changes in organic biomarkers indicating ecosystem changes in the lake and catchment, which accelerated from 800 and again from 500 BP, indicating a much longer human history in this region.

In the northern mountains, although animal DNA was not successfully extracted, fecal biomarkers indicative of reindeer were extracted for the entire Holocene record. An increase in dwarf birch from c. 1200 BP, with a slight increase in fecal biomarkers, occurs together with changes in geochemistry – the timing of which is consistent with the age of dated stállo settlements in the region. A brief excursion in lead also records short-lived silver mining in the area in the late 17<sup>th</sup> century. In the past 150 yr a sharp increase in fecal biomarkers occurs along with other geochemical indicators indicating more significant human-driven changes in the surrounding landscape.

O-3103

## Middle-Holocene Sea-Level Fluctuations Interrupted the Developing Hemudu Culture in the Lower Yangtze River, China

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### Abstract

The eastern coastal zone of China is densely populated and widely recognized as a center of rice domestication, which has undergone dramatic sea-level fluctuation during the Holocene epoch. Hemudu culture is distributed mainly in the eastern coastal area and was once presumed as a mature agricultural economy based on rice, making it an ideal case for examining the remarkable human-environment interaction in the Lower Yangtze River. Though numerous studies have been conducted on the cultural evolution, ecological environment, and rice domestication of Hemudu culture, the impact of sea-level fluctuation on human settlement and food production remains controversial. In this study, we report high-resolution pollen, phytolith, and diatom records, and accurately measured elevation from the Yushan site, which is the closest site of Hemudu culture to the modern coastline. Based on the data gathered, we suggest that the Hemudu culture and subsequent Liangzhu culture developed in the context of regression and were interrupted by two transgressions that occurred during 6300-5600 BP and 5000-4500 BP. The regional ecological environment of the Yushan site alternated between intertidal mudflat and freshwater wetlands induced by sea-level fluctuations in the mid-late Holocene. Though rice was cultivated in the wetland as early as 6700 BP, this cultivation was subsequently discontinued due to the transgression; thus, full domestication of rice did not occur until 5600 BP in this region. Comprehensive analysis of multiple proxies in this study promote the understanding of the relationship between environmental evolution, cultural interruption, and rice domestication.

**O-3104**

## **Phytolith Research on Modern Paddy Soil**

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### **Abstract**

Rice, as staple crop, is crucial to the formation of civilization of China and makes great contribution to the development of worldwide civilization. However, there is still controversy regarding when, where and how the domestication of rice began since current methods cannot effectively identify early rice remains recovered from archaeological sites. In particular, the lack of quantitative indicators differentiating wild rice and domesticated rice makes it difficult to establish early rice domestication process, thereby limiting the study of early rice origin.

Here, based on systematical study on differences in bulliform phytolith fish-scale decoration numbers between domesticated rice paddy soil and wild rice field soil in South China, results showed that, in domesticated rice soil, the proportion of bulliform phytoliths with  $\geq 9$  fish-scale decorations was higher than  $57.7\% \pm 8.7\%$ , whereas the proportion was less than  $17.5\% \pm 8.3\%$  in wild rice soil. The results therefore indicate that the proportion of bulliform phytoliths with  $\geq 9$  fish-scale decorations can be used to discriminate between wild and domesticated rice. This method is potentially significant in the study of domesticated rice origin.

Furthermore, by analyses phytoliths in 168 soil samples from wild and domesticated rice fields and non-rice fields, we established the discriminant functions which can correctly classified 89.3% of the above samples. The results provide us a robust method for identifying rice paddies and distinguishing between wild and domesticated rice fields.

**O-3105**

**Early urban impact on vegetation dynamics: palaeoecological evidence from the Dongzhao site, Henan Province, China**

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**Abstract**

The evolution of early urbanism and its environmental consequences have gained great interests, however, the urban impact on vegetation dynamics remains unclear, especially during the early Bronze Age in China. Here, we report vegetation dynamics and early urban impacts based on pollen analysis for an age-controlled profile from late Neolithic to Bronze Age at the early urban settlement Dongzhao, Henan province, China. Our results show that steppe forests developed well around the study site from late Neolithic to Bronze Age. Anthropogenic signature associated with cereal cultivation has been detected by pollen data during the late Neolithic period. The intense human impact from early urban management and arable farming expansion was recorded after 3850 BP, equivalent the period of the Xinzhai and Erlitou cultures. Forest recovery occurred following the abandonment of Dongzhao urban settlement during 3600 ~ 3400 BP. Vegetation degradation between 3400 and 2910 BP happened probably due to increasing human land use coupled with a drying climate.

O-3106

## Micro- and Macrofossils as Indicators of Early Holocene Palaeoenvironmental Changes in northwestern Saudi Arabia

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### Abstract

Drill cores in the sabkha of the oasis of Tayma (NW Saudi Arabia), revealed the existence of an Early to Mid-Holocene palaeo-lake 250 km away from the Red Sea and about 800 m above sea level. It yielded a fauna almost completely composed of the barnacle *Amphibalanus amphitrite*, two gastropods (*Melanoides tuberculatus*, *Hydrobia* sp.), four foraminifer species (*Ammonia tepida*, *Quinqueloculina seminula*, *Flintinoides labiosa*, *Trichohyalus aguayoi*), and the brackish water ostracod *Cyprideis torosa*, beside very rare freshwater ostracods. The association indicates a brackish water lake with temporary inflows of freshwater. All of the documented species originate from the intertidal zone of the Red Sea or the Mediterranean, and are adapted to highly variable environmental conditions. Morphological and taphonomical analyses of *Cyprideis torosa* (i.e., sieve pores, population structure, preservation status) and test malformations of foraminifers reveal salinity changes and habitat types typical for the center and the margins of the lake basin.

Micro- and macrofossils occur almost exclusively in the laminated and varved sediment unit of the cores.

Macrofossils, the two gastropod species, and the barnacle *Amphibalanus amphitrite* occur mainly in its upper part, seeds of *Ruppia maritima* both in its lower and uppermost parts. Based on the faunal and floral distribution the section can be subdivided into four ecological zones:

In the lowermost Zone I, plant remains and rare freshwater ostracods indicate slightly brackish, very shallow conditions, probably a swampy wetland which had established around 9000 cal BP due to humid climate conditions. In the following Zone II, the high abundance of the brackish ostracod *Cyprideis torosa* indicates a lake-level rise and the first development of a permanent water body, starting about 8600 cal BP. In this phase, the sieve-pore analysis of *Cyprideis torosa* points to a variable salinity and therefore to unstable conditions of the early phase of the lake. After a short break, where all fossil abundances decrease, *Cyprideis torosa* increases again in number, and foraminifers reach their first maximum, roughly around 8300 cal BP (Zone III). All parameters indicate an increase in salinity, followed by a relatively stable salinity level, which characterizes a fully established, relatively large water body. The high number of juvenile foraminifers indicates stable environmental conditions of a permanent saline lake. The decrease of all microfossil taxa and the increase of coastal brackish macrofossils, like gastropods and barnacles, point to a lake-level drop, starting ca. 8100 cal BP (Zone IV). About 7800 cal BP started the definite trend to aridification; as a consequence, the lake of Tayma vanished.

This study is a contribution to the research project "CLEAR – Holocene Climatic Events of Northern Arabia" (DFG ref. nos. PL 535/2-1, FR 1489/5-1, EN 977/2-1; <https://clear2018.wordpress.com/>).

O-3107

## Hydroclimate of the western Nefud Desert during humid phases of Marine Isotope Stage 5

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### Abstract

Fossil, genetic and archaeological evidence increasingly support the idea that *Homo sapiens* populations dispersed from Africa and into Eurasia during Marine Isotope Stage (MIS) 5. However, the dispersal pathways used remain contentious, despite considerable efforts to understand them. This is primarily due to a sparse fossil record coupled with a limited understanding of resource distribution across southwest Asia. The western Nefud Desert lies at a critical crossroads between Africa and Eurasia as it is just ~550 km southeast of the Sinai Peninsula, the only terrestrial route from Africa. Today the region is hyper-arid and a formidable barrier to overland movement, yet in the past has experienced episodic humid phases characterised by increased resource availability in the form of a savannah grassland containing freshwater interdunal lakes. However, detailed empirical palaeoenvironmental records in direct association with archaeology and/or fossil remains are rare. Here, we reconstruct freshwater availability within the western Nefud Desert during MIS 5. We apply a multi-proxy palaeoenvironmental analysis to four interdunal palaeolake sediment deposits with direct evidence for human occupation. A combination of macro-sedimentology, micromorphology, diatom palaeoecology, and oxygen and carbon isotope analysis, in combination with a luminescence-based chronology, demonstrate that the western Nefud Desert contained interconnected, freshwater and perennial interdunal lakes during two separate humid phases in MIS 5. These lakes lay within a resource rich landscape inhabited by *Homo sapiens*, suggesting that the Nefud Desert was an important dispersal pathway out of Africa.

O-3108

## Last interglacial lacustrine/wetland records from the Umm ar-Rimmam depression Kuwait

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### Abstract

Compared with other regions of the Arabian Peninsula the Quaternary palaeoenvironmental history of Kuwait is poorly understood. Geological and geomorphological mapping of the Kuwaiti landscape has been well documented but depositional ages and palaeoenvironmental details are lacking from Quaternary sediments. The Dibdabba Formation represents distal alluvial outwash fan gravels, which cover ~60,000 km<sup>2</sup>, fed by the Wadi Al Batin. The fan forms one of several large outwash complexes derived from drainage originating on the Arabian Shield. The fan covers the southern part of western Iraq, the northeastern corner of Saudi Arabia, and the northern desert of Kuwait. The Wadi al-Batin extends 700 km from its headwater source region on the Arabian Shield. The Umm ar-Rimman, located towards to distal end of the outwash fan, forms a large depression formed in the Miocene sediments located on the backslope of the Jaz az-Zor escarpment. The sink area of the depression covers approximately 12 km<sup>2</sup> and comprises two playa basins (khabra). Remnant shorelines, which form low ridges above the playa floor, show the former extent of wetland/lake level highstands. These comprise lacustrine/wetland, carbonate rich silts, underlain by coarse sands. Physical, chemical and biological analyses provide detailed records of palaeoenvironmental change as well as the first terrestrial-based chronology from this region from the last interglacial. Lacustrine/wetland facies are dated to MIS5c (~110 ka) and MIS5a (~80 ka). During MIS5a both playa basins were connected indicating a waterbody over 5m in depth with the waterbody extending over 10 km<sup>2</sup>. Phytolith analysis indicates the development of savanna grassland cover with changes in C<sub>3</sub> and C<sub>4</sub> composition across the surrounding landscape. Microscopic charcoal analysis indicates episodes of burning associated with drier conditions and a shift to predominantly C<sub>4</sub> grassland. Geochemical analyses trace changes in lake/playa development /composition. The importance of Wadi Batin as a potential corridor for human dispersals across Arabia during MIS5c and MIS5a is considered under wetter conditions and grassland vegetation cover.

O-3109

## Precipitation in the semi-arid region of the Northeastern Brazil dependent on the contraction/expansion of the tropical rainbelt

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### Abstract

Recent paleoclimatic studies suggest that changes in the tropical rainbelt across the Atlantic Ocean during the past two millennia are linked to a latitudinal shift of the Intertropical Convergence Zone (ITCZ) driven by the Northern Hemisphere (NH) climate. However, little is known regarding other potential drivers that can affect tropical Atlantic rainfall, mainly due to the scarcity of adequate and high-resolution records. This study fills this gap by reconstructing precipitation changes in Northeastern Brazil (NEB), a semi-arid area, during the last 2,300 years from a high-resolution Boqueirão lake record of hydrogen isotope compositions of plant waxes ( $dD_{wax}$ ). Changes in  $dD_{wax}$  reflect changes in  $dD$  precipitation used by terrestrial plants for biosynthesis of wax lipids. The lake record documents a predominantly humid period between 500 yrs BCE and 420 yrs CE associated with lower  $dD_{wax}$  values. These climate conditions are followed by an abrupt aridification and a long dry phase from 500 to 1,300 yrs CE as revealed by higher  $dD_{wax}$ . Between 1580 and 1900 yrs CE, the  $dD_{wax}$  values rapidly declined, reaching values similar to those prior to 420 yrs CE, thus characterizing a long humid period during the Little Ice Age (LIA) in NEB. The latitudinal ITCZ displacement was investigated by comparing the  $dD_{wax}$  from Boqueirão Lake and the Ti record from Cariaco Basin. Both periods, from 500 to 1,300 yrs CE and from 1580 and 1900 yrs CE present a northern and southern ITCZ displacement, respectively. This is consistent with the traditional pattern of meridional ITCZ displacement regulating precipitation at both sites. Before ~500 yrs CE, relatively humid conditions prevail in both NEB and Cariaco, which is not consistent with the pattern of meridional ITCZ. The lake record combined with the Cariaco, instead suggest an expansion of the tropical rainbelt that would correspond to a longer rainy season in both hemispheres. The results indicated that regional precipitation along the coastal area of South America was not solely governed by north-south displacements of the ITCZ due to changes in NH climate, but also by the contraction and expansion of the tropical rainbelt due to variations in sea surface temperature and southeast trade winds in the tropical South Atlantic Basin. This work was supported by the Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP), Brazil, PIRE NSF-FAPESP 2017/50085-3.

O-3110

## Searles Lake evaporite sequences: indicators of paleotemperatures and $p\text{CO}_2$

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### Abstract

Searles dry lake is located in the Mojave Desert of southeastern California, USA. A new drill core, SLAPP-SRLS17, collected from Searles Lake in January 2017, extends from the surface to 76 m and records continuous lake deposition through the past ~150 kyr. During pluvial conditions, Searles Lake was integrated into the Owens Valley watershed as one in a chain of five lakes which spilled into each other (Smith, 1979; Smith et al., 1983). During drier climates, increased evaporation concentrated Searles Lake waters into Na-CO<sub>3</sub>-SO<sub>4</sub>-K-B-Ca-Mg-Cl brines which deposited chemical sediments. The Searles Lake deposit contains at least 25 different evaporite minerals, where the mineral phase, abundance, and precipitation sequence is controlled by climate-related conditions, such as temperature, salinity, and  $p\text{CO}_2$ .

The computer program EQL/EVP simulates stepwise evaporation of natural waters, and subsequent mineral precipitation, using Pitzer equations to determine activity coefficients of high ionic-strength brines (Risacher and Clement, 2001). Here, EQL/EVP is used to simulate the evaporation of the presumed source waters to Searle Lake, the Owens River (Hollett et al., 1991; Smith, 2000), under various input conditions, including: temperatures from 0-30°C;  $p\text{CO}_2$  of 200 and 1200 ppm; and equilibrium vs. fractional crystallization system behavior.

EQL/EVP model runs indicate that the solubility of each mineral phase responds uniquely to changes in temperature and  $p\text{CO}_2$ . Therefore, for each evaporite layer within the SLAPP-SRLS17 core, we can constrain the temperature range,  $p\text{CO}_2$ , and degree of evaporation based on which minerals are present, their relative abundances, and their stratigraphic position within the evaporation sequence.

For example, evaporating Owens River water at 25°C and 200ppm  $p\text{CO}_2$  produces the following sequence of major minerals: NORTHUPITE [Na<sub>3</sub>Mg(CO<sub>3</sub>)<sub>2</sub>Cl] → TRONA [Na<sub>2</sub>CO<sub>3</sub> · NaHCO<sub>3</sub> · 2H<sub>2</sub>O] → BURKEITE [Na<sub>6</sub>(CO<sub>3</sub>)(SO<sub>4</sub>)<sub>2</sub>] → HALITE [NaCl]. However, the solubility of BURKEITE is significantly more sensitive to changes in temperature and  $p\text{CO}_2$  than TRONA, resulting in BURKEITE precipitating before TRONA at 200 ppm  $p\text{CO}_2$  and temperatures ≥ 30°C. Both sequences are found in the SLAPP-SRLS17 core which enables us to constrain temperature and  $p\text{CO}_2$  conditions at each stratigraphic interval.

More broadly, the saline mineral sequences found in the SLAPP-SRLS17 core can be used to define crystallization and hydroclimate conditions at Searles Lake. For example, the Lower Salt unit of the Searles Lake deposit is ~13 m thick and composed of 7 salt layers and 6 saline mud intervals which were deposited from 24-32 ka (Smith et al., 1983). Here, the high-frequency mineralogical variability indicates temperatures between 10 and 30°C and  $p\text{CO}_2$  values of ~200 ppm, in equilibrium with the atmosphere.

O-3111

## Tropical and high-latitude influence on annual to centennial precipitation variability in Southern California's Mediterranean climate during the Holocene.

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### Abstract

Southern California (SC) experiences an extreme Mediterranean-type hydroclimate with dry summers and wet winters. Droughts occur when winter rains fail, yet winter can also produce extreme rainfall *via* atmospheric rivers (ARs) generating flooding. The Santa Barbara Basin (SBB), SC preserves an annually laminated marine sedimentary archive of hydroclimate variability. A continuous 9 ka record that includes the 20<sup>th</sup> century was generated from spliced cores SPR0901-04BC (34°16.8950' N, 120°02.4890' W, 588 m water depth), SPR0901-03KC (34°16.914' N, 120°02.419' W; 591 m water depth), and MV0811-14JC (34°16.906' N, 120°02.162' W; 580 m water depth) collected from SBB. Here we present sub-annually (4-7 samples per year) resolved scanning XRF titanium data to reconstruct an annual precipitation record for the past 9000 years. Titanium (associated with siliceous detrital sediment) is delivered to SBB sediments by river runoff after winter rains. Droughts indicated by low Ti counts, accompanied by fewer floods (identified as gray clay layers) coincide with low regional lake levels at 800-1500, 2300-2700, 3300-3800, 4800-5300, 5700-6600 and 8000-8400 yr BP. Ti variability in the El Niño-Southern Oscillation (ENSO) band (2-7 years) increases after ~4500 yr BP.

SC rainfall is influenced by changes in the strength and location of the North Pacific Jet (NPJ), which is atmospherically teleconnected to the equator and high latitudes through atmospheric pressure systems. Changing climate patterns on centennial to interannual time scales shift the NPJ equator- or poleward across the Pacific, influencing the trajectories of storm tracks and ARs. The probability of drought in SC increases during Northern Hemisphere (NH) warming when the ITCZ is shifted poleward, enhancing high pressure ridging over the NE Pacific and pushing the NPJ away from the region. This weakens the ENSO teleconnection and interannual hydroclimate variability is reduced. During NH cooling, multi-decadal hydroclimate variability in SC follows high latitude climate change via the Aleutian Low. As the ITCZ moves equatorward and the Aleutian Low strengthens, the NPJ steers storms and AR events toward SC and increases the precipitation response to ENSO and the possibility of flooding.

**O-3112**

## **Holocene paleolimnology of Walker Lake, Nevada, USA**

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### **Abstract**

Drought conditions have come to dominate the climate of the western USA in recent decades, even as dryland communities continue to expand. We use paleolimnological records from Walker Lake, Nevada, to assess the timing and amplitude of hydroclimate variability in the westernmost Basin and Range province, USA, to generate a Holocene record of drought in this extensive catchment. Walker Lake is a terminal basin that contains a long sediment record, and formed part of the Lahontan Lake system in the late Pleistocene. Abundant Pleistocene-age lacustrine tufas are observed around the margins of the basin, and recent tufas are observed near the modern shorelines. Ten kullenberg sediment cores, and ~300 km of high-resolution seismic reflection data were acquired from the lake in 2013 and are used to evaluate the basin's environmental history. We develop a robust seismic-stratigraphic framework based upon observed stratal relationships, which suggest several lake lowstand or desiccation events in the basin. Fossil pollen, concentrated using flow cytometry, was used to date the sediment and to develop the core chronologies, rather than dating of bulk sediment. Core climate proxy analyses include bulk organic (abundance and isotope analyses) and physical properties analyses. Using integrated seismic stratigraphic and sediment core analysis, we interpret three periods of lake-level drop during the Holocene at ~8600 cal. year B.P., ~7630 cal. year B.P., and ~3540 cal. year B.P., interpreted to correspond to regional drought conditions at those times in the western Basin and Range and eastern Sierras.

O-3113

## Cryptotephra and sulphur in polar ice: a powerful tandem for climate research

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### Abstract

Volcanic eruptions have been identified as a primary driver of climate variability, impacting surface air temperature, atmospheric circulation and hydroclimate. The observational record of the timing of volcanic eruptions, their location, magnitude of sulphate aerosol injection and its atmospheric life-cycle, however, is incomplete, with gaps in our record of past volcanic activity increasing dramatically before the Modern (pre-1800) era. A 2,500 year-long ice-core record of volcanic activity (Sigl *et al.*, 2015) and resulting stratospheric sulphur injections and radiative properties (Toohey & Sigl, 2017) sheds new light on past volcanism and its relation to climate. Sulphuric acid layers in ice cores prove that several centuries were volcanically much more active than the 20<sup>th</sup> century.

The polar ice sheets also contain an abundance of cryptotephra from past eruptions, sometimes transported over several thousands of kilometers (Jensen *et al.*, 2014). However, finding these precious deposits in ice cores has proven challenging. Here, we demonstrate novel approaches to detect the presence of cryptotephra in ice cores that take advantage of new-generation aerosol records obtained from ice cores in Greenland and Antarctica. These records allowed, for the first time, the discovery and precise dating of tephra from East Asia (Changbaishan 946 AD; Sun *et al.*, 2014) in an ice core from Greenland, and tephra from New Zealand (Taupo's Oruanui supereruption, 25.3 kyr BP; Dunbar *et al.*, 2017) in an ice core from Antarctica.

Using specific ancient eruptions (e.g., those causing the "worst year to be alive" in 536 AD; Gibbons 2018) we discuss the potential and limitations of combining state-of-the-art aerosol and geochemical records from ice-cores and other archives to advance our understanding of the timing and location of past eruptions and their consequences to climate and human societies.

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**O-3114**

**Harnessing the potential of CT scanning to identify cryptotephra in sediment cores: a controlled experiment.**

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**Abstract**

Volcanic ash (tephra) markers represent a powerful geochronological tool: rapid widespread deposition allows for correlation of geological records across vast areas. This enables us to study the behavior of Earth's climate system through time and across space. Analytical advances over the past decades now allow identification of invisible (crypto) tephra deposited thousands of kilometers from their volcanic source. This greatly expands the reach and potential of tephrostratigraphy by, for example, connecting existing tephra frameworks or expanding them into new geographical areas. However, the laborious and specialized nature of lab routines involved in extracting ash shards and establish tephra concentration profiles from geological archives hamper progress. Computed Tomography (CT) scanning may help us overcome some of these limitations by allowing non-destructive and rapid visualization of both visible and invisible ash horizons in 3D. We explore the potential of this tool using a controlled experiment: adding known (visible to invisible) amounts of rhyolitic or basaltic tephra to different sediment matrices (organic to minerogenic) in 50 ml test tubes. To calibrate floating CT greyscale values, we add standards of a known density to each of our artificial sediment cores. Our results show that we can identify invisible ash horizons down to 600 shards.

**O-3115**

## **Examining experimental methods in tephra extraction and preparation**

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### **Abstract**

The reliable and non-destructive extraction of tephra is essential for modern applications of tephrochronology and volcanology. While many methods have been proposed and practiced for the separation of tephra from peat and lake sediments, including the acid digestion method of Persson (1971) and the density separation method of Blockley (2005), doubts have been raised concerning the geochemical alteration of volcanic glass through these processes. In particular, the use of acid and base digestion methods have been indicated in the formation of alteration zones around small glass shards, resulting in complications when performing scanning electron microscope (SEM) analysis or electron probe microanalysis (EPMA). Several attempts have been made to introduce less damaging techniques. However, the efficacy of these techniques in removing unwanted biogenic and organic material, such as plant material, peat, and biogenic silica, is questionable in comparison to traditional chemical digestion-based methods. This trade-off between sample cleanliness and geochemical purity is the cause of some dispute, all the more so as the differing methods have not been thoroughly and comprehensively tested against each other. In this project, we present the results of an experiment designed to compare and quantify the degree of geochemical alteration and the efficiency in removing excess organic material produced by three common chemical-based methods of tephra preparation, and outline our recommendations for future procedures.

We compare the effects of diluted hydrochloric acid, concentrated nitric and sulphuric acids, and concentrated potassium hydroxide on eleven samples of tephra ranging in composition from basaltic (Katla 1357) to ultra silicic (Lipari obsidian). We observe that, while the concentrated acid digestion method is highly effective and time-efficient in the removal of unwanted material, it also causes a significant degree of destruction to volcanic glass. This alteration is present in all glass compositions tested in this experiment, but is most notable in those of a basaltic composition (<52% silica). The alteration creates a hydration rim which may be up to 70  $\mu\text{m}$  in width, creating significant difficulties in the analysis of smaller shards, such as those utilised in most cryptotephra studies. We observe similar hydration rims in the samples treated with dilute hydrochloric acid, though to a much less significant degree, typically creating rims 10-15  $\mu\text{m}$  across. The samples treated with potassium hydroxide present a lower degree of alteration than those treated with acid digestion, but we found this method to be the least efficient in removing organic material.

This presentation challenges the procedures accepted as standard in the preparation of cryptotephra for EMPA and SEM analysis, a crucial step in all applications of tephrochronology. We recommend against the use of concentrated acids or bases in the preparation of basaltic tephra, and in the preparation of shards <150  $\mu\text{m}$  in width.

O-3116

## New distal cryptotephra findings in annually laminated lacustrine sediments of northern Poland

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### Abstract

Cryptotephra findings, especially ultra-distal discoveries of Icelandic ash on the European continent, have fascinated multidisciplinary researchers. Tephra from explosive volcanic eruptions can be transported for long distances from the source and therefore is ideal for dating and synchronising sedimentary records. Numerous tephra studies during the last three decades showed that continental northern and central Europe was regularly impacted by large-scale eruptions from Iceland and the Eifel Volcanic Field since the Late Glacial. Tephra studies in Poland were so far limited to only a few sites due to the distal to ultra-distal position to European volcanoes restricting a deposition of macroscopic visible ash layers. Moreover, time consuming extraction techniques and uncertain success, discouraged conducting tephra research and forced to develop effective techniques.

We took advantage of annually laminated sediments from selected lakes along a W-E transect in northern Poland in order to extend the knowledge about the occurrence and dispersal of cryptotephra. We investigated short gravity cores from nine lakes and focused on the detection of tephra from Askja AD 1875 (VEI=5), Eyjafjallajökull AD 2010 and Grímsvötn AD 2011 (VEI=4) eruptions. Additionally, three lakes were selected for the Late Glacial and Early Holocene tephra investigations. Volcanic glass shards were found in all sites, however, extreme low concentrations and small grain sizes of single shards are a challenge for geochemical fingerprinting. As a first result, however, the rhyolitic cryptotephra originating from Askja AD 1875 eruption was confirmed by WDS-EPMA in the far east located site in Poland, in Lake Szurpiły. This finding allows us to extend the previously known tephra dispersal fan further to the SE.

Further new findings will improve usage of this particular and other cryptotephra as isochrones and enable precise correlation of palaeo-records. Our study indicates the potential of distal, annual laminated lacustrine sites in Poland as valuable tephra archives, but also the need for more effective methods dedicated to extremely low glass shard concentrations.

This work was supported by the Polish National Science Centre grant no. 2015/19/D/ST10/02854.

O-3117

## The potential of tephrochronology for linking climate, environmental change and human colonisation of the South Pacific

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### Abstract

The archipelagos of Polynesia (some 7,500 islands) in the South Pacific were the last habitable places on earth colonised by prehistoric humans. However, the timing of this colonisation has been poorly resolved across many islands, with dates varying by up to 1000 years, precluding understanding of the interplay between human, ecological and climate impacts on these pristine ecosystems. The late colonisation of many Pacific islands makes them, theoretically, the ideal location to study natural environments prior to, and subsequent to the arrival of humans, but conversely there is a paucity of palaeoenvironmental research. Very little high quality well dated palaeoenvironmental data spanning this period exists for the South Pacific. In order to begin to answer questions about the interplay between prehistoric human migration, the climate and environment, archaeological and palaeoenvironmental records need to be well dated and independently synchronised, something which is not currently possible. Existing chronologies are based on radiocarbon dating which is challenging in some of these sites especially where plant macrofossils are not available. Here we examine how volcanic ash can provide a chronological framework for dealing with these questions against a suite of new palaeoenvironmental and palaeoclimate data from Holocene lake sediment archives across the South Pacific. Results are presented from Lake Lanoto'o in Samoa and Lake Teroto in the Cook Islands, where discrete cryptotephra layers are identified throughout the Holocene sequences. Geochemical results indicate non-local sources for the layers, highlighting the potential of tephrochronology in this part of the world.

**O-3118**

## **Evidence for multiple large Holocene eruptions of Mt. Churchill, Alaska**

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### **Abstract**

Mt. Churchill, located in the Wrangell Volcanic Field close to the Alaska/Yukon border, is the suggested source of the late Holocene White River Ashes (WRAn and WR Ae). Studied extensively since the late 19<sup>th</sup> century, the thick, widespread visible deposits in the Yukon and eastern Alaska were initially believed to be from one bilobate eruption but were later reinterpreted as two separate eruptions with distinct plume directions.

More recent discoveries - a cryptotephra record from Alaska (Payne et al., 2008) and one visible bed in the Yukon (Preece et al., 2014) - suggest at least one, potentially two, additional Holocene eruptions from this volcano. Here we present evidence from a new cryptotephra record from the central Yukon, and visible samples collected from Alaska and the Yukon in 2018, with evidence for a total of at least seven Mt. Churchill eruptions since ~9000 yr cal BP.

A cryptotephra record from DHP174, located along the Dempster Highway in central Yukon 460km NNE of Mt. Churchill, is produced from a soligenic peatland that records 10,400 cal yr BP of peat accumulation. Using major element glass EPMA data, seven glass peaks are identified as 'primary eruptions' where evidence for a unique airfall event is clear (including WRAn and WR Ae correlatives). One additional period of activity is defined, where Mt. Churchill-like glass is present but there is some ambiguity in peak identification (related to possible reworking in the permafrost active layer).

New visible samples present further opportunities to support the distal cryptotephra records as they allow analysis of associated volcanic minerals (e.g. magnetite, ilmenite). This is important as previous analyses of the White River Ashes and the one additional visible bed (Preece et al., 2014) show Fe-Ti oxide data are more diagnostic for differentiating between eruptions than the more commonly used major element glass geochemistry.

These new data are compared to previous sites with beds that have geochemical data similar to Mt. Churchill in order to produce the best estimate to date of its' Holocene eruption frequency. Our results represent a significant revision for the eruptive history of Mt. Churchill and have implications for regional tephrostratigraphies, natural hazards and our understanding of palaeoenvironmental responses to volcanic activity in the area.

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O-3119

## Tephabase and the lessons learned over the past 25 years

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### Abstract

Tephabase is a tephrochronological database launched in June 1995. It was initially aimed at providing locational and geochemical tephra data to the fledging European tephrochronological community. Initially, the database developed as a repository for what were thought be Icelandic-origin distal cryptotephra layers, but over time it has expanded to include macroscopic tephra layers in Iceland, Germany and Mexico. Initially, all the European tephra layers included in Tephabase were thought to be erupted in Iceland, but it is now clear that is not the case with ultra-distal tephra layers identified as coming from North American volcanoes. In addition, in 2011, sites (recent updated to 570) containing the Laacher See tephra were added. The Laacher See records include both macroscopic and more distal tephra records. In total, Tephabase currently holds records of some 4,500 tephra deposits, from over 1100 sites and over 6500 geochemical analyses.

Maintaining Tephabase over nearly a quarter of a century has highlighted a number of issues and one highlighted in this talk is the naming of distal layers and tephra layers in general. In Iceland, proximal, historically dated tephra layers are dated using the volcano's name (which is usually known) and the year it was erupted (e.g. Hekla 1341). However, it becomes more problematic when correlating distal tephra layers across large distances, where layers identified as one tephra layer on further investigation turn out to be another. The tephra may also be first identified at a distal site and lack a source name. Also, the name of the identified layers may also change due to new data, dating or the adoption of a more "sensible name". Ice-core dates may change, resulting in a tephra layer with an inappropriate name. There are many reasons for names changing, but it is important that the tephra layers found at a particular site remains identifiable. Tephabase always had a naming hierarchy and recent updates have made sure that all new data include a local name included in the published work, along with any "correlated name". If a local name is not available, a local name is given based on the site and depth the tephra layer occurs at. Older data in the database is being updated to include this information and other useful metadata. Tephabase also provides alternative names for tephra layers, which is not definitive, but growing. This also highlights a wider naming issue the community should discuss.

Databases work best when data is easily compartmentalised, is "correct" when inputted and is consistent across all researchers. Tephra data, and especially distal tephra, often does not always meet these criteria and as a community we need to establish standards for how data is recorded in our systems.

**O-3120**

## **A review of Lake-Dust-Snow dynamics “from sources to sinks” in the semi-arid Bonneville Basin, Utah, USA**

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### **Abstract**

The Great Basin physiographic province is the largest desert region in the USA, and a known source area for windblown dusts, including aerosols, black carbon, nutrients, and mineral particles. This paper reviews what is known about dust composition, atmospheric loading and fluxes “from sources to sinks.” Within this semi-arid region, intermountain cyclonic storms and aeolian dynamics are important drivers of dust entrainment and transport. In the 1930s, Utah newspapers reported spring cold front passages and dust storms that caused it to “rain mud.” Various studies on the prevailing winds and synoptic meteorological conditions relate the development of strong intermountain cyclones with elevated wind speeds and dust storm events. Dust event days (DEDs) peak in frequency during spring months (March-April) when southerly ‘Hatu winds’ blow.

Key source areas providing dust for transport downwind to the populated regions of Utah were identified by assessing 51 DEDs that affected air quality in Salt Lake City during the 2004-2010 period. Among the recurrently active “hotspot” areas prone to dust emission are: barren and sparsely vegetated land; fallow fields; playa (ephemeral lake) surfaces relict from Pleistocene Lake Bonneville (per G.K. Gilbert); and areas disturbed by wildfire, agriculture, vehicular traffic, and military activities. Intensified winds enhance dust outputs downstream of mountain gaps, or along fetches with higher wind speeds from terrain contouring. Enhanced dust production occurs after severe drought and/or disturbance by wildfire, agriculture, and military activity. The 2007 Milford Flat Burned Area (Utah’s largest wildfire) actually generated more dusts after revegetation techniques disturbed soil via drilling, chaining, and herbicide use.

Dust storms may deposit materials on montane snowpack; Dust-On-Snow (DOS) affects surface albedo and radiative properties and may increase melt rates, causing an earlier “snow-free” date by up to a month, causing higher peak streamflows. Dust-forced changes in hydroclimatology can adversely impact Salt Lake City, which relies on seasonal snowpack in the Wasatch Mountains as their main water supply.

An intense intermountain cyclone affected the Salt Lake City, UT region on 14-15 April 2015, providing a case study of a DED from inception to dust deposition on montane snowpack. Analyzing the “Black Tuesday” storm from “cradle to grave” or “source to sink” enabled real-time documentation of storm development, dust-source emission and associated DOS in the Wasatch Mountains. We resolved particle size, elemental composition, albedo and radiative properties of samples of a single specific dust storm event layer. Plumes observed on MODIS imagery indicate dust mobilization from known point sources in the Escalante Desert, Sevier Lake region and modern playas within Paleolake Bonneville Basin. Snowpack dust includes metals sourced to urban and industrial activities, including heavy metals (Cu, Pb, As, Cd, Mo, Zn) common in regional mine operations.

O-3121

## Short-range aeolian transport in high mountain environments: an overlooked phenomenon

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### Abstract

Wind action in mountain environments is a topic seldom investigated from geomorphological and geopedological standpoints. Mountainous environments are known as a loess source during glacial phases and as a potential sink for long-range (hundreds to thousands of km) contribution of dust and volcanic ashes (e.g., Saharan dust to the Alps and Pleistocene tephra over European mountains). However, the short-range (tens to hundreds of km) transport of aeolian materials within mountain environments during cool and dry phases is poorly understood and in general downplayed in the larger system of wind deposition dynamics. When climatic conditions shift towards increasing aridity, the potential for aeolian activity in these environments greatly increases. Moreover, the complexity of topography in these regions offers ideal conditions for development of intense localised air fluxes. As a result, systems of micro-sources and micro-sinks take form, changing in intensity and shifting in space with the variation of local air circulation patterns, often climate induced. Processes of denudation and loss of vegetation cover as a consequence of cool and dry periods strongly contribute to the mobilization of aeolian material and its redeposition over short distances.

We investigated the geomorphological setting of a mountain ridge in the high Northern Apennines (Cusna Ridge, Italy) characterised by strong constant winds perpendicular to the direction of the ridge itself. A detailed field geomorphological and soil survey allowed to find evidence for aeolian sources and deposits. On the summit of the ridge, we found multiple deflation areas tens of meters wide, which signal the action of intense wind erosion. Evidences of dust deposition were found in the adjacent soils: a discontinuous and distinct layer of recently deposited fine sand and silt covers the ridge top itself. We relate this layer to a combination of low-energy colluvial activity and short-range wind transport from lower elevations. In one soil sequence, analytical data from sedimentological and micromorphological analyses allowed to observe four different phases of deposition with possible aeolian contributions. These phases potentially correspond to short-timed Holocene periods of denudation and deflation triggered by enhanced wind strength.

O-3122

## The provenance of loess-palaeosol sequences along the Middle and Lower Danube

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### Abstract

Sediment provenance can be a powerful tool in understanding sediment system dynamics, and through them, climate. Loess sequences preserve evidence of source regions, and therefore can be used to investigate and quantify the production, transport and deposition of dust during the past. These investigations can also provide insights into sedimentary dynamics on a range of scales, from local to continental. By complimenting these understandings of sediment processes and provenance with chronologies, we can quantify rates of process over the longer term, which is crucial when using loess as palaeoclimatic and palaeoenvironmental proxies.

Here we present the results of a provenance analysis from three loess-palaeosol sequences along the Danube. Erdut (Croatia), Surduk (Serbia), and Slivata (Bulgaria) were selected to investigate source variability along the Danube River. This research is predominately focused on single grain detrital zircon techniques, which have greatly advanced our understanding of the Chinese Loess Plateau's provenance (c.f. Nie et al., 2015). We provide the results of U-Pb dating combined with Hf isotopes from single grain zircons obtained from multiple loess-palaeosol units. By supplementing this work with chronologies based on Optically Stimulated Luminescence (OSL) dating we are able to investigate provenance changes over time at each site. Finally, single grain zircon analysis is combined with the results of bulk sample trace elements, and Nd-Sr isotopes to achieve a better understanding of source regions. We also compare our new single-grain zircon datasets with existing published potential source geochemical records to explore the primary sediment sources and sediment transport pathways on a source to sink scale.

**O-3123**

## **Comparative study of silt production under Natural and Simulated conditions**

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### **Abstract**

A comparative study of silt from NW Himalaya produced under the influence of natural environment by glacial grinding was conducted with the silt production from Cretaceous Leighton Buzzard Quartz Sand from Bedfordshire, England under laboratory simulation giving different conditions like load, speed, wet/dry, duration of grinding and quantity of sample were taken into consideration. The silt studies of the Himalayan region was accomplished by filtration of suspension, wet/dry sieving and particle size analysis conducted on particle size analyser (Malvern U.K. Make). The studies were conducted on Naradu Glacier Himachal Pradesh (H.P.), Kol Glacier Jammu and Kashmir (J&K) and Chourabari Glacier Uttra Khand (U.K.) all located in western Himalaya (India). The grinding of Cretaceous Leighton Buzzard Quartz Sand was accomplished on Bromhead Ring Shear Machine in Nottingham Trent University. On the completion of each test conducted in laboratory the obtained production was analysed on a Coulter Counter to determine particle size range besides its proportion by wet/dry sieving. The study was carried out with the objective to compare the level of production of silt under natural environment and simulated conditions from two different regions. The results indicates that the dominant silt size produced was medium to fine i.e. 20 - 63  $\mu\text{m}$  whereas under nature environmental conditions the dominant size of silt production was also ranges from medium to fine with dominance of fine silt. The variation in dominance of the silt size is attributed to the diversity in the composition , type, structure of the respective bedrocks of the areas as well as the glaciated valleys taken into consideration.

**O-3124**

## **Why are soils in Loess-Paleosol-Sequences in Southern Tunisia sandy?**

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### **Abstract**

The Sahara is the world's largest hot desert and therefore it is and was one of the biggest global dust emitter today and during the past. Several environmental archives indicate fluctuations of aridity during the Quaternary. The interpretation of Loess-Paleosol-Sequences (LPS) may help to enlarge our understanding of this fluctuations.

Thick and widespread distributed Desert Margin Loess-deposits are quite rare. In surrounding areas of the village of Matmata in southern Tunisia, Quaternary Loess deposits are still preserved. Especially valley and depression floors are covered by up to 30 m of clayey and silty Loess with intercalated sandy Paleosols.

Our first results from the Matmata loess area in Southern Tunisia will be presented aiming to reconstruct the Quaternary environmental changes between Loess deposition and soil formation.

More than 11 LPS have been investigated so far in order to build up a solid loess stratigraphy for this region. The deposits show a clear internal stratigraphy of loess units interrupted by intercalated reddish sandy paleosols. These soils have clear features of CaCO<sub>3</sub>-leaching in the main soil horizon, whereas lower parts show a strong enrichment of carbonate (Cc-Horizon).

These features should be a result of more humid conditions under which soil formation could happen in contrast to arid loess forming environments. However, soils and loess within the same sequence show distinct analytical results. A look into the sediment sources may contribute to understand this phenomenon.

Our chronostratigraphy frame will be based on several OSL age estimations.

O-3125

## Fingerprinting the sources of aeolian deposits in northern China by using trace elements composition of detrital quartz

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### Abstract

The thick loess and Red Clay deposits in northern China preserve unique records of past climate changes and atmospheric circulation during the Quaternary and Late Neogene. Provenance analysis of these sediments is essential for understanding the wind patterns, climate conditions and tectonic activities of northern China during the Cenozoic Era. A variety of tools have been applied to investigate the sources of these aeolian deposits, including grain-size analysis, whole bulk geochemistry, heavy mineral assemblage, isotopic composition and single grain zircon U-Pb chronology. Among these methods, detrital zircon U-Pb dating has been increasingly used because of its advantage in distinguishing multiple sources for the sediments. However, as a heavy mineral, zircon grain cannot be transported with bulk sediments over long distance. Such hydraulic/ density property of zircon may bias the results interpretation towards proximal source regions.

Quartz is one of the primary rock-forming minerals during the rock cycle and is relatively resistant to weathering during transport. Compared to the heavy zircon, it has a much lower density, which means that it can be easily transported over long distances during aeolian processes, and can thus be potentially indicative for the relatively distal source areas. The major advantage of using quartz for provenance analysis is that it is the major component of the Asian dust and it travels with the bulk of the sediments. Therefore, provenance analysis based on quartz grains will provide more complete information about the dust sources and travel history of the sediments, compared to that of zircon. In this study, we introduce a new approach based on *in-situ* trace element analysis of detrital quartz, using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to characterise the provenance of the Chinese aeolian loess and Red Clay deposits. Three trace elements in quartz: Li, Sc and Ti are analysed. The comparison of trace elements in quartz between desert sand of the potential source areas, the Quaternary loess and late Miocene-Pliocene Red Clay has yielded results that are consistent with zircon U-Pb ages. The results indicate Qaidam Basin has a similar trace element distribution in the quartz to that of the Quaternary loess of the Mangshan Plateau and also suggest a possible dust supply from the Taklimakan Desert to the Baode Red Clay. This study sheds new light on the application of *in situ* quartz trace element analysis by LA-ICP-MS in tracking the sources of the bulk of wind-blown sediments.

O-3126

## The Central Andes primary dust sources of the Chaco-Pampean loess (South America)

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### Abstract

The loess of the Chaco-Pampa Plain (Argentina) is the most extensive and voluminous dust archive in the Southern Hemisphere, providing mineralogical, physical and chemical information on transported dust. The Pampean Aeolian System (PAS) generated during the Last Glacial Maximum (LGM), represents the largest Quaternary aeolian system of South America (ca. 600,000 km<sup>2</sup>), forming by a loess belt and a sand sea. Stratigraphic and sedimentological studies of Pampean loess units have been applied to understand the provenance of dust. The grain-size trend in SW-NE direction, the mineralogical association, and the geochemical data are indicators of multiple sources of the LGM loess. Some geomorphological units of the Central Andes were identified and characterized as the main primary sources. Dust emission of key areas of the Andes and the characteristics of their dust sink region in the Late Quaternary sedimentary archives (loess, wetlands and soils) were investigated. A significant geomorphological control on dust emission is observed. Field studies on representative areas, the installation of sediment sampling towers linked to a meteorological station, and GPR surveys have enhanced the understanding of surface process geomorphology on present-day dust sources identified by other authors using remotely sensed products. The hyper-arid Altiplano/Puna Plateau, ca. 1,500 km long and 300 km wide and with an average elevation of ca. 4,100 m a.s.l., is one of the main dust sources of the Central Andes, also being a present active area of dust. It comprises extensive sedimentary basins that are internally drained, formed by ignimbritic rocks and volcanic calderas. Tectonic depressions are occupied by Quaternary dry lakes (playas), alluvial fans, sand dunes, outwash plains and hypersaline lakes. The Southern Puna Plateau (25°-27°S; 68°30'-66°30'W) shows impressive Late Quaternary aeolian landforms as the largest megaripples on Earth, gravel dunes, yardangs and aeolian scars indicating a NW-SE wind direction. Particularly, the Purulla depression (NW Argentina) represents a unique natural laboratory for the evaluation of the dust exported to the lowlands, with a registered net loss of ca. 4 m of volcanoclastic sediments and ignimbrites. Salt pans of Puna also show large evidence of deflation process during the Holocene. Other important dust areas in South America are the arid Southern Central Andes and North Patagonia (Western Argentina). Silt-producing mechanisms as frost weathering, glacial grinding and fluvial comminution, mainly in the Andean upper basin of the Bermejo-Desaguadero-Salado fluvial system during the LGM, generated large volumes of clastic sediments that were transported by meltwaters along the eastern Andean piedmont and spreading out in terminal sand flats, ephemeral streams and wide alluvial plains. Their deposits were deflated by SW winds to the Pampa region. Changes in dust emission and mobilization reflect the occurrence of different processes.

O-3127

## The paleogeography of the Danube Deep-Sea Fan, NW Black Sea

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### Abstract

During the Holocene, the Black Sea basin suffered a major shift from a fresh water environment to a brackish one, which is mirrored in the biotical turnover. The transition of the Black Sea from an inland lake to a marine basin during the last glacial/deglacial episode is still generating debates. In Black Sea basin deeper parts, i.e., below 200m water depth, Ross and Degens (1974) recorded three stratigraphic units (from young to old): Unit 1 (the microlaminated coccolith ooze, deposited under marine conditions), Unit 2 (the sapropel mud, corresponding to a brackish, anoxic phase), and Unit 3 (the lacustrine lutite deposited during the freshwater or oligohaline stage).

The Danube Deep-Sea Fan is one of the most developed deep-sea sedimentary structures in Europe (Panin & Jipa, 2002). In 2018, in the framework of the uBiogas Project (24PCCDI/2018), several cores were acquired from the Danube Deep-Sea Fan area for investigating the processes that led to the formation and accumulation of methane. In this study, high resolution microfaunal analyses coupled with sedimentological and calcium carbonate (CaCO<sub>3</sub>) ones, were performed on two gravity cores, MN183\_3\_GC\_1 (401cm long) and MN183\_8\_GC\_1 (376.5cm long), revealed changes that occur in the Black Sea from the Last Glacial Maximum through the transition to the present day semi-enclosed marine basin.

The cores were collected from two secondary canyons situated to the east of the Danube Canyon, from 655,7 (MN183\_3\_GC\_1) and 1315m water depth (MN183\_8\_GC\_1). In both studied cores, three stratigraphic units were identified: the youngest Unit 1 (Coccolith Mud), Unit 2 (Sapropel Mud) and the oldest Unit 3 (Lacustrine lutite). The glacial cold period is marked by the presence of the cold-water ostracod species. The cores contain a reddish-brown clay and silt interval belonging to the post-glacial melt-water pulse of the Heinrich Event 1. In the upper part of the cores, in Unit 1, a brackish ostracod assemblage, with low diversity and abundance was identified. This interval is characterized by the presence of polyhaline ostracods with Mediterranean origin. The ostracods from this assemblage tolerate salinities comprised between 17-21‰ and characterize a sub-littoral environment.

The aim of this study is to decipher the paleoenvironmental and paleoecological conditions by the integration of the fossil record with the CaCO<sub>3</sub> values. Detailed micropaleontological studies, based on ostracod and foraminifera analyses, are also presented herein.

Panin, N., Jipa, D., 2002. Danube river sediment input and its interaction with the northwestern Black Sea. *Estuarine Coastline Shelf Science* 54: 551–562.

Ross, D.A., Degens, E.T., 1974. Recent sediments of the Black Sea. In: Degens E.T. and Ross D.A. (Eds.), *The Black Sea: Geology, Chemistry, and Biology*. American Association of Petroleum Geologists, Tulsa, USA: 183–199.

O-3128

## Sratigraphy and neotectonic structure of Lower Pleistocene deposits in the NW Taman Peninsula (Azov Sea, Eastern Europe)

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### Abstract

The eastern part of the Taman Peninsula at its northern coast is known to host a uniquely rich large mammal site of Sinaya Balka with remains of many dozens of southern elephants and giant rhinos elasmothers unearthed. This site is exposed in a displaced sedimentary block lacking a geological context. Studied by generations of researchers for over a century the site is still enigmatic in its origin, structural, and stratigraphic position. Recent field study (2017-2018) produced new data on geology and paleontology of this important area of Quaternary deposits. According to our model, the sedimentary sequence observed in the coastal cliff is a series of discontinuous blocks separated by faults frequently camouflaged by mud volcano clays. The blocks show differing facies structure. The sequence can be divided into three units. Two upper units overlie the lower unit 1 with angular unconformity. Units 2 and 3 shows a stratigraphic gap at their boundary. The strata of unit 1 in the NW block dip towards NW contrary to the SE block that dip into the opposite direction. The dip angle is increasing to the SE. The upper formations are nearly horizontal.

New paleomagnetic data showed that unit 1 with predominant reversed polarity and an interval of normal polarity can be correlated to Matuyama Chron immediately before the Olduvai Subchron. Records of small mammals (*Allophaiomys deucalion*, *Lagurodon arankae*, *Mimomys cf. pliocaenicus*, *Pitymimomys pitymyoides*, *Ellobius kujalnikensis*), molluscs (*Teodoxus sp.*, *Fagotia esperi*, *F. acicularis*, *Parafossarulus sp.* (opercula), *Bithynia sp.* (opercula), *Lithoglyphus sp.*, *Viviparus sp.*, *Limax sp.*, *Dreissena polymorpha*, *Margaritifera arca*, *Bogatschevia ex gr. sturi*, and a very important find of *Apsheronia cf. propinqua*) and palynology enable the correlation of this section with the late Gelasian – early Calabrian (1.8–2.1 Ma).

The base of the second unit shows normal polarity (?Jaramillo) capped by reversely magnetised sediments. The biostratigraphic content of this unit with large and small mammals (*Allophaiomys ex gr. pliocenicus*), freshwater molluscs, and palynology indicates a middle-late Calabrian (0.78–1.4 Ma) time interval. The dislocated Sinya Balka locality of large mammals we correlate to unit 2. The age of the unit 3 we estimate as middle Pleistocene.

The work is supported by grants of RSF 17-17-01073, and RFBR-18-00-00977

O-3129

## Combination of fluvial and coastal records of the southern Black Sea basin to reveal sea-level changes during the late Pleistocene

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### Abstract

The global sea level changes during the middle-late Pleistocene is well documented by using direct evidence or multi-proxy data from various data resources distributed worldwide. This global sea-level curve is used to correlate the regional data to decipher other influences, such as tectonic settings. The history of the changing levels of the Black Sea is rather more complicated phenomena, considering its wide catchment extending to the Eurasia and also its connection to the global ocean via narrow and shallow gateways such as the Bosphorus and Dardanelles straits. As a result the resolution of the Quaternary sea level curve for the Black Sea is comparably low.

During the Last Glacial, there are two major reported drops of the Black Sea level, post-Karangatian (MIS4) and Neoeuxinian (MIS2-Holocene) and in between Surozhian (MIS3) high stand. The latest episode of this history, the abrupt rise at the early-middle Holocene, is also well-known and have a remarkable impact on the prehistoric societies.

We aim to build up a luminescence chronology of the terrestrial records gathered from the southern Black Sea domain such as fluvial terraces (e.g. Sakarya, Yeşilırmak and Filyos Rivers) and coastal dunes (Karasu and Sinop). The initiation and termination of depositions are discussed in order to maintain a correlation to the Black Sea level curve during the late Pleistocene and beyond.

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O-3130

## Circumnavigating the complexities of radiocarbon dating the Late Quaternary evolution of the Black Sea Basin

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### Abstract

Since the 1990s, the Black Sea basin has been the subject of multiple hypotheses and studies relating to its Late Quaternary hydrological development, including the much-publicised claims for a catastrophic flooding event. One of the principle causes for the disparity in hypotheses relates to the complexity of obtaining reliable chronologies for the sequence of events since the Last Glacial Maximum. Radiocarbon dating, mainly of shells, has been used as the main source of dating in most studies but it is well-recognised that reservoir ages, critical to robust calibration, have fluctuated markedly over time due to a complex interplay of riverine run-off, changes in catchment, evaporation and precipitation of the basin, and changes in water depth and circulation patterns. The dating uncertainties generated are frequently a source of the contradictions between the timing of key events from different researchers. To circumvent these problems, a non-radiocarbon-based chronology on sediment cores from the Bulgarian shelf, in the western Black Sea basin, has been produced. This provides an independent assessment of the timing of Late Quaternary hydrological events within the Black Sea basin against which radiocarbon calibration approaches can be tested.

This study is part of the Black Sea Maritime Archaeology Project (MAP), which took place between 2015-2018. Extensive geophysical surveying covering >2000km<sup>2</sup>, coupled with 92 piston and vibrocores cores, has provided unprecedented levels of detail of this area of the Black Sea shelf. Core chronologies covering the last 30ka have been determined using a combination of palaeomagnetism, tephrochronology and radionuclide dating (<sup>210</sup>Pb and <sup>137</sup>Cs), coupled with geochemical and biostratigraphic analysis. The results demonstrate the presence of both visible and cryptotephra within the western Black Sea basin, extending the northern distal range of some Late Quaternary Mediterranean eruptions and providing isochrons. The palaeomagnetic results demonstrate the great potential of using this technique for dating the Late Quaternary sediments of the Black Sea basin with good replication of palaeomagnetic signals in multiple cores and close correlation to the tephra isochrons.

O-3131

## Age of raised marine terraces of the eastern Mediterranean, Turkey, determined by amino acid racemization and electron spin resonance dating

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### Abstract

The coastal area in the eastern Mediterranean Basin presents a deformed system of raised coastal deposits, some of which have been tectonically affected. This deformation has produced several stacked marine terraces due to successive tectonic movements and Quaternary sea-level fluctuations at elevations ranging from 3 and 175 m in this region. Here, molluscs from terrace deposits were dated using standard electron spin resonance (ESR) dating. Then, amino acid racemization (AAR) values measured from marine molluscs are demonstrated to be an important aid to correlations and chronology of raised marine terrace deposits in the study area. For molluscs *in situ* in the terraces, the ESR ages ranged from ~ 8 to ~ 214 ka are consistent with the aspartic (Asp) and glutamic acid (Glu) racemization values in shell samples in spite of significant differences occur between species at the taxonomic level. This is also the first established amino-stratigraphical sequence from marine terrace sites in this study and their combination with ESR dating. The results allowed corroborating the age of some studied sites, the general amino-stratigraphical framework for the raised marine terrace deposits was confirmed with ages between Marine Isotopic Stage (MIS) 2 and MIS 7. The amino-zones from oldest to youngest found along eastern Mediterranean coast support the reliability of the ESR ages, as well as compatible with the mean values for the amino-zones established in the western Mediterranean coasts. On the basis of our study, we conclude that the results of AAR dating can be used widely for the reference the geochronological investigation and/or effective diagenetic temperature in different areas of the Mediterranean realm.

O-3132

## Molluscs of the genus *Corbicula* as climatic and stratigraphic markers

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### Abstract

Bivalves of the genus *Corbicula* are well known markers of warm climate. The mean air temperatures in modern habitats of *Corbicula* in Central Asia range from 13 to 16°C. Normally *Corbicula* cannot stand water temperature drops to 0°C for more than a week. *Corbicula* occurred several times in the fossil record of Eastern Europe. The first, late Gelasian entry is recorded in the North Caucasus as *Corbicula* aff. *jassinensis*. Widespread sites of *Corbicula* *apscheronica* are known in late Early Pleistocene (Calabrian) of Azerbaijan, Stavropol, and Kerch (Andrusov, 1923; Semenenko, 1987). The genus went extinct in the south of Eastern Europe by mid Calabrian.

First records of *Corbicula* in Western Europe are known from Early Pleistocene. *C. fluminalis* is recorded in early and late Gelasian sites of France, Netherlands, and East Anglia. And from Cablarian (Bavelian) of the Netherlands (Meijer, Preece, 2000).

In south of Western Siberia and in the foothills of the Altai Mts, *Corbicula* occurs in a narrow stratigraphic range at the end of Gelasian (Popova, 1981; Zykin, 1991). The finds are attributed here to *C. tibetensis* and *C. ferhanensis*, that possibly dispersed from Central Asia (Zykin, 2012). In the Baikal region, the end Gelasian warm spell also showed a dispersal of the genus (as *C. praebaikalensis*) to the headwaters of the Lena River (Logachev, Popova, 1962).

The next extensive northward migration of *Corbicula* occurred during warm interglacials of the mid Middle Pleistocene (Holsteinian, etc.). The northern boundary of the range of this mollusc in the mouths of the Kama and Irtysh rivers reached 55-60° N, being 10-15° further north from its modern range. In Eastern Europe *Corbicula* is present in Holsteinian sediments in the Black and Azov seas regions. Likewise, the last appearance of *Corbicula* in NW Europe occurred at MIS11-7 (Meijer, Preece, 2000). The reliable presence of *Corbicula* in the middle latitudes of Eurasia during the Eemian (MIS5) interglacial has not been supported by unambiguous records.

The two waves of northward dispersal of *Corbicula* in Early and Middle Pleistocene represent the most important climatic and stratigraphic benchmarks, invaluable for deciphering the bioclimatic history of Northern Eurasia. The taxonomic position of the fossil forms of this genus needs a revision. The modern extensive invasion of *Corbicula* is mainly connected with human activity.

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O-3134

## Legacy-based targets for restoration of the tropical montane forests of northern Ecuador

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### Abstract

Conservation and restoration efforts that aim to return an ecosystem to a desirable past state require a designated target against which success may be measured. Records of past ecological change, preserved in sedimentary archives can provide empirical data of ecosystem dynamics over periods beyond that of observational studies, offering a range of potential reference conditions. Here we identify possible restoration options for the tropical montane forest of the Andean-Amazonian corridor based on varying degrees of landscape and vegetation modification through time. Human disturbance of the landscape is viewed along a gradient of impact from a pre-human arrival tropical montane forest through to the intensely managed cultural landscape created by pre-European indigenous peoples. Ecosystem dynamics, vegetation composition and structure are characterised through three periods corresponding to an ancient (pre-human arrival), historic (indigenous land-use) and modern landscape (cattle farming), in order to provide restoration ecologists and resource managers information on various past reference states. In this study we propose that, following the depopulation of the indigenous American people (c. AD 1600), the mature and structurally functional montane forest that was established after ~ 130 years of forest recovery represents the most practical target for restoration efforts looking to re-establish a 'near-natural' vegetation community. The ability of palaeoecology to register long-term ecosystem change and vegetation response to ecosystem drivers can offer advice to conservation and restoration projects in landscapes that have undergone extensive and prolonged human impact.

O-3135

## Millennial-scale history of Bolivian forest plots

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### Abstract

In Amazonia, most palaeoecological reconstructions have been dependent on pollen records from lake sediments. Unfortunately, the scarcity of such sites has hampered our understanding of the impact of Holocene climate change and pre-Columbian land use upon Amazonia's forests. Phytolith analysis, however, has the potential to circumvent this problem because, unlike pollen, phytoliths are well preserved in soils and can thus serve as an alternate, or complementary, proxy for reconstructing vegetation histories. Furthermore, unlike pollen, soil phytolith records provide comparable spatial resolution to 1 ha plot-scale ecological studies, enabling direct comparison between ecological and palaeoecological data. This PhD project addresses the following questions regarding Amazonian Bolivia:

1. What was the spatial scale of drought-induced forest die-back during the middle Holocene?
2. What is the relative importance of climate versus edaphic factors in controlling the dry forest-savanna boundary?
3. How does the mid-late Holocene fire regime compare between different types of tropical forest in the context of climate change and human land use?
4. How did pre-Columbian land use compare between fluvial and interfluvial rainforest settings?

Phytoliths, stable C isotopes and charcoal were analysed from 1 m soil-pit profiles from 1 ha plots from different types of forest across lowland Bolivia to create vegetation and fire histories extending to the middle Holocene, when the climate was drier than present. Selected sites are: (a) 'El Tigre' – inter-fluvial rainforest, Pando; (b) Tumichucua – fluvial rainforest at archaeological ring-ditch site, Pando; (c) Ottavio – dry forest/savannah boundary, Chiquitania; (d) Santa Cruz Botanic Garden dry forest – ecotone with Chaco-scrub.

Radiocarbon dates and stable C isotope data are pending, but previous studies suggest the soil profiles extend to ca. 6 ka BP. Preliminary findings:

1. The El Tigre site in Pando shows continuous presence of rainforest throughout the record, constraining the scale of mid-Holocene drought-induced forest die-back to within 650 km of the present-day rainforest ecotone at Noel Kempff Mercado Park (NE Bolivia).
2. The Ottavio plot also shows dry forest dominance throughout the 1 m profile, demonstrating resilience of dry forest to increased drought, and showing that edaphic factors are more important than climate in controlling the dry forest-savanna ecotone in Chiquitania.
3. Fire activity is lowest at the El Tigre interfluvial rainforest site (low flammability) and highest at the Tumichucua fluvial rainforest archaeological site (high anthropogenic burning), supporting the model of highest Pre-Columbian human impacts in fluvial settings.
4. Although palms are likely to have been an important resource for humans through the Holocene, as they are today, we find no relationship between palm abundance and human population density across space (Tumichucua versus El



Tigre) or time (mid-Holocene to present). 5. Despite construction of ring-ditches at Tumichucua, there is no evidence for significant pre-Columbian deforestation.

O-3136

## First palaeoecological evidence of Buffaloes husbandry and rice cultivation in the Kerinci Seblat National Park in Sumatra, Indonesia

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### Abstract

Rice is one of the most important subsistence, however evidence of the origin and domestication of rice cultivation is still scarce in Indonesia. This study aims to trace the beginning of rice cultivation and buffalo husbandry in Sumatra, Indonesia. We carried out palaeoecological multi-proxy analysis of pollen and spores, non-pollen palynomorphs (NPPs) and macro-charcoal analysis on a sediment core from the swamp forest of Danau Bento (DB) in the Kerinci Seblat National Park (KSNP). Our results provide first evidence of buffalo husbandry in the Kerinci since at least 4300 years ago, in line with the migration of the Austronesians to Sumatra. NPPs and pollen results indicate the existence of grassland around the site until about 3200 cal B.P, which was used for buffalo grazing and not for rice cultivation. The rise of Poaceae about 2500 cal B.P suggests the beginning of rice cultivation in the swamp contemporary with a decline in grazing as shown by the NPPs. However, this phase lasted only few centuries until ca. 2100 cal B.P. Following the decline of rice cultivation, the swamp remained in use as a grassland for grazing.

O-3137

## Palaeoecological and palaeoclimatological perspectives on human use of swamp forests in lowland New Guinea

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### Abstract

The Sago palm (*Metroxylon*) is an important food (starch) source across its range from Southeast Asia, New Guinea and the Pacific Islands. In Papua New Guinea *Metroxylon sagu* is cultivated in lowland tropical freshwater swamps, where it is a major staple food for around 10% of rural villages. The economic and cultural significance of sago in lowland PNG is immense, but the extent to which human populations have managed sago in the past is poorly understood. Here I review pollen and phytolith records from freshwater swamplands in the northern and southern lowlands (0-800m altitude) of Papua New Guinea and present a new record from Lake Kutubu in the Southern Highlands. The evidence shows the presence of *Metroxylon sagu* in association with lowland swamp forest disturbance (fire related) by at least 5000 yr BP, though it appears to undergo expansion in area planted after 1500 yr BP. This suggests that these environments were being managed for the production of sago at a time when swamp forests in the highlands of PNG were also rapidly declining in extent due to clearance for horticulture/agriculture. The links between past climate change and ENSO-related climate variability and food production in the New Guinea tropics will be discussed.

O-3138

## Ancient wetland agroecosystems based on multiproxy excavation and LiDAR Imagery of the Maya tropical forest

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### Abstract

Key hallmarks of indigenous alteration and adaptation of tropical forests were wetland agroecosystems. These occur and occurred in the tropical forests of South America, Africa, and East Asia, adapting local and regional environments and possibly influencing global climate over the Holocene. This paper synthesizes and presents new geoarchaeological and paleoecological records of wetland field complexes based on soil stratigraphy, geochemical, and pollen records. We compare perennial and seasonal ancient Maya wetland field complexes created from 3000 to 1000 years ago. Both areas have tropical forest vegetation with little evidence for human alteration since the Early Post Classic Maya period, about 1000 years ago. We present chronological and stratigraphic evidence of paleosols, sedimentation, and field formation. Our methods include AMS dating, typical soil analyses, magnetic susceptibility, XRF/XRD, pollen, and isotopic and elemental geochemistry of sediment sequences and water chemistry. Ancient farmers built the perennial wetland field and canals in the coastal plain of Belize sometime in the Maya Late Classic and these lasted until 1000 years ago in the Maya Terminal and Post Classic. Based on new Lidar imagery, possible wetland fields appear in many upland sinks of Belize and Guatemala's Peten. The paper presents these new LiDAR surveys with the first excavations into these possible canals and fields from the 2018 and 2019 field seasons. We interpret the extent, timing, formation of these fields compared with the large body of evidence we have produced for the perennial wetland field systems based on two decades of soil geomorphology, water chemistry, and archaeological study. We will thus compare multiple scales of long-term environmental change and multiple drivers of landscape formation over the early "Anthropocene" in these Neotropical fluvio karst depressions.

O-3139

## The high dynamism of Western Amazonian lowlands: a long-term view of the vegetation communities of Yasuní National Park (Ecuador).

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### Abstract

Since the first pollen diagram presented in 1916 by von Post, the study of the vegetation long-term (>50 years) dynamics through the use of palynology has spread worldwide. However, this increment in the number of analyses has been patchy, with locations densely studied and other areas with still limited knowledge, as it is the case of the tropics. For instance, South American tropics and specially the lowlands (*Amazonia sensu lato*), represents a region largely understudied, thus limiting obtaining accurate information of the plant communities' dynamics of such an ecologically and economic important area. Some of the reasons for this low density of available studies are the difficulty of arriving and exploring the study area or the finding of suitable locations. Among the problems for finding suitable records, western Amazonia has been highlighted as a very geomorphologically active location, preventing the development of long, continuous, sediments spanning several thousand years without a sedimentary gap or hiatus. Here we present a Holocene sequence of western northern Amazonian lowlands, in the Ecuadorian Yasuní National Park. The sequence (PATAM25\_B16, 0°41'07.1''S-76°25'58''W, 217 m asl), spans the last 6000 years, and pollen, non-pollen palynomorphs, and charcoal analyses have been performed. The beginning of the record is characterised by the presence of some disturbance indicators such as *Cecropia*, and Asteraceae and Anacardiaceae. Around 5000 years ago, the forest was characterised by high abundances of Urticales, Araliaceae, *Virola*, *Sterculia* and *Mimosa*. Other rainforest elements became important around 3000 years ago, including *Acalypha*, *Alchornea* and Malpighiaceae. Finally, the modern forest composition was established during the last millennium, with important contributions from *Hyeronima*, *Geonoma/Euterpe*, *Iriartea*, *Ficus*, and more recently, *Machaerium* and *Mauritia*. The results show the continuous presence of a rainforest, but with a high dynamism changing the abundance of the dominant taxa several times during the last 6000 years. In this sense, the forest with a higher evenness is the present-day one, established during the last millennium. It is suggested that the changes in the vegetation were primarily driven by geomorphological activity including changes in the drainage system, as well as human occurrence, which could have been only sporadic in the study area. Today, the study site is inhabited by Waorani indigenous, and it is subjected to oil extraction activities. The high dynamism of the forest and the unidirectional trends of the taxa shown in this record highlight the importance of studying in more details the trends of the current vegetation in order to secure the present and future ecosystem services of such unique location. Project refs.: 2014 BP-B-00094 and IJCI-2015-24273.

O-3140

## Examining the Role of Natural and Anthropogenic Fire Activity on the Biogeographic Distribution of the Amazonian Rainforest Ecotone (ARE)

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### Abstract

Amazonian rainforest ecotones (AREs) are vegetation transition zones from rainforest to seasonally dry forests and savanna woodlands. AREs are vital ecosystems that play an important role in rainforest speciation, harbor high-levels of habitat heterogeneity (*beta* diversity), and provide migration corridors that allow species to shift geographic ranges in response climate change. Increased human activity has caused AREs to be one of the most heavily exploited and most threatened ecosystems in the Amazon. Fire plays an integral role in maintaining the biogeographic distribution of AREs. Synergies between direct human activity and indirect climate change impacts threaten to accelerate forest transformation through positive feedback loops by increasing future fire susceptibility, fuel loads and fire intensity. In the upcoming century, a reduction in annual precipitation in the region is expected in response to deforestation and reduced evapotranspiration, while natural- and human-caused ignitions are projected to increase fire in AREs. The combined results will likely drive the expansion of savanna woodlands at the expense of rainforest vegetation. To date, however, the long-term factors driving fire in AREs remain poorly understood because of the challenge of disentangling the effects of prolonged climatic variability and over 7,000 years of human land-use in the AREs. Thus, the long-term role of fire in shaping the biogeographic distribution of Amazon ecotones remains elusive. To address this issue, an interdisciplinary framework incorporating fossilized macrocharcoal (>125  $\mu\text{m}$ ) and stable carbon isotopes from large (>20km<sup>2</sup>; for regional paleofire reconstructions) and small lakes (< 5km<sup>2</sup>; for local scale paleofire reconstructions) traversing the Bolivian ARE are compared with existing palaeoclimatological and regional archaeological data to investigate the potential natural and anthropogenic drivers of fire activity since the Last Glacial Maximum (LGM ; ca. 21,000 cal BP). Together these records indicate an expansion of C<sub>4</sub> grasslands in the ARE during the LGM. Despite the presence of drought and fire adapted C<sub>4</sub> vegetation, fire is at its lowest point which is attributed to cooler temperatures and decreased fuel connectivity. C<sub>4</sub> grasslands are gradually replaced by in C<sub>3</sub> woody vegetation during the early Holocene coupled with an increase in fire activity around the smaller lake basins while fire activity remains low around larger lake basins. These data suggest the higher sensitivity of small basins to detect changes in local-scale paleofire activity. However, during the mid-Holocene (~6,500 cal yr BP) the small basin charcoal records become asynchronous despite similar regional climate conditions in the Bolivian lowlands. Increased evidence of human occupation during this period combined with intensified crop cultivation, may potentially explain the increased heterogeneity of local-scale fire regimes, further contributing to the biogeographic distribution and diversification of AREs in the Bolivian Amazon.

O-3141

## Exploring the climate of South Africa during the Extended LGM: lessons from proxy evidence

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### Abstract

Located at the transition between the mid-latitudes and the sub-tropics, southern Africa has a climatic dichotomy between zones of winter- and summer-rainfall. The latitudinal extent of the winter-rainfall zone during the Extended Last Glacial Maximum (LGM), the regional changes in rainfall amount, and the extent of the temperature depression remain points of contentious debate, spanning divergent disciplines of palaeosciences. The synoptic scale shifts in the latitudinal position of the westerly belt, a function of the expansion of Antarctic sea ice and the contraction of the tropical Hadley Cell, represents the greatest driver of regional to local scale climatic changes during the extended LGM in South Africa. The accurate determination of precipitation seasonality for a given location is important in inferring the concurrent shifts in mean annual precipitation, water availability and temperature. While previous interpretations of precipitation seasonality during the LGM have relied heavily on the geomorphological record, more recent analyses have involved more continuous palaeoclimatic reconstructions utilising interpretations of more complex measures of water availability inferred from isotopes, pollen, diatoms and fossil rodents. These methods represent developments in proxy interpretation, which are necessarily highly location specific in their application, yet contain significant overlaps with the reconstruction of concurrent temperature and rainfall changes which present challenges in quantifying the changes for individual climate variables. Critical reflection of their validity, both in determining the contemporary validity of such proxies, and the potential for long-term seasonal reconstruction is thus essential. This paper outlines the current understanding of palaeoclimates during the extended LGM in South Africa on the basis of proxy evidence including pollen, minerogenic microfossils and micromammalian remains, considering the spatial and temporal heterogeneity in the regional record.

O-3142

## Environmental change at high altitude sites in southern Africa during the last glacial maximum

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### Abstract

Southern Africa is located at the junction of three of the world's major oceans and is affected by subtropical and temperate circulation systems, making it ideal for the study of past environmental change. Cold climate landforms present at high altitude sites allow for the timing of cold events to be determined through dating and for the reconstruction of past climatic conditions at the time of their formation. In addition, archaeological evidence from high altitude sites allows us to explore how humans reacted and adapted to environmental change during the last glacial maximum.

Here we summarise work that has been undertaken at high altitude sites in Lesotho and the Eastern Cape Drakensberg, and we present new ages for the timing of glaciation in Lesotho based on surface exposure dating using  $^{36}\text{Cl}$ . In Lesotho, geomorphological evidence in the form of moraines at a number of sites dated to the last glacial cycle attest to cold temperatures at the time of their formation. Glacier reconstructions, including steady-state mass balance and flow dynamics, suggest that temperatures during this time were approximately  $6\text{ }^{\circ}\text{C}$  colder than present, consistent with other proxy records from southern Africa. The occurrence of glaciers at these high altitude sites in Lesotho suggest a seasonal shift towards cold-season precipitation. In comparison, high altitude sites in the Eastern Cape Drakensberg retain no evidence for glaciation, however there is widespread evidence for periglacial activity down to an elevation of 1700 m a.s.l. Periglacial deposits dated to the last glacial cycle corroborate a  $6\text{ }^{\circ}\text{C}$  temperature depression during this time.

Archaeological evidence suggests that humans were present in the highlands at  $\sim 24\text{ ka}$ , despite the evidence of reduced temperatures and arid conditions at this time. Lesotho would have been attractive to hunter-gatherer populations due to the perennial surface water availability, in contrast to many regions of the sub-continent. The period  $\sim 23\text{-}17\text{ ka}$  is, however, represented by low frequencies of radiocarbon ages in the archaeological record, suggesting that hunter-gatherers reduced visits to the high Drakensberg during this time as a result of particularly cold conditions. Sustained reoccupation commenced after 17 ka, however the Eastern Cape appears to have remained unoccupied during this period, possibly reflecting climatic heterogeneity across southern Africa at this time.

O-3143

## Last Maximum Glacial records in the Rio Blanco basin (32° S), Argentinean Central Andes.

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### Abstract

Throughout the Andes, the glacier history reveals that glaciers had a maximum extension during the Last Glacial Maximum (LGM) and the Late Glacial, with rather consistent ages of ca. 31–18 ka BP and 18–12 ka BP from Alaska to Southern Chile (Clapperton, 2000). Diachronic intervals of glacier advances have been determined for the humid tropical Andes, the Central Andes of Argentina and Chile, and the Patagonian Andes (Zech et al., 2008). However, a regional glacial chronology is not yet fully established for the Central Andes. Late glacial advances were distinguished both in the subtropical Andes (Espizúa, 1999; Espizúa, 2004; Zech et al., 2005; Zech et al., 2007) and Patagonia (Rabassa et al., 2011), where drifts identified between ~36°-39°S have been interpreted as LGM in age. However, climatic archives show a complex pattern of timing and even antiphase climate responses in the arid Central Andes (Grosjean et al., 2003; Font and Chiesa, 2015). Knowledge about timing is severely limited in this region due to the scarcity of organic material for radiocarbon dating.

In the Blanco River Basin (BRB), a number of ambiguous Quaternary glacial stages have been proposed (Corte, 1957; Polanski, 1958, 1965; Wayne, 1981; Wayne and Corte 1983). Wayne (1981) proposed at least four main glaciations along the BRB that would have reached very low altitudes near the confluence of the Mendoza River valley (1400 masl). Assuming temporal correlations with Northern Hemisphere Glaciations and using relative dating techniques (e.g., soil development, loess thickness, block weathering degree, and preserved morphology) a tentative chronology for glacial deposits was suggested (Wayne and Corte, 1983). The Vallecitos Glaciation, evidenced by moraine deposits (Vallecitos I) and moraines related to fossil rock glaciers (Vallecitos II) located above (2600 to 3400 masl) were assigned to the Late Pleistocene. The authors proposed a speculative age of 17–22 ka BP for Vallecitos I and 12–16 ka BP for Vallecitos II.

This work presents the first numerical cosmogenic ages of glacial deposits from the eastern slope of the Plata peak (6200 masl) along the BRB (32°S). Surface boulders on the top of moraines were sampled for Be10. Obtained ages fit very well with local stratigraphy and regional paleoclimate evidence. The Loma de los Morteritos moraine II (3000 masl) was dated to ~25,000 years, while ages of ~8,000 and ~12,000 years were found for the Angostura II deposit (~3300 masl). These ages could be evidencing the Last Glacial Maximum (LGM) period for this region.

O-3144

## Annually-resolved (varved) record of ice sheet–climate interaction at the onset of the Last Termination in central Patagonia (46.5°S)

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### Abstract

Records of former ice sheet behaviour have proven vitally important in understanding the southern mid-latitude terrestrial response to climate variability during the Last Glacial Maximum and Last Termination (35–15 ka ago), with key studies contributing to conceptual models of ocean–atmosphere dynamics during this interval, such as the nature of wind belt and Southern Ocean frontal migration. Such records have relied primarily on cosmogenic nuclide exposure dating of glacially-transported boulders and/or luminescence dating of outwash sands to constrain past glacier dynamics. While effective, the resultant archives may be fragmentary or biased towards periods of glacier stability (e.g. moraine construction) and are typically limited to millennial-scale chronological precision.

By contrast, varved sediment sequences accumulated in former proglacial lakes offer the potential to develop continuous, annually resolved records of past glacier dynamics during periods of climatic change. Here we utilise a ~1000-year duration varve record from Lago General Carrera (Chile)–Buenos Aires (Argentina; 46.5°S) to reconstruct the retreat behaviour of a major Patagonian Ice Sheet outlet glacier between ~18 and 17 ka. The annual incremental record is tied to the calendar-year timescale via tephrochronology and offers unprecedented insights into the interplay between southern mid-latitude glacier and climate variability at centennial (i.e. through ice-margin position changes) and sub-centennial (i.e. through glacier ablation and sediment flux changes) temporal resolution.

Using annual sediment flux (varve thickness) data (and through comparison with regional palaeoclimate records and modelling data) we infer that distinct changes in ice lobe retreat dynamics coincide with several major climate shifts, namely an abrupt migration or weakening of the Southern Westerly Winds at ~18.0 ka, followed by a lagged oceanic and atmospheric warming associated with the propagation of hemispheric climate anomalies through the oceanic bipolar seesaw. Under this background of centennial scale glacial change, we also detect significant interannual to decadal cyclicity in the thickness of annual sediment layers (varves). The identified cycles are suggestive of El Niño–Southern Oscillation (ENSO) and/or Southern Annular Mode (SAM) influences on regional ice sheet ablation rates, likely through controls on Southern Westerly Wind strength and/or location and regional solar radiation receipts. This new evidence hinting at climate teleconnections between the tropics and the southern mid-latitudes at the onset of the Last Termination is consistent with reconstructions of coupled ocean-atmosphere frontal shifts at that time, and some climate model simulations that predict enhanced ENSO variability during this time period.

O-3145

## Climate and Environmental Change in New Zealand between 35-15 ka – a contribution to SHeMax

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### Abstract

The SHeMax (The LGM in the Southern Hemisphere) project seeks to develop a greater understanding of the timing, duration and nature of the LGM in the Southern Hemisphere. It is centred on the period 35-15 ka, encompassing the termination of the last glacial cycle, and the traditionally accepted timing of the global LGM (24-18 ka). Emerging evidence suggests that instead of being a relatively short event centered on 21 ka, the LGM in the Southern Hemisphere may have been an extended period of time, with an early onset at 35-30 ka. It has also been suggested that the LGM was not uniformly cool and dry but may have been characterized by millennial-scale variability.

New Zealand's unique physiography, and position spanning the middle latitudes of the Southern Hemisphere produces a dynamic climate, with teleconnections to a range of tropical and polar climate processes. In New Zealand, evidence for an extended LGM period was initially recognised through pollen-based palaeovegetation records, glacial evidence, and aeolian quartz sequences. These archives indicated that glacial conditions prevailed across most, if not all, of New Zealand during the interval 29–18 ka, much longer than the 'traditional' timeframe of 24-18 ka. This interval was subsequently dubbed the 'Last Glacial Coldest Period' (LGCP). Variations in pollen spectra, supported by other proxies (beetles, chironomids and plant macrofossils) provided for further subdivision of the LGCP into a series of 3 stadial and 2 interstadial events, which correspond reasonably well with the timing of terminal moraine formation from around New Zealand at ca. 28 ka, ca. 22 ka and ca. 18 ka.

In this presentation, we draw together proxy climate and environmental records derived from speleothems, lacustrine sediments, peat sequences, glacial sediments and moraines, and ocean sediment cores from the New Zealand region to illustrate the latest in our understanding of the climate and environmental variability over the SHeMax timeframe. We link our records chronologically through various dating approaches, including cosmogenic isotopes, tephrostratigraphy, Uranium-Thorium and radiocarbon. We focus on three particular events during the timeframe: 1) the onset of the LGM; 2) the period of maximum cooling; and 3) Termination 1. We compare and contrast how these events were captured across the different proxies, in terms of both timing and magnitude, and assess how variations in timing and magnitude between proxies can be interpreted in terms of the different climate and environmental drivers to which each proxy was responding.

O-3146

## The last deglaciation in New Zealand ; new $^{10}\text{Be}$ production rates from Misery moraines, Arthur's Pass, Southern Alps.

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### Abstract

Recent debate on mid-latitude New Zealand glaciation has focused on reconstructing paleo-climate conditions leading into the (global) Last Glacial Maximum and subsequent deglaciation dynamics during the last termination. Paleo-environmental evidence coupled with reliable glacial chronologies confirms significant differences from that observed in northern hemisphere signatures of glacial change. The New Zealand glacial record does not show glacial readvance and strong cooling commensurate with Younger Dryas timing (~11.7-12.9 ka) and many lake pollen records suggest a minor cooling or hiatus in warming during the period from ~14.5 – 12.0 ka that is more commonly associated with the Antarctic Cold Reversal (ACR) (~14.7 - 13.0 ka). The Arthur's Pass Moraine complex at 950 masl, deposited by an alpine glacier advancing out of the Otira Valley splaying east and westward over the divide of the Southern Alps in New Zealand, exhibits a full post-LGM glacial chronology. We have determined paired  $^{10}\text{Be}$  and  $^{26}\text{Al}$  exposure ages from 58 greywacke samples taken from all major moraines. Calculated exposure ages (using accepted local NZ production rates) show that the Arthur's Pass moraine system spans a period of 19.5 ka to 12.0 ka with mean recessional moraine ages in chrono-stratigraphic sequence. The overall timing of deglaciation after peak LGM conditions is similar to the glacial systems we have dated in the Rakaia, Waimakariri and Rangitata Valleys. The Misery sequence shows ice retreat at the end of the ACR and no major advance during the YD period. Multiple cores from two intermorainal bog (Lances and Misery Tarns), separated by ~1 km and constrained by the terminal Dobson and Misery moraines, have been recovered for paleo-climate study. Basal glacial silts and organic matter have provided radiocarbon ages representing a minimum age for glacial retreat. Combined with the Misery moraine cosmogenic concentrations, new  $^{10}\text{Be}$  and  $^{26}\text{Al}$  production rate calibrations can be made for New Zealand to improve exposure age accuracy.

**O-3147**

## **The onset of Termination 1 in the South Shetland Islands**

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### **Abstract**

The Antarctic Peninsula is undergoing accelerated environmental changes in response to changing climate patterns over the last decades. In this context, understanding the calendar of deglaciation is crucial to frame past changes with recent trends. To this purpose, nunataks are excellent areas to examine the mechanisms and rates of glacial retreat during the deglaciation process as well as environmental dynamics during the paraglacial phase, particularly vegetation colonization.

In January 2017 we collected 26 samples from three (paleo)nunataks (Chester, Cerro Negro and Clark), composed of basaltic rocks, in the Byers Peninsula (South Shetland Islands, Antarctica), a 60 km<sup>2</sup> ice-free area in this archipelago where our knowledge of the spatio-temporal pattern of deglaciation was only based on a few radiocarbon dates from basal lacustrine sediments. Samples from polished surfaces at different elevations from the top to the base of these three volcanic plugs were selected for <sup>36</sup>Cl surface exposure dating.

The data show evidence that glacial thinning already started during the Last Glacial Maximum, with the tops of nunataks becoming ice-free between 26 and 19 ka. A first stage of massive deglaciation occurred until 17-16 ka, when the highest parts of the nunataks in the Byers Peninsula were deglaciated. A relative stability of the ice cap occurred until 12-11 ka, followed by another massive glacier retreat with rapid ice thinning that exposed the land surface of the central plateau of Byers by 8-5-7.5 ka. This is also in agreement with lake records that also showed evidence that the Chester and Cerro Negro hills were no longer isolated nunataks by that time. Despite the fact that the eastern fringe of nunatak Clark is still connected with the Rotch dome glacier, the deglaciation followed a similar pattern, with its western side becoming ice-free by 7.5 ka. Small glacier advances were recorded during the Late Holocene.

These new data on the deglaciation of currently ice-free areas in the South Shetland Islands opens new perspectives for vegetation colonization of ice-free areas in the Antarctic Peninsula as well as for the interior of the continent. The first ice-free areas appeared much earlier than known to date, which has major implications for the diversity of species and its distribution.

O-3148

## Stable carbon isotope analysis on fossil *Cedrus* pollen shows climatic aridification in Morocco during the last 5000 years

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### Abstract

Quantitative climate reconstructions from pollen typically rely on empirical relationships between pollen abundances or assemblages and climate, such as the modern analogue technique. However, these techniques may be problematic when applied to fossil sequences as they, for example, cannot separate anthropogenic from climatic influence on pollen assemblages.

On the other hand, geochemical analysis of pollen allows quantitative relationships to be established with environmental and climatic conditions which directly influence the pollen geochemistry. Stable carbon isotope analysis on fossil pollen allows for reconstruction of moisture availability and aridity conditions. This approach is based on well documented plant physiological responses to moisture stress and is therefore independent from vegetation composition.

We reconstruct mid- to late-Holocene aridity in the Middle Atlas, Morocco, using stable carbon isotope analysis on isolated fossil *Cedrus* pollen. *Cedrus atlantica* (Atlas cedar) is an endemic tree found across North Africa, growing in sub-humid and semi-arid mountainous environments. It has been present in the region throughout the Holocene and Late Glacial period. As an early autumn pollinating tree where pollen develops over the summer months, it is an ideal species for reconstruction of summer aridity in Morocco, and indeed North Africa.

We find that there has been a general long-term trend of increasing summer aridity in the region during the last 5000 years. Pollen records show a gradual decline of *Cedrus* forest during the late-Holocene which follows the increase in summer aridity. Our findings indicate that climate has become drier, confirming the mid- to late-Holocene aridification trend, as seen elsewhere in the western Mediterranean, using a novel proxy for this region. The findings also help to resolve the often conflicting signals of climate change interpreted from pollen assemblages alone, while this technique has good potential for wider application in similar environments.

O-3149

## Climate changes in semi-arid Spain from the last interglacial to the late Holocene

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### Abstract

The Villarquemado palaeolake sequence provides a unique palaeoenvironmental record from the western Mediterranean Basin spanning the interval from the end of MIS6 to the late Holocene. The pollen and sedimentological record from Villarquemado provides qualitative information about changes in temperature seasonality and moisture conditions. Here we use Weighted Averaging Partial Least-Squares (WA-PLS) regression to derive quantitative reconstructions of winter and summer temperature regimes, expressed in terms of the mean temperature of the coldest month (MTCO) and growing degree days above a baseline of 0° C (GDD<sub>0</sub>) respectively. We also reconstruct a moisture index (MI), the ratio of annual precipitation to annual potential evapotranspiration, taking account of the effect of low CO<sub>2</sub> on water use efficiency. We reconstruct a relatively rapid summer warming at the beginning of MIS5. Summers are relatively cold during MIS4 and MIS2, but there are intervals in MIS3 (and, counterintuitively, also at the beginning of MIS 2) characterized by summers as warm as during the warmest phases of MIS5 or the Holocene. However, MIS3 is not significantly warmer in winter than other intervals during the glacial, and indeed there is a gradual decline in winter temperature from MIS4 through MIS3 to MIS2. The ecophysiological effects of changing CO<sub>2</sub> concentration through the glacial cycle has a significant impact on reconstructed MI. Conditions become progressively more humid during MIS5 and MIS4 is also relatively humid, while MIS3 represents the most arid phase of the glacial. The highest values of MI are reconstructed during the deglaciation and there is a pronounced increase in aridity during the Holocene. These changes largely reflect orbitally-controlled changes in climate and its seasonality, but the record also provide insights into superimposed millennial-scale climate variability and its impact on vegetation dynamics.

O-3150

## A new approach using uranium isotopes to better assess the interplay of climate, landscape and anthropogenic activity in the Mediterranean

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### Abstract

Due to the lack of appropriate analytical methods, high-resolution studies on the frequently non-linear interplay between climate, vegetation, and anthropogenic activity that severely impact the landscape through geological history are challenging. To address this, catchment-wide erosion processes have been quantified by means of novel uranium (U) isotope analyses on a lacustrine sediment succession from Lake Ohrid (FYROM, Albania) on the Balkan Peninsula. The new proxy is applied using the same material from which the climatic and environmental history has been inferred by means of conventional proxy analyses, such as pollen (for vegetation development and paleoclimate), carbon isotopes (for soil development), and (bio-)geochemical data (for soil development and paleoclimate). The comprehensive understanding of catchment-wide erosion processes and detrital matter delivered to the lake, as inferred from uranium isotopes, also helps to better understand the paleoclimate signal recorded in the sedimentary archive.

Uranium isotopes ( $^{234}\text{U}/^{238}\text{U}$  activity ratio) determine the time that has elapsed since physical and chemical weathering have formed silt and clay-sized detrital matter as the  $^{234}\text{U}/^{238}\text{U}$  activity ratio decreases in fine-grained grains  $<63\mu\text{m}$ . Deep weathering horizons, where fine-grained detrital matter is produced close to the regolith-bedrock interface, consequently have lower ratio  $^{234}\text{U}/^{238}\text{U}$  activity ratios than shallow soil horizons. Consequently, a lower  $^{234}\text{U}/^{238}\text{U}$  ratio in sedimentary deposits indicates shallow erosion, while a higher ratio reflects deep erosion.

A consistent pattern of soil erosion in response to rapid climate variability is inferred for the Late Glacial and Early Holocene, with shallower erosion (sheet wash) prevailing during cold and dry periods such as the Younger Dryas. Humid (and warmer) time intervals (Bølling/Allerød and Early Holocene) are characterized by deeper erosion, such as gully erosion. A pronounced shift in uranium isotope compositions indicates that stabilization of hillslopes by vegetation crossed a threshold at the Early to Mid-Holocene transition ( $\sim 8,300$  cal a BP), preventing deep erosion of thin soils in the catchment of Lake Ohrid. Hillslope stabilization and the threshold in catchment erosion are not mirrored by soil development over time, as inferred from carbon isotopes and elemental ratios. Human land use during the Late Holocene is reflected by reduced soil development.

O-3151

## Vegetation and climate changes during the last ~ 200,000 years based on a new long pollen record from Padul (southern Spain)

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### Abstract

A new sediment core from Padul wetland (Granada, southern Iberian Peninsula) provides a long and continuous paleoenvironmental record of the last ~200,000 years. This study aims to reconstruct the regional vegetation and local paleoenvironmental signal of the last two glacial-interglacial cycles from the southern Iberian Peninsula and the western Mediterranean region. Pollen analysis from this core shows orbital-scale vegetation oscillations (mainly forced by precession and eccentricity) pointing into insolation as the principal factor controlling vegetation changes at this latitude. Lake level reconstruction based on palynological data showed that local paleoenvironmental changes seems to be related to precipitation/evapotranspiration balance, and therefore, to changes in regional climate conditions. In addition, high siliciclastic/detrital input in the wetland carried from Sierra Nevada range have been related to enhanced soil weathering/erosion during regional aridity and lower forest cover recorded by the arboreal pollen data. Therefore, the combination of different proxies have provided good information not only about regional vegetation but also about detrital input and lake level evolution in the wetland during the last ~200 kyr.

O-3152

## Trends and anomalies in the Mediterranean palæoarchive

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### Abstract

The demise or flourishing of societies as a simple reaction to climate is never a fully satisfactory explanation. Predictable long-term trends facilitate adjustment of civilizations, and interactive processes of cultural and technological transformation become predominant factors. Nevertheless, societies may recall anomalies, i.e. prominent departures from previous average conditions, frequently with local particularities and hard to predict. In the Mediterranean context, an anomaly could be a period of sustained cold/wet summers or exacerbated cold/dry winters.

In this study, a compilation of Mediterranean sites is used to determine interactions between atmospheric, marine, cryosphere and terrestrial climate elements. These records allow us to identify climatic structures and discuss interhemispherical connections at multi-decadal resolution over the last two deglaciations and interglacials and over the past glacial.

None of anomalies recorded was an exact reproduction of the others because patterns of spatial and temporal evolution of the climate elements involved were never identical. However, some common features can be identified in their development:

- Firstly, anomalies can contain an abrupt warming event (e.g. as much as +4°C in few centuries), commonly in the middle of their progression
- Secondly, even when early cold conditions are registered, the maximum wind strengthening, aridity take place after the warming event, during a cooling phase as rapid as the warming; periods of scarcity of continental ice near the north Atlantic do not necessarily imply a more stable climate; in fact, quite the opposite, as some of the most extreme rapid cooling events occurred under these climate conditions.
- Thirdly, the warming event establishes a climate shift from one state to another, which differs depending on the relative occurrence of the anomaly with respect to precessional oscillation. The most prominent anomalies occur during periods around perihelion passage in NH spring equinox, in line with maximum extent of ice sheets, preceding deglacial processes. Anomalies linked to acceleration of the increase in ice volume accumulated on land, occur close to perihelion passage in the NH winter solstice. During such anomalies (for instance, 117200 years ago or 115300 years ago or 2800 and 700 years ago; Tzedakis et al., 2018, NATURE COMM.; Martrat et al., 2014, QUAT. SCI. REV.), climate change making an impact on societies cannot be ruled out completely. For instance, the most notable aspect of climate during the Little Ice Age (Abram et al., 2016, NATURE; McGregor et al., 2015, NATURE GEO.) was its great year-to-year variability: extreme events, prolonged droughts during the winter and spring seasons and then deluges or catastrophic floods during late summer and early autumn; severe winters, advances of high mountains glaciers. Other events happening around perihelion passage in the NH autumn equinox or summer solstice share complex characterisation, and appear implicit in predictable long-term trends.

O-3153

## Warm signature of the Roman period in Mediterranean sea surface temperatures

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### Abstract

Sea surface temperature reconstruction (SST) over the last millennia in the Mediterranean area represent an important challenges to document the possible link of past climate variability on the rise and fall of ancient civilizations. In addition, the last report of the Intergovernmental Panel on Climate Change (IPCC 2018) underlines the requirement to assess climate feedbacks during past episodes of moderately warmer (1.5°C-2°C) conditions. Within this framework, we present the reconstruction of the SST anomaly over the last five millennia based on the Mg/Ca ratios measured in the planktonic foraminifer *Globigerinoides ruber* from the sediment core SW104-ND11 extracted in the western part of Sicily Channel (water depth 475 m, central Mediterranean Sea). This new generated SST record is compared with previous published SST records reconstructed from Alboran Sea, Minorca Basin, Aegean Sea and from a north Hemisphere temperature reconstruction. This exercise brings the bases to discuss the regional impact of the most recent episode of apparently warmer conditions than present in the social-economical development of the Mediterranean region.

According to the Mg/Ca *G. ruber* SST record, the Late Holocene maximum temperatures (22.7°C) were reached at ca. 424 CE during the Roman period, after an overall warming trend that started at ca. 3300 BCE and was punctuated by several abrupt short term oscillation. After the Roman period, the Mg/Ca *G. ruber* SST record shows a cooling trend reaching the minimum temperature (18.2°C) at ca. 1673 CE, during the Little Ice Age. During the last three centuries the Mg/Ca *G. ruber* SST record shows warming trend to present day (20.3°C). The comparison of the studied record with other SST records, based in both Mg/Ca and alkenone proxies from several areas of the Mediterranean basin, supports homogeneous warm conditions at regional scale between from 100 BCE to 500 CE, and documents the occurrence of a distinct warming phase of ca. 2°C at the beginning of the Roman Period that led to the so called “Roman Climatic Optimum”. This period corresponded to an important demographic increase during the Roman Empire. At ca. 600 CE a cooling phase is recorded, which age corresponds to the Late Antique Little Ice Age (LALIA) event; after this event, the SST Mg/Ca *G. ruber* reconstruction documents the onset, at ca. 1180 CE, of the well-known Medieval Warm Period. The cooling associated to the Little Ice Age event occurred between 1320 CE and ca. 1850 CE with an anomaly of ca. 2°C vs negative values. The studied record of Sicily Channel ends with a turnover from ca. 1850 CE to 2014 CE vs a warming phase of ca. 1°C probably associated to the onset of the Industrial Period/Modern Warm Period. This research was financially supported by NEXTDATA and ERC-TIMED 525 (683237) projects.

O-3154

## Western-eastern Mediterranean freshening during MIS 12 deglaciation

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### Abstract

During MIS 12 deglaciation the Earth underwent the loss of a wide continental ice sheet in the Northern Hemisphere, which was larger than during the last glacial maximum. In order to clarify the timing, origins and dynamics of the freshwater entrance during this glacial Termination, eastern-western Mediterranean gradients were studied through a quantitative study of the planktonic foraminifera assemblages carried out in two cores: ODP 977 and KC01B.

Additionally, the isotopic composition of surface water ( $d^{18}O_{sw}$ ) was calculated using the calcite shell measurements of *Globigerina bulloides* and *Neogloquadrina pachyderma* dextral. These values have been corrected for ice volume and sea surface temperature (SST), the latter calculated using the artificial neural networks (ANN) method.

In general, low isotopic values were found in both basins during the whole deglaciation period. However, three episodes with maximum abundances of polar planktonic foraminifer species - *Neogloquadrina pachyderma* sinistral and *Turborotalita quinqueloba* - are highlighted in the record. Those episodes are associated with Mediterranean freshening events since they correlate to decreases in the  $d^{18}O_{sw}$ . Although major freshening events in the Mediterranean are described in the literature as a result of the release of Laurentian icebergs and the consequent entry of melt-waters through the Strait of Gibraltar, our study points also to the disruption and melting of the European reservoirs in the first part of the deglaciation, from both Fennoscandian and British ice sheets. The intervals with larger isotopic drops in the eastern Mediterranean indicate a possible extra source of fresh water from the southern Alps and the Apennines, melting through the Po River, and/or Black Sea outflows.

According to our planktonic foraminifer assemblages, before MIS 11 begins there is a sharp warming in the Mediterranean and an increase in  $d^{18}O_{sw}$ , reaching values similar to those at present.

O-3155

## The exceptional flash flood in Central Bohemia in May 1872: really so strong event?

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### Abstract

*The flash flood occurring on May 25, 1872 ranks among the most extreme events recorded within the Czech Republic. The causative torrential rain affected approximately 2000 km<sup>2</sup>. A corresponding intensity of precipitation observed incidentally at two sites exceeded 200 mm in 3-8 h. The consequent flood caused tremendous damages to ponds, houses, and infrastructure and resulted in a temporary collapse of transport especially due to a total break of trains operation. The flood led to approximately 240-300 fatalities according to various sources. An extent of the total area affected reached approximately 2000-3000 km<sup>2</sup> representing an unusually large scale for such a type of flood. The intensive rain and inflow caused for Czech territory the biggest rupture of a water reservoir in Mladotice so far. The respective Mladotice pond held very likely more than 5 million cubic meters of water before its rupture. With a delay of 2 to 3 days, a substantial saturation triggered a massive landslide blocking the Mladotice water stream and creating a new water body named the Odlezly Lake. The flood event motivated elaboration of at least 5 scholarly papers already between 1872 and 1875. Accordingly, this flood presents for Czech hydrologists an outstanding example of such an incredible magnitude until now. The flood in 1872 and drought in 1874 led directly to establishing the Hydrological service of the Czech Kingdoms in 1875. Hitherto, we have no comparison for such extreme flood including recent floods occurring in 2002, 2010 and 2013. The flood peaks exceeded other historical or recent floods by at least 1-2 m. As there were no regular hydrological observations including precipitation measurements available for the affected areas before 1883, the prevailing data source comprise documentary sources and their relevant interpretations. The aim of our study is to explain in a more detail the course of this flood and a number of indeterminate circumstances during the flood. An important question was an effect of the collapse of approximately 100 ponds and a role of the collapsed sizeable Mladotice pond. These phenomena were partly explained by newspapers and chronicles describing an incredibly rapid increase of water level at a relatively large number of sites. We have completed a hydraulic estimation of peak discharges at major profiles. In our research we used the Agualog hydrological modelling system. The hydrological modelling enabled us to complete and check the reliability of observed causative precipitation for the affected area and peak flow rates at the Beroun and Prague municipalities. This flood is of crucial importance for the Prague flood protection system. The main reason being a short time span of 22 hours between the beginning of causative rainfall and occurrence of maximum flood flow rate at Prague.*

O-3156

## Identification of extraordinary floods in the Late Holocene fluvial deposits of the Copiapó River (southern Atacama Desert, Chile)

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### Abstract

After the last two extreme hydrometeorological events that caused large floods in the southern Atacama Desert, March 2015 and May 2017, knowledge of extreme event patterns has become necessary for understanding disaster risk and strengthening disaster risk governance. Although extremes are an intrinsic characteristic of the hydrological regime in this arid region, short gauge records difficult their characterization and the paleohydrological study of the fluvial Quaternary sequences can be used to address this issue. With this aim, we have first focused in two outcrops located in the Lower Copiapó basin, upstream and downstream of the Angostura sector. Here, the valley, which drains at this point a catchment area of 18,000 km<sup>2</sup>, narrows and incises the Palaeozoic bedrock forming a 10.5 km long canyon. Mean annual discharge rate in the study area, near its mouth, is 0.43 m<sup>3</sup>/s. Despite this low value, extraordinary floods with peaks discharges more than 500 times the mean occur (240 m<sup>3</sup>/s in the March 2015 event).

In Angostura, a low bench with multiple flood units was recognized. Upstream the canyon deposition of suspended sediment and bedload occur controlled by the constriction while downstream, changes in the valley geometry result in a reduction of the flow velocity. At the base of section A (upstream), a relatively thick (80 cm) calcareous tufa level, related to a paleowetland environment, appear overlaid by 5 flood units. The deposition period for these flood units is well constrained: 1) 1390 – 1445 AD below the tufa; 2) 1628 – 1803 AD above flood unit 1; and 3) March 2015 flood unit 5. Section B can be separated in four sets. The lower set comprises two flood units, interbedded between shale and peat deposits, consisting of fine sands with rizolites. The second set contains four successive flood units of silty sand while the third set includes only one event. Finally, in the uppermost set three flood units appear consisting of silty sand with undulated and upper plane bed horizontal lamination as well as fluid scape structures. Set one ranges from BC 541 – 370 to BC 234 – 66 and denotes wetter conditions than present ones. The base of set four has been dated as 1810 – 1839 AD. The paleodischarge estimation of the three more recent flood units will allow increasing the extreme event discharge record to the beginning of the 19<sup>th</sup> century what combined with the analysis of the historical record will help reconstructing the paleoflood history of the arid Copiapó basin.

O-3157

## Spatio-temporal variability of modern sediment composition in Baker fjord (Chilean Patagonia, 48°S): A pre-requisite for paleohydrological reconstructions

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### Abstract

Fjord sediments, like fluvial and lacustrine archives, are increasingly recognized as accurate recorders of past and current hydrological variability. Fjords exhibit particularly high sediment accumulation rates (>3cm/year), allowing for high-resolution hydroclimate reconstructions. Nevertheless, accurately interpreting fjord sediments in terms of past changes in hydrology requires a comprehensive understanding of the variables that affect the composition of the sediment. In this context, we conducted a spatial and temporal study of the relations between sediment composition and particle size in Baker Fjord (Chilean Patagonia, 48°S), and we compare our results to the discharge of Rio Baker; the main source of sediment to the fjord and Chile's largest river. Grain size, major and selected trace elements, biogenic silica, carbonate content and bulk organic geochemistry (TOC,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) were compiled from: (i) 13 surface grab sediment samples collected along a proximal-distal transect in the proximal part of the fjord (i.e. with increasing distance from the river mouth); and (ii) from a sequential sediment trap with 24 samples integrated over an entire year with a bi-weekly resolution. These data are then compared to daily precipitation, temperature, and discharge from local stations (Caleta Tortel meteorological station and Rio Baker Bajo Ñadis gauging station, respectively). We show that: (i) magnetic susceptibility significantly depends on mean particle size ( $r = 0.84$ ,  $p < 0.01$ ,  $n = 24$ ); (ii) particle size skewness strongly reflects river discharge seasonality, with positive values (towards fine grains) in summer, typical of proglacial sediment input (grain size mode = 5 $\mu\text{m}$ ), whereas negative skewness (towards coarser grains) is recorded in winter, reflecting a reduced influence of glacial meltwater and a higher sensitivity to short and intense rainfall events (grain size mode = 15 $\mu\text{m}$ ); and (iii) total inorganic carbon content of detrital origin peaks during rainfall events independently of grain size changes. These findings are being tested against an additional year of sedimentation (sequential sediment trap retrieved in Feb. 2019), and they will serve as a basis towards the production of long, accurate and high-resolution records of hydrological variability from fjord sediments, including reconstructions of precipitation, floods, and glacier mass balance (meltwater input).

O-3158

## A 1000-year-long documentary record of the lower Yellow River ice-jam floods and its climatic implications

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### Abstract

The Yellow River floodplain is a low-lying landmass, which is remarkably susceptible to excessive precipitation and prone to floods. Therefore, it has a strong association with calamity and has traditionally been regarded as “China's sorrow.” Also, given its immense ecological, societal, and economic importance, the Yellow River floodplain contributes significantly to human welfare, which has colloquially known as the birthplace of Chinese civilization. Therefore, a deeper understanding of flooding frequency in this area is especially important for the assessment of socio-economic risks associated with future climate changes. The late 20th century contained a number of catastrophic floods in the lower Yellow River, which has exerted devastating impacts on the human livelihood. However, the long-term context of apparently anomalous flooding events witnessed in recent decades has received very limited attention.

To better understand the nature, evolution, and driving mechanisms of river floods, it is widely recognised that the instrumental time series should be placed within a longer time framework. Here we present a 1000-year-long documentary record of ice-jam floods of the lower Yellow River by compiling flooding events in terms of levee breaches and overflows during the early spring months as documented in official dynamic histories. A time series with a yearly resolution was formed by using a binary expression with “1” denoting the presence and “0” the absence of flooding event for a year. The flood frequency is computed by convolution with a 31-year-wide window. Our results reveal an increasing frequency of ice-jam floods since AD 1855 when an avulsion occurred, and the river shifted northward to its current channel. As the occurrence of the ice-jam floods is essentially induced by a deepened temperature gradient between the inland and maritime region in the lower Yellow River area during the early spring months (January-March), we ascribe the increasing frequency of ice-jam floods to the prolonged negative phase of ENSO (i.e., La Nina). Our finding implies the global teleconnection of terrestrial hydrological systems to the ENSO cycles.

O-3159

## Meandering river dynamics in response to glacial-interglacial cycles

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### Abstract

Meandering rivers are usually associated with active meandering processes. However, many meandering rivers are relatively laterally stable, and can have very complex planforms. We show that these rivers became autogenically constrained within their self-formed, heterogeneous floodplain, by a reconstruction of the Late-Glacial to Holocene planform evolution of a small meandering river; the Dommel River in The Netherlands. Here we combined coring, ground-penetrating radar (GPR), optically stimulated luminescence (OSL) dating and radiocarbon (<sup>14</sup>C) dating. The Dommel River developed a complex sinuous planform with very limited lateral migration due to insufficient flow strength to erode its self-formed cohesive banks, which largely consist of oxbow channel fills and counterpoint deposits. We compared data on river energy, bank strength and planform complexity of 48 rivers from around the world, which confirmed that complex planforms occur where rivers are constrained within their self-formed cohesive banks. This self-constraining of rivers is initiated once river energy decreases, which occurred to many rivers in temperate regions during the transition from a glacial to interglacial period. Due to better preservation of cohesive deposits compared to non-cohesive deposits, the required energy needed to break out of the self-constraining tendency increases over time. Self-constraining thereby enhances resilience of the system. The river is able to escape from the self-constraining tendency if river energy increases to such an extent that the threshold for erosion of cohesive bank material is crossed, such as during the transition from an interglacial to a glacial period. Our study provides a novel explanation for meandering planforms and meandering dynamics and their responses to climatic changes.

### Acknowledgments

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O-3160

## Identifying late Quaternary pluvial episodes beyond MIS 5 in south-eastern Australian highlands using single-grain quartz and feldspar luminescence dating

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### Abstract

Fluvial sediments in Australia provide important archives for assessing late Quaternary flow regime changes. In south-eastern Australia abundant evidence exists of enhanced runoff conditions (relative to today) throughout and beyond the last full glacial cycle. These include palaeochannel deposits and fluvial terraces which have been interpreted as evidence for pluvial episodes and enhanced flow regimes. The hydrological setting in the east of the Great Dividing Range is characterised by a series of smaller coastal-draining catchments (< 1000 km<sup>2</sup>) surrounded by larger basins, such as the Hunter and Shoalhaven extending to the west of the great escarpment and with areas > 5000 km<sup>2</sup>. Previous studies mostly focused on small basins or concentrated on late Pleistocene or Holocene alluvium; fewer studies have investigated the much larger catchments containing drainage areas above the escarpment (on the tablelands), despite preserving antecedent fluvial landforms of much greater antiquity. Recently, a single-grain (SG) optically stimulated luminescence (OSL) study on three fluvial terraces in the upper Hunter catchment showed that extreme fluvial aggradational episodes in the catchment are mainly correlated with glacial or stadial periods since MIS 6 (Fu et al., 2019), in contrast with records from northern Australia and inland rivers draining west from the Great Dividing Range. Further confirmation and understanding of this regional pattern requires more chronological studies on fluvial archives in these large coastal draining catchments.

This study presents the latest OSL dating results of several previously undated or partially-dated fluvial terraces in the Shoalhaven and upper Hunter catchments, namely the Larbet terraces, the lower and upper Mayfield terraces, and the Razorback terraces. SG quartz and/or SG K-feldspar dating were applied to fluvial sediments collected from these terraces. These include several challenging samples in terms of luminescence dating, exhibiting complex luminescence properties (especially for quartz), and/or strong bioturbation, and/or are close to signal saturation. A comparison between SG quartz and feldspar equivalent dose distribution was used to assess the extent of bleaching for individual samples and to select the most reasonable dose population for age estimation (for bioturbated samples); new statistical models were also used to provide more reliable chronologies for samples near saturation. Our dating results, for the first time using SG data, extend the fluvial sedimentary record in south-eastern Australia to Marine Isotope Stage 8. These new chronologies, together with previously published data, continue to suggest that enhanced river valley aggradation in the south-eastern Australian highlands took place mostly during glacial or stadial periods throughout the late Quaternary rather than during peak interglacial episodes. Phases of valley-floor aggradation in south-eastern Australian highland are inferred to be a function of increased sediment supply during the cold periods in the late Quaternary, resulting from strong periglacial activities in the adjacent Australian highlands.

O-3161

## Using depositional architecture and luminescence dating to understand the genesis of the Lower Tejo and Lower Thames terraces

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### Abstract

The Thames and Tejo terrace stratigraphies have long histories of research, with an enviable profusion of Palaeolithic artefact content in both valleys and copious fossils in interglacial Thames sediments in the valley downstream of London. Thus biostratigraphy is a well-established basis for classification of the lithostratigraphical sequence in the Thames, along with the trace-fossil value of artefact assemblages in both systems. In the Thames this has provided clear indications of the marine isotope stages (MIS) represented, especially in the post-MIS 12 record in the Lower Thames.

Chronological control in the Lower Tejo has relied on geochronological methods, notably OSL and ESR, with ranges up to 300 and 900 ka, respectively.

In order to provide further temporal constraint for boundaries of depositional architecture within the Thames sequence, comparable with data from the Tejo, improved numerical geochronology is required, this being a prime aim of the authors. In both river systems a combination of published and targeted new dates, principally of luminescence type (quartz-OSL and K-feldspar post-IRIR<sub>290</sub>) is used to constrain episodes of deposition and, by means of proximity, of incision.

A key aim is to identify and compare the prime drivers of fluvial activity in these systems (set against background uplift): climate change *versus* sea level (not that these are fully independent of one another).

O-3162

## Metagenomics of tsunami deposits using eDNA: First results from the Shetland Islands, U.K.

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### Abstract

With the development of high-throughput sequencing technologies in the recent years, there has been a growing number of projects using environmental DNA (eDNA) technologies in environmental, ecological and conservation research and broad areas of Quaternary science.

We will present the first results of the “GEN-EX - Metagenomics of Extreme Wave Events” pioneer project, which is developing high-throughput, metagenomic sequencing techniques to identify foraminifera assemblages (key bioindicators in tsunami and storm deposits), and to unravel their cryptic diversities in onshore extreme wave deposits from their DNA remains.

The project has sampled tsunami deposits from coastal peat sections at three sites on the Shetland Islands, UK (Dury Voe, Garth Loch and Maggie Kettle's Loch), dated to approximately 1.5, 5.5 and 8 ka BP, respectively. By applying classical micropalaeontological techniques, no foraminiferal tests have been found in any of the tsunami deposits analysed to date, whilst inter- to subtidal offshore source deposits show moderate to high foraminiferal concentrations, indicating likely post-depositional dissolution of foraminifera in the onshore tsunami deposits, i.e. a massive loss of information.

The first DNA results are very promising. In the laboratory using stringent precautions to avoid extraneous contamination, foraminiferal DNA has been successfully extracted from palaeo- and modern sediments and also from individual foraminifera. After extensive Polymerase Chain Reaction (PCR) optimisation, amplification of the D1–D2 region of the Large ribosomal Subunit (LSU; 18S) ribosomal DNA from modern individuals has been successfully achieved.

Currently foraminifera are an underrepresented taxonomic group in genetic databases such as GENBANK and BOLD. Thus, Sanger DNA sequencing is in progress to allow us to construct a reference database. For the first time, sequences available to deposit in this database are presented, including our methodology protocols for DNA sample treatment and for the development of custom nuclear DNA primers, which are specific to the target taxonomic group.

All molecular analyses have been complimented by an integrative and comparative approach utilising geoscientific techniques such as micropalaeontological analysis (foraminifera), grain-size distribution, CT scanning, multi-sensor core logging and geochemical analyses.

O-3163

## Characterization of coastal sediments in Zamboanga del Sur, Philippines in relation to offshore tsunamigenic earthquakes

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### Abstract

The 1976 Mw 8.1 Moro Gulf earthquake, which occurred on the shallow portion of the subducting slab along the Cotabato Trench in northern Celebes Sea, produced a tsunami with reported tsunami wave heights of up to 9 m. Among the worst-hit areas in southern Philippines include the province of Zamboanga del Sur where the height of tsunami waves reached up to 5 m. This unprecedented event resulted to thousands of casualties and millions worth of damage in the coastal communities bordering Moro Gulf. In order to gain insight on the potential of Cotabato Trench to generate large magnitude tsunamigenic earthquakes, our study conducted sediment sampling in the coastal areas of Pagadian City and Tukuran, Zamboanga del Sur to find potential geologic evidence of past tsunami events. Test pits, auger, and the handy geoslicer were used to observe the subsurface stratigraphy of coastal plains and mangrove swamps up to 1.5 m deep. The sedimentary structures observed in the stratigraphy, i.e. parallel laminations, heavy mineral laminations, and erosive base overlain by coarser sediments, are similar to the descriptions of tsunami deposits in Asia, such as the 2011 Tohoku and 2004 Indian Ocean tsunamis. The sediments collected from the subsurface were also compared to nearshore, fluvial, and terrestrial samples to further understand the sedimentary environment. Satellite imageries from Landsat were also used to interpret if the changes in sediment sizes are influenced by anthropogenic activities. The sediment samples vary in sizes from mud to very coarse sand. The composition is generally detrital grains such as mica, quartz, diorite, andesite, pumice, and other volcanic and pyroclastic rock fragments. While additional analyses are needed to confirm if the sedimentary characteristics are related to a tsunami event, this study is the first to report the characteristics of coastal sediments in northern Celebes Sea, particularly in the Moro Gulf region.

O-3164

## Storm-wave movement of megagravel, and formation of imbricated boulder ridges: evidence from Froude-scaled wave-tank experiments

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### Abstract

Coastal boulder deposits (CBD) are supratidal clastic deposits that include isolated boulders, small clusters, and extensive ridge systems built of stacked, imbricated clasts. Individual boulders can weigh many 10s to 100s of tonnes. They are emplaced by waves along steep rocky coasts. Some are on cliffs as high as 50m above high water, and others are found at the back of shallowly dipping coastal ramps, up to 250 m inland of the tide line. They occur worldwide, but some of the best examples occur on the west coast of Ireland. An outstanding question about these deposits is whether storm waves can produce the structured and imbricated boulder ridges that are characteristic of CBD, or whether they are the signatures of tsunami.

We carried out Froude-scaled 1:100 wave tank experiments, using a JONSWAP spectrum to simulate realistic storm conditions, with  $H_s$  ranging from 10-14 m (scaled equivalent). Model boulders (441-1075t scaled equivalent) were situated on a cliff-top platform (10 m a.s.l. scaled equivalent), and we examined both the movement of individual blocks and the formation of boulder clusters and ridges on the platform. We ran multiple tests, varying boulder size and configuration. Wave gauges at several locations in the tank recorded water surface elevation, and video footage captured wave parameters and wave-boulder interactions that are difficult to measure at full scale.

Overtopping waves did not disperse cliff-top boulders, but tended to deposit them in clumps and ridges, with imbrication and geometry matching coastal boulder deposits, indicating that storm waves can and do form imbricated boulder ridges. The majority of boulder displacements were caused by a small subset of the incident waves, the key to boulder transport being development of a high velocity bore. The largest waves are not necessarily the most effective: instead, wave-front steepness just before cliff impact seems to control the strength of post-collapse cross-platform flow. Waves that approached the cliff unbroken, had a front slope angle in the range 15°-25°, and were taller than the cliff, generated the most powerful bores. These waves moved very large boulders with masses in excess of those predicted by existing hydrodynamic equations.

O-3165

## Pluri-decadal to annual storm-induced geomorphic processes on the Valahnúkur coastal boulder ridge, SW Iceland

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### Abstract

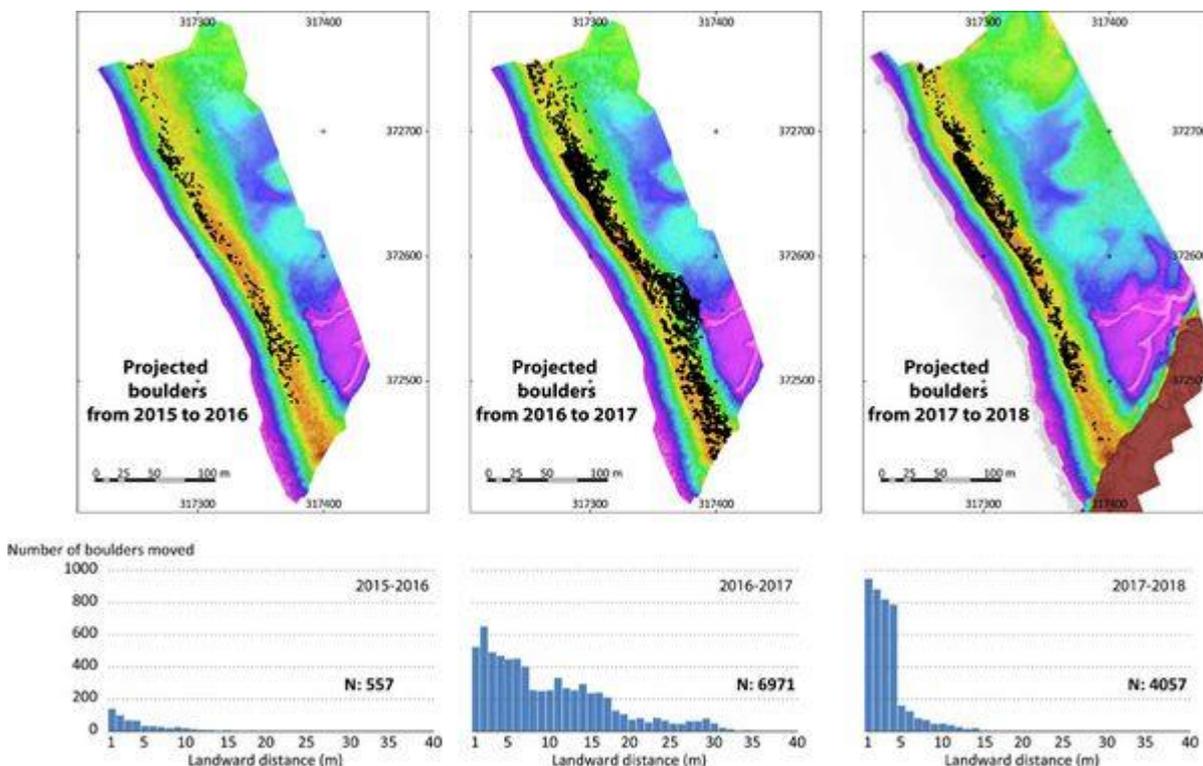
While recent studies highlighted the great mobility of boulder beaches related to the impact of storm waves, numerous researches are still needed to better understand the morphodynamic of coastal boulder accumulations and to better interpret fossil boulders deposits. This paper provides original data about storm-induced geomorphic processes and their impact on the Valahnúkur boulder ridge (figure 1). The study site is located west of the Reykjanes Peninsula, in the south-west of Iceland.



Firstly, the historical evolution of the boulder ridge was reconstructed from a set of aerial photographs between 1978 and 2010. Photographs were geometrically corrected and georeferenced according to the standard procedure to quantify the shoreline changes. Secondly, four kite and drone surveys were realized yearly between May 2015 and May 2018. The Digital Elevation Models (DEMs) produced using Structure-from-Motion photogrammetry were compared to deduce the morphological changes. Four orthophotographs were analyzed to quantify the movement of boulders. Hydrodynamic conditions were reconstructed using wave buoy and tide gauge measurements. Storminess was first assessed using a POT method. The extreme morphogenetic events were recognized using the 98th percentile of the significant wave height. The storm duration was estimated using the 75th percentile to define the start-time and the end-time of storm events. Wave runup were calibrated from the analysis of a wave/swash motion data set acquired by video monitoring.

The historical analysis of shoreline change shows a significant landward retreat of the ridge during the last 40 years. The Highest rates of retreat are recorded in the northern part of the barrier where a large washover fan was formed during the 1990s and reactivated in the 2000s. This suggests a set of overwash events and the episodic flooding of the boulder ridge, probably during major storm events. The southern part of the barrier also shows high migration rates suggesting sediment transfers from the beachface to the back-barrier.

The annual topo-morphological survey indicates various morphological responses according to the frequency and magnitude of winter storm events. From May 2015 to May 2016, the swash processes were dominant. The mobility of boulders was moderate (N=557) and restricted to the beachface (figure 2). These changes were attributed to fair weather conditions during the winter. The period from May 2016 to May 2017 was dominated by overwash processes. The results highlighted a crest reworking and a landward projection of high number of boulders (N= 6971) due to several intense winter storm events associated with high water levels. From May 2017 to May 2018, the morphodynamic regime was dominated by overtopping processes. Despite the large number of boulders moved (N=4057), the sediment transfer was limited to the crest line. These changes can be attributed to three storm events associated to moderate water levels.



O-3166

## Modern and historical tropical cyclone and tsunami deposits at the coast of Myanmar

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### Abstract

Myanmar's coast is prone to flooding by both tropical cyclones (TCs) and tsunamis from multiple sources. However, although TCs (e.g. TC Mala 2006 and TC Nargis 2008) and tsunamis (2004 Indian Ocean Tsunami) repeatedly caused flooding during the last decades, the temporal restriction of existing records limits the robustness of regional long-term frequency-magnitude information. While there is only a single historical tsunami in AD 1762, associated with a major rupture of the Rakhine segment and with inconclusive information with regard to its impact at the coast, that provides data beyond the instrumental record, sediments of past flooding events might allow the extend it to much longer time periods.

So far, very limited research on coastal flooding deposits has been conducted in Myanmar. This study presents results of a field survey along Myanmar's western (Rakhine) and eastern (Thanintharyi) coast. To provide a local reference for the sediment characteristics and preservation potential of TC and tsunami sediments, onshore deposits of 2006 TC Mala and 2008 TC Nargis were documented. Both events formed sand sheets with landward extents of up to ~100 m or washover fans in back-barrier areas. Significant flooding by the 2004 tsunami was only reported at the eastern coast, where it is reflected by a thin sand sheet identified in a paddy field. However, at most sites the flooding deposits display a very poor preservation potential. After only a few years most evidence is already overprinted by soil formation that probably obliterates all differences to sandy subsoils within decades.

Only where sand sheets extend into swales or back-barrier depressions characterized by the deposition of terrestrial fine sediments during the rainy season, preservation may potentially allow for detection after longer time periods. In the swales of a beach-ridge plain at the west coast, distinct marine sand layers predating the TCs and tsunami in the early 2000s were identified. A combination of luminescence, radiocarbon and <sup>137</sup>Cs dating points to 1982 TC Gwa and an unrecorded TC in the 1950s as the most likely candidates. Comparison with the complete historical TC record indicates that the archive is only sensitive to TCs of category 4 (or higher) with landfall directly in or a few tens of kilometers north of the study area. While the presented TC records are restricted to the last 100 years, luminescence ages of the beach-ridges indicate that the swales landward of the one investigated in this study might provide TC information for at least the past 700 years.

O-3167

## Sedimentary and erosional features caused by hurricane Irma

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### Abstract

The 2017 Atlantic Hurricane Season drew renewed attention to the need for storm risk assessment as it was the costliest season on record. Irma was the strongest recorded hurricane to form in the Atlantic Ocean and reached the northwestern Caribbean Islands as a category 5 hurricane on Sept 5<sup>th</sup> 2017.

A post-hurricane survey was conducted on Anegada (British Virgin Islands). The project takes advantage of pre-event field data collected on Anegada in earlier years that allows for a detailed comparison of pre- and post-Irma data. Irma passed ca. 35 km south of Anegada. Maximum wind speed on Anegada was ~256 km/h, related maximum offshore wave heights were ~17 m. Irma had a surprisingly weak storm surge of <3 m as indicated by wrack lines and overwash deposits. The small surge may be explained by the fact that Irma's eyewall passed south of the island and winds were mainly shore parallel. Thus, even though a category 5 hurricane, very close to the island, Irma does not represent the worst-case scenario for a storm on Anegada.

Substantial coastal erosion occurred on Anegada's north shore. A steep erosional scarp of about 1 to 1.5 m height and a retreat of the coastline by several meters were documented. While erosion dominates the northwest and central north shore, depositional evidence is present along the northeastern and southern shore. Thick faintly laminated sand sheets that cover beach sand have a max. thickness of ca. 35 cm. Deposits are massive and well-sorted carbonate sands. Small washover lobes that contain shell hash have sediment thicknesses of 5 cm. The deposits contains *Homotrema rubra*, a red foraminifer that bleaches predictably following detachment from the reef. The relatively high concentration of vibrantly colored *Homotrema* suggests that the majority of sediment was freshly sourced from the fringing reef. Furthermore, a pre-existing coast-parallel coral rubble ridge was entirely reworked. Cobbles and boulders were moved several meters in landward direction. Few cobbles were washed into the sea, moved shore parallel towards the west and transported back onto the coastal platform.

The depositional and erosional evidence of Irma differ significantly from features left by historical tsunami that breached the coastal dunes and transported sand and large living corals several hundreds of meters on land. The deposits of the 1755 Lisbon tsunami revealed key differences in their sediment provenance as they contain reef crest foraminiferal assemblages with a contribution of offshore planktics, whereas the Irma deposits are characterized by reef flat to reef crest assemblages.

O-3168

## 3500-year western Pacific storm record warns of additional storm activity in a warming warm pool

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### Abstract

Frequent storm surges often cause catastrophic impacts on human lives and the global economy; however, these phenomena are not well understood. In this study, a regional storm reconstruction is performed based on a grain-size analysis and stratigraphic modelling of the accelerator mass spectrometry radiocarbon dates of benthic foraminifera from two neighbouring lagoon cores from Lingyang Reef in the Xisha Islands located in the northern South China Sea of the western Pacific. The dating results from the lagoon cores reveal a ~3500-year depositional history. Three different depositional units are recognized based on a time series of distinct grain-size variations that correspond to the following three stages of storm activity: intense and frequent storms from ~3500 to 3100 cal yr BP and ~1800 cal yr BP to present and weak and infrequent storms from ~3100 to 1800 cal yr BP. A high sedimentation rate is observed from ~2800 to 2600 cal yr BP in both cores, and it was likely caused by a slump deposit associated with a tsunami event. In addition, grain-size variability may be associated with changes over time caused by the synchronous Asian monsoon and may also be correlated with climate records retrieved from the ice cores from Greenland; thus, this variability could indicate pervasive global climatic teleconnections. The overall temporal patterns of the isolated coral branches and shells from the sediment sequences are well correlated with the high sea surface temperatures in the western tropical Pacific. We suggest that increasing sea surface temperatures in the future may lead to more intense storm activity in the western Pacific warm pool as the planet warms.

O-3169

## Human-environment interactions since the latest Pleistocene west of the subtropical Andes (31°-32° S), South America.

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### Abstract

The geographical band between 31°-32° S, from the Pacific to the Andes, lies in the southernmost part of the Semi-Arid North of Chile, south of the Atacama Desert. Multidisciplinary research in this area has exposed the potential for discussing human-environment interactions since the latest Pleistocene. This area is ideal for such assessment due to its environmental sensitivity because it lies in the margin of the northernmost area of influence of the westerlies. Also, the dominance of an archaeological record produced by mobile human groups, bestows this region of high anthropogenic sensitivity as can be examined by the different degrees of permanence/avoidance of certain spaces.

However, research efforts across the area remain uneven, therefore in need of complementing studies in those sectors left behind. The aim after a four-year period of research is to understand the relative intensity of the human traces across the landscape and evaluate if environmental changes conditioned such distribution at different points in time.

Currently, the combined pollen records in the coast and highlands provide a semi continuous climate history for the last 15,000 years. After wetter and colder late Pleistocene conditions, pollen records indicate arid phases between 7.8-6.2 ka and 3.5-2.2 ka and the wettest period within the last 2 ka. Anthropogenic dates (>430) range from 13.5 ka to modern over a 10,000 km<sup>2</sup> area (Figure 1). Such chronometric resolution, attained by long lasting archaeological programs and CRM studies, provides grounds for discussing the intensity of human occupation and comparing the human chronological signature with the available paleoclimatic data to discuss if aridity, its magnitude, and regional expression, and therefore shortages in resources, exerted pressures over human groups inhabiting this area (Figure 2).

On one hand, the coastal radiocarbon record is nearly continuous, thus indicative of a sustained human presence across the Holocene. Inland valleys, on the other hand, show a remarkable prevalence of radiocarbon records on the last 3000 years as motivated by profound changes in settlement patterns, economy and technology.

Earlier discussions suggested the hyper arid mid-Holocene conditions lead to population relocation or even demographic decrease based on region-wide radiocarbon assessments. New research efforts into previously neglected areas have yielded dates precisely within the time gap detected in earlier human records. This preliminary collation argues in favor of relocation and posits environmental change as a potential mechanism influencing the past human spatial distributions. Assessing human responses to environmental change in the margins of the desert should prove useful for the broader understanding of landscape use and its variation throughout the Holocene.

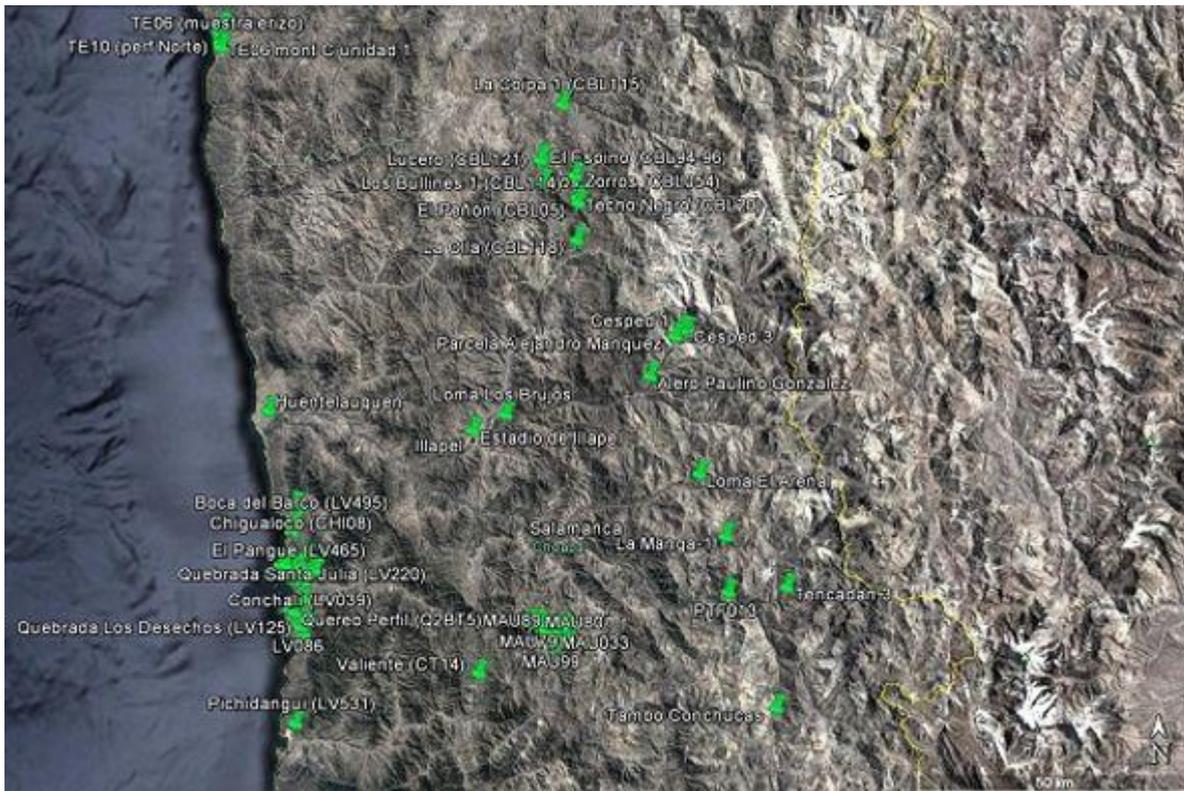


Figure 1. Distribution of dated archaeological sites between 31°-32° S.

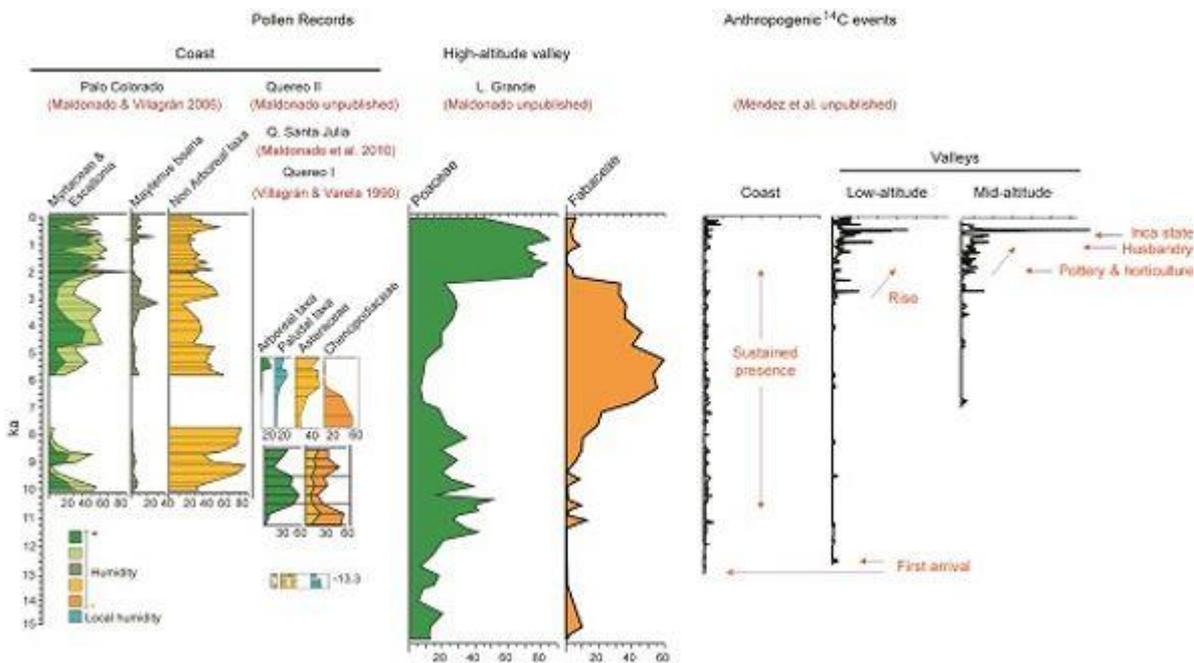


Figure 2. Comparison between pollen records and summed distributions of anthropogenic radiocarbon dates partitioned by landscape band.

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O-3170

## The Synchrony and Magnitude of Energy Booms and Busts among Human Societies Throughout the Holocene

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### Abstract

We conduct a comparison of the consumption of energy by human populations throughout the Holocene and statistically quantify coincident changes in the consumption of energy over space and time—synchrony—as well as amplitudes of change over multiple time scales. When populations synchronize, adverse changes in ecosystems and social systems may cascade from society to society. Thus, to develop policies that favor the sustained use of resources, we must understand both the processes that cause the synchrony of human populations and why amplitudes of change vary from society to society. Our analysis begins to fill these knowledge gaps. We document that (i) the creation of social ties that couple populations over smaller scales and (ii) much larger scale, globally convergent trajectories of cultural evolution toward more energy-consuming political economies with higher carrying capacities creates a synchrony of energy consumption among human populations throughout the Holocene. However, (iii) the magnitudes of changes in energy consumption vary from society to society. Agricultural populations unwittingly tradeoff more stable energy dynamics at small time scales for vulnerability to large booms and busts at larger time scales. Conversely, hunter-gatherers experience moderate intensity booms and busts in their economies and populations, but fewer large and small amplitude changes.

O-3171

## **Withdrawn - Evaluating the resilience of traditional agriculture systems to climate change in the Peruvian Andes over the last 2000 years**

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### **Abstract**

The cultural history of highland Peru suggests that once great empires, from the Early Intermediate Period through to the Late Horizon (200BC – 1533AD), supported their populations through highly innovative agricultural systems. The construction of agricultural systems, including terraces, canals, reservoirs, corrals and raised fields, transformed the morphology of the Andean landscape. This significantly increased food production and ‘risk spreading’ through complex engineering involving the movement of soil, stone and water, and the selection of appropriate cultivars, which resulted in highly sophisticated agricultural systems. The archaeological record indicates that these agricultural systems were remarkably resilient as evidenced by the apparent persistence of human occupation in many highland areas. Nevertheless, several studies have highlighted the potential impact of water stress due to enhanced climate variability during this time that led to social and economic collapse. For example, published data suggest that these systems flourished due to high precipitation (e.g. ~600-800AD), but may have been unsustainable due to drought which led to agricultural terrace abandonment (e.g. ~800-1000AD). However, the relationship between increased climatic variability and the sustainability of the agricultural systems is still poorly understood.

Despite the growing number of high-resolution records for past climate change in Peru from lakes, caves (speleothems) and ice, as well as marine records, there remains a paucity of palaeoenvironmental data documenting changing land-use patterns and vegetation succession, especially from small lakes and mires proximal to zones of intensive human activity. Palaeoenvironmental information recorded in these wetland archives provides an important insight into the sensitivity of the surrounding landscape and human environment to past climate change.

Using radiocarbon-dated sediment geochemistry, pollen, phytoliths and non-pollen palynomorphs, alongside archaeological and ethnographical evidence, we present an improved understanding of the relationship between the past agro-pastoral economy and climate change in the Peruvian Andes. We will provide new data from three study areas: Ancash Region (Santa Valley); Lima Region (Chillon Valley); Apurimac Region (Chicha-Soras Valley). Within each of these locations, we will present records from three infilled lake / mire sequences: Huarca near Yungay (Ancash); Cantamarca near Canta (Lima); Ayapampa near Pampachiri (Apurimac).

The study sheds new light on the resilience of past agricultural systems to climate change, which has implications for our understanding of the issues that govern sustainable food production in Peru at present day among rural communities employing traditional agricultural practices.

O-3172

## Inca rituals on the summits of the Andes: a tale from tree-rings

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### Abstract

Fluctuations in the availability of water resources represents the main factor which has modulated ecosystem dynamics, human population changes and culture in arid and semiarid regions. One of the largest high-altitude semiarid regions of South America is the Altiplano plateau in the Central Andes (~14°S-26°S). With a mean elevation of 4.000 m a.s.l. and many volcanoes up to 6.700 m a.s.l., the Altiplano has been the physical environment for the settlement of many local communities who have inhabited the region for thousands of years. Historically, human activities in the Altiplano have been strongly modulated by variations in climate, particularly water availability.

During the last decade, tree-ring research has been developed in this region allowing the reconstruction of the dynamics of water resources at annual resolution during the last millennia. In the other hand on the mountain tops of the Altiplano exists many high-altitude pre-Columbian sanctuaries which are framed within the remarkable relationship between mountains and water, which was a fundamental feature on which local cultures of the Altiplano based their complex religious beliefs related to mountains as sources of water and fertility. The existence of archaeological wood on this sites utilized as offerings and/or firewood, and the possibility to develop regional tree-ring chronologies in the area allow the tree-ring dating and the development of precipitation reconstructions. On this investigation we present a new tree-ring based regional precipitation reconstruction for the Altiplano for the last millennia, and the dating of three high-altitude sanctuaries located on mountain tops at ~6,000 m a.s.l. utilizing tree-ring widths and 14C wiggle-matching of tree-ring sequences. For the last, we utilize a recently developed regional 14C curve from the Altiplano region. The dating and occupancy of these water-related sanctuaries will contribute to a better understanding of the relationship between humans' religious beliefs and the semiarid environment that inhabited, on which century-scale dry periods are demonstrated to be a recurrent feature in the regional climate.

O-3173

## A palaeoecological investigation of Ancient Maya land-use strategies at low-density settlements

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### Abstract

The Ancient Maya Civilisation (ca. 2500 BCE - 1500 CE) are one of the best documented past societies in Mesoamerica. Numerous high-resolution palaeoenvironmental investigations have highlighted a link between environmental degradation and the decline of the Classic Maya civilisation around the 8<sup>th</sup> century CE, occurring against the backdrop of known periods of climate instability (specifically drought). Many of these studies focus around large ceremonial centres, which may reflect the intensive agriculture that was required to support high population densities. Palaeoecological investigations from low-density sites provide an opportunity to investigate how the Ancient Maya managed their landscapes using alternative strategies, such as agroforestry and small-scale crop production. We use a combination of high-resolution pollen and charcoal records to show the local impact of the Ancient Maya on their environment from island (Basil Jones) and mainland (Laguna Esmeralda) sites. Both sites do not contain evidence of large civic architecture (e.g., temples), but show evidence for small-scale occupation by the Ancient Maya. The dominant ecosystem type of each site is seasonally dry tropical forest. A 6,000-yr sediment core from Basil Jones was extracted from a local sinkhole adjacent to a small Maya settlement. Evidence for crop production is shown with the appearance of maize pollen, which dates human occupation at the site to 2500 BCE. Pollen and charcoal data indicate there were no large deforestation events, but smaller clearances were made for the production of crops. The most notable impact on the environment is the complete clearance of palms (*Acromia* spp.) by 1700BCE. Charcoal analysis of the 6000 -yr sediment core from Laguna Esmeralda suggests that fire was not as prominent as in Basil Jones, suggesting low impact on dry forest cover, but preliminary pollen data show variations in constituent forest taxa. The results of this research highlights the importance of selecting suitable sampling locations (proximity to temple structures) to understand the heterogeneity of Ancient Maya land-use in Mesoamerica.

O-3174

## Ecosystem impacts of human arrival in the Azores: a comparative study of high-resolution multi-proxy lake sediment records

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### Abstract

Human settlement of uninhabited land masses can dramatically transform local ecosystems and its endemic biota around the world. These changes are particularly evident on islands, where human settlement usually marked a period of large-scale habitat destruction and extinctions of local flora and fauna. Historical records specify that the Azores archipelago in the North Atlantic Ocean was settled in the mid-15th century CE. The human footprint in the Azores was large and widespread: within six centuries of colonization more than 95% of the original native forests were destroyed. Paleoecological and geochemical reconstructions from the Azores have allowed us to compare ecosystem processes and dynamics before and after colonization.

To document the cultural evolution of human settlement in the Azores archipelago, we studied lake sediment records from four distant islands, located in the Western (Flores), Central (Pico and Terceira) and Eastern (São Miguel) group of islands. In particular, we investigated the role of the Medieval Warm Period and the Little Ice Age climatic periods as external driving forces for human displacement and potential triggers for cultural transformations. A suite of proxies – pollen, diatoms, chironomids, cladocerans, hydrogen isotopes, macroscopic charcoal, organic matter, inorganic composition (XRF scanning and X-ray diffractions), and lithofacies – were used to distinguish between different signals of climate change, landscape and ecosystem dynamics, and their local lacustrine responses. A comprehensive multi-disciplinary analysis of all the proxies provides strong indications that the Azores were colonized more than two centuries earlier than currently recognised. These early colonizers first reached the Central group of islands around 1100 yr CE and the Eastern group before the end of the 13<sup>th</sup> Century. The Western group was subsequently reached around 1300 yr CE. Early human activities included the introduction of domestic animals, land clearance and small-scale agriculture, and extractive forestry mostly for charcoal production. The origin of the early colonizers is further discussed during the presentation.

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O-3175

## Late Holocene Demographic Trajectories and Human Subsistence Change: Exploring Patterns in the Subtropical Andes

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### Abstract

Historical records from the Subtropical Andes reveal a surprising mosaic of human subsistence strategies, ranging from intensive reliance on domestic plants to a sole reliance on wild resources. This presentation focuses on this diversity in Central West Argentina by developing summed probability distributions of radiocarbon data and stable isotope on human bone collagen for different regions in order to reconstruct and compare Late Holocene demographic and dietary trajectories. We compare the northern area, where historic farmers lived, with the southern area, where historic hunter-gatherers lived. We find just one significant difference between both areas throughout the entire Late Holocene, which occurred between 800-1100 AD. During this period, a significant positive change in demographic growth in the north was associated with an increase and abrupt drop in maize consumption. At the same time, the southern area shows a drop in demography. Stable isotopes on human bone collagen (<sup>13</sup>C and <sup>15</sup>N) show a similar pattern between both areas, with values being more enriched in the north than in the south. In both areas, the inter-individual variation was high. This variation spikes when individual bone collagen  $\delta^{13}\text{C}$  values cross -14‰ in both areas. Higher standard deviations suggest that individuals have more diverse subsistence adaptations when <sup>13</sup>C bone collagen (maize) reached the highest values. This strategy could reflect the adaptability and flexibility of subsistence systems under highly variable environment conditions. Maize diets were unstable as a consequence of high interannual variation of climatic conditions. Subsistence that focused predominantly on maize was not viable over the long-term, and prevented high-energy extraction necessary for driving sustainable population increases.

O-3176

## The missing piece: late Pleistocene changes in the ecological function of mammal communities in North America

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### Abstract

By the late Pleistocene, the genus *Homo* had increased exploitation of other mammals for food and resources. As hominins became increasingly abundant and dispersed across the globe, a temporally and spatially transgressive extinction of large-bodied mammals followed; the degree of selectivity was unprecedented in the Cenozoic fossil record. The rate of extinction has only increased over time; today the conservation status of the largest mammals is precarious owing to a disastrous combination of continued hunting, habitat loss/alterations, and conflict with humans.

Recent work suggests that large-bodied species perform many essential ecosystem services, which are not fully characterized. Because biodiversity threats are ongoing, conservation biologists cannot wait for the results of long-term studies before proposing potential mitigation strategies. Yet, understanding the functional role of large-bodied mammals is essential for effective management of the remaining wild areas on Earth. Here, a paleo-perspective provides powerful insights; by studying the consequences of the catastrophic biodiversity loss at the terminal Pleistocene (ca 13 ka), we can characterize the long-term ecological effects of the loss of large-bodied animals on the rest of the mammal community.

Here, we focus on changes in morphological and isotopic dietary space of the mammal community in the Edwards Plateau, Texas before and after the megafauna extinction. Body size was estimated based on measurements of molars or post-cranial material; carbon ( $\delta^{13}\text{C}$ ), nitrogen ( $\delta^{15}\text{N}$ ) and/or oxygen isotope ( $\delta^{18}\text{O}$ ) values were derived from analysis of collagen or apatite extracted from fossil materials. When available, literature values were also employed. We find that prior to the extinction, there was a diverse community of large-bodied C4 grazers, C3 browsers and mixed-feeders. The carnivore guild was more specialized and tightly linked to their prey base, especially felids who were hyper-carnivorous and ate C4 grazers, similar to their counterparts in modern African systems. Ursids (*Arctodus* and *Ursus*) regardless of body size, fell into mixed C3-C4 to pure C3 dietary isotopic ranges. Post-extinction, diversity in body size and isotopic space is lost within the mammal community, although these shifts are complex and appear to be related to both body size and trophic guild. For example, while the  $\delta^{13}\text{C}$  niche space of browsers such as deer did not change, the larger bodied grazing *Bison* did demonstrate a shift. Moreover, a baseline shift in nitrogen appears to have influenced all surviving herbivores, which may reflect a changes in biogeochemical cycling commensurate with the loss of megafauna. We conclude that the ecological function lost with the terminal Pleistocene megafauna extinction was not restored over the Holocene.

O-3177

## Exploring beneficial plant-fungal symbioses in the Quaternary

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### Abstract

Mycorrhizal symbioses have been an important component of terrestrial ecosystems since plants invaded the land over 450 million years ago. The important contribution of these below-ground plant-fungal symbioses to nutrient cycling, carbon storage, water uptake, and protection from pathogens is receiving increasing attention. However, examination of the geohistorical interactions between mycorrhizal host plants and fungi remains a largely unstudied field of research. Our recent work on postglacial biotic interactions in North America (Pither et al. 2018) is a rare exception and suggests that certain types of mycorrhizal fungi played an important role in moderating the range dynamics of their hosts during past periods of climate change.

Here we use host pollen data, extracted from the Neotoma database, to interpolate the residence times of different types of mycorrhizal host in grid squares across North America since the last glacial maximum. The spatiotemporal heat maps produced by this method highlight locations in which specific types of mycorrhizal association have dominated, or been repeatedly excluded, over millennia. Using this information we discuss the implications of host residence times for symbiont diversity, and *vice versa*. Specifically we explore what the spatial distribution and temporal residence times of key plant genera allows us to infer us about species pools of mycorrhizal fungi.

### Reference

Pither J\*, Pickles BJ\*, Simard SW, Ordonez A, Williams JW, 2018. Below-ground biotic interactions moderated the postglacial range dynamics of trees. *New Phytologist* **220**: 1148-1160.

O-3178

## A multi-proxy reconstruction of a terrestrial-marine linkage in the Falkland Islands

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### Abstract

The Falkland Islands (51° S) are a biodiversity hotspot for seabirds in the South Atlantic Ocean, yet little is known about how seabirds will respond to rapid climate change. Seabird guano is an important source of nutrients to the coastal grasslands that form critical seabird breeding habitat. The availability of these marine-derived nutrients is influenced by not only seabird populations, but also the marine food web. Because seabirds are sensitive indicators of climate change, we hypothesize the linkage between marine and terrestrial environments (guano inputs to grasslands) is sensitive to climate variability. Deep peat-forming coastal grasslands in the Falkland Islands provide a natural archive to assess the responses of seabird populations and terrestrial ecosystem to past climate change. We analyzed pollen, charcoal, and geochemical proxies for seabirds from a 4.76-m radiocarbon-dated peat core. Our multi-proxy reconstruction of the past 14,000 years demonstrates a terrestrial ecosystem shift occurred at ~5,000 years ago when seabird populations reached higher levels than the previous 9,000 years. The increase in seabird populations coincided with the development of a grassland ecosystem. The coastal grassland ecosystem that persisted over the last 5,000 years is largely degraded today because of introduced livestock grazing with the arrival of European settlers two centuries ago. Grassland fires, which are suppressed today, were present throughout the past 14,000 years, but most frequent when seabird nutrient inputs fueled the coastal grassland ecosystem. This shift in the terrestrial-marine ecosystem linkage coincides with well recognized records of Southern Hemisphere neoglaciation, such as lower sea surface temperatures on the western Antarctic Peninsula and expanded sea ice in the South Atlantic Ocean. Our reconstruction linking terrestrial-marine ecosystems suggests that Falklands coastal ecosystems respond to past cooling shifts and are a refuge for seabirds during cold periods in Antarctica. The terrestrial-marine linkage between coastal grasslands and seabirds is sensitive to climate change. Our understanding of the natural range of variability of the terrestrial marine linkage suggests that marine-derived nutrients are essential for restoring and conserving now degraded coastal grasslands.

O-3179

## A new paleoecological indicator for reconstructing insect outbreaks in forest ecosystems

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### Abstract

Natural disturbance is one of the major topics in forest ecology. However, most paleoecological studies have only considered the influence of wildfire as an agent of disturbance, with fire history based primarily on the use of charcoal as a proxy for fire events. The frequency and intensity of insect outbreaks and their effect on the forest landscape have been neglected due to the absence of an effective proxy tool. Finding indicators able to provide insight into the impacts of past insect outbreaks is therefore essential due to the economic and ecological implications under climate change scenarios, where there is a projected change in the occurrence and severity of natural disturbances in forest ecosystems. Fossil moth (Lepidoptera) scales offer a new approach for interpreting past insect-related disturbances and assessing the interactions between climate, fire and insect outbreaks. Paleoindicators must respond to three main criteria: (1) be in high abundance, (2) allow for easy identification and (3) remain well-preserved in sediment records. We demonstrate that Lepidoptera scales are abundant in the boreal forest during insect outbreak periods. We also show that due to their chitin composition, these scales remain well-preserved throughout a 10,000-year sediment record. Furthermore, they are relatively easy to identify after being recovered from lake sediments. We will show the current research to develop the potential of this paleoindicator as well as our innovating results.

At a multi-millennial scale, various disturbances shape boreal forest stand mosaics and the distribution of species. Here, we combine macrocharcoal and plant macrofossils with our new proxy—lepidopteran scales—to describe the Holocene ecology around a boreal lake. Lepidopteran scales turned out to be a more robust proxy of insect outbreaks than the traditional proxies such as cephalic head capsules and feces. We identified 87 significant peaks in scale abundance over the last 10 000 years. These results indicate that SBW outbreaks were more frequent over the Holocene than suggested by previous studies. Charcoal accumulation rates match the established fire history in eastern Canada: a more fire-prone early and late Holocene and reduced fire frequency during the mid-Holocene. Although on occasion, both fire and insect outbreaks were coeval, our results show a generally inverse relationship between fire frequency and insect outbreaks over the Holocene.

Therefore, we introduce the needs, potential and applications of this paleoindicator in forest ecology, and the main directions for the future research. This new approach offers an important scientific advance in ecology through a much improved, higher resolution reconstruction of a major natural disturbance: insect outbreaks.

O-3180

## A multi-proxy approach to advance our understanding of niches in fossil mammals

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### Abstract

With the prospect of climate change, conservation biologists are challenged with predicting future impacts on populations and communities of species. The fossil record provides an opportunity to study the broad array of responses to climate change in the past – conservation paleobiology seeks to apply this knowledge to inform modern conservation. Our focus is on the multidimensional nature of the ecological niche of mammals. Species have the ability to adjust ranges to remain within physiological tolerance limits within their abiotic environment, or they may adapt to changing environments. Biotic interactions also constrain the geographic ranges of species, with changing interspecific interactions additionally impacting where species are found. Here, we investigate the combined effects of abiotic factors (climate) and biotic factors (diet) on the distribution of fossil mammals, with a focus on the Quaternary. We ask if species changed diets in response to climate change in the past, and if our ability to predict the range shifts in response to climate change can be improved by including aspects of the dietary niche.

Our research program unites three separate tools that have been invaluable in understanding various aspects of both modern and ancient ecological systems: stable isotope analysis (SIA), dental microwear texture analysis (DMTA), and species distribution modeling (SDM). Individually, SDM, SIA, and DMTA are powerful tools for understanding the impacts of climate and the environment on species. SDM describes the suitable environment for a species. At the individual level, SIA and DMTA describe what resources are being used, and at population and community levels they are a tool that can describe how resources are partitioned. Integrating these techniques and applying them to the fossil record may help us gain a deeper understanding of species responses to changes in their environment.

We present a framework for integrating SDM, SIA, and DMTA, with examples from the fossil record. We explore how dietary specialization and individualism may impact niche conservatism and the ability for species to respond to climate change. A broad survey of SIA analyses finds that species tend to be fairly consistent in their dietary strategies over time. However, across strategies, individuals tend to be specialized, even within species that are considered to have broad, or mixed, diets. Species level constraints and individual specialization have implications for predictive SDM, and we present examples using the maximum entropy method.

**O-3181**

## **Niche evolution and resource competition: herbivore stable isotopes reveal changing species interactions during the Late Pleistocene**

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### **Abstract**

The megafaunal extinctions that characterise the Late Pleistocene and Early Holocene periods are one of the most prominent ecological events to have occurred during the Quaternary. The pattern of extinction and survival of large and medium bodied herbivores varies between different geographical locations. The drivers behind these changes, which affected both species composition and diversity, have been extensively debated. One promising avenue of research is to look at the interaction between the different species in different environments. Stable isotope analysis ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ,  $\delta^{34}\text{S}$ ) of the fossil record offers one such tool to do this; by providing a dietary proxy, ecological niches can be explored. Preliminary data hints at dietary shifts as a prelude to extinctions in some species, in some environmental contexts. In other contexts, no such changes are observed. Such dietary shifts have implications for understand changing patterns of interaction between different species, and possibly changing resource competition dynamics. In this paper we discuss these initial findings from Eurasian and North America contexts and discuss possible interpretations.

O-3182

## Modeling mammals food webs in the Orce sites: Quantitative reconstruction of prey-predator relationships for the first humans of Western Europe

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### Abstract

Many researchers consider that meat was a relevant trophic resource for the first hominin populations that dispersed in Europe during Early Pleistocene times. Moreover, meat availability could have conditioned human presence if we take into account the intensity of competition with other carnivores for the access to these resources. From this point of view, it is very interesting to test past ecosystems which have fossil records before and after human presence. The Early Pleistocene sites of Orce (Baza Basin, SE Spain) offer a unique opportunity to analyze the food webs of the mammalian paleocommunities in these conditions. With an age of 1.6-1.5 Ma and absence of evidence on human presence, the Venta Micena site provides the scenery before the initial peopling. In contrast, Barranco León and Fuente Nueva-3, dated at around 1.4 Ma, preserve evidence of human presence at the Baza Basin. The latter sites have provided huge large mammals assemblages with an excellent state of preservation, which has allowed carrying out a number of taphonomic, geochemical isotopic and paleoecological analyses. This has allowed contextualizing the environmental context of the first human settlements in Western Europe. For this reason, it is very interesting to reconstruct the Orce food webs for estimating how meat availability could have influenced their structure. In this study, we have applied a mathematical approach based on Leslie matrices to quantify the biomass of large mammals available to the guild of secondary consumers, including humans in Barranco León and Fuente Nueva-3, in order to analyze the pattern of meat distribution and intraguild competition. The model determines: (1) the age structures that would make stable the population of each primary consumer; (2) the distributions of individuals among body mass categories; and (3) the average biomasses that could be extracted in the long term from these populations. Finally, it distributes the ungulate meat among the secondary consumers and estimates the sustainable densities of each carnivore species. The results for Orce allowed reconstructing the food webs of the sites, which showed that meat was not the main limiting factor to hominin presence in Western Europe before 1.4 Ma.

O-3183

## Westerly wind variability at sub-Antarctic Macquarie Island: links to the Southern Annular Mode and Southern Hemisphere rainfall and temperature

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### Abstract

The position and strength of the Southern Hemisphere westerly winds is important for temperature and rainfall variability from the mid- to high-latitudes of the Southern Hemisphere. They also influence Southern Ocean circulation and sea ice extent around Antarctica and are closely linked to changes in the Southern Annular Mode (SAM). While observations available since the 1950s show the winds have strengthened and shifted southwards, this period is too short to understand their natural variability, especially as stratospheric ozone depletion and rising greenhouse gases from anthropogenic activities are considered to be driving these changes. Sub-Antarctic islands, such as Macquarie Island (54°S, 158°E), are ideally situated to reconstruct changes in the westerly winds as they lie within the latitudes where the winds are strongest. Here, we reconstruct changes in westerly wind strength of the last ca. 1800 years using lake sediment records from Macquarie Island. The reconstruction involves the application of a diatom-sea spray inference model (transfer function) supported by geochemical, minerogenic and sedimentological analyses. The inference model was used to assess changes in sea spray inputs to a small, exposed lake on the western edge of the Macquarie Island plateau, where the amount of sea spray is directly related to the strength of the westerlies. The reconstruction shows close agreement with the southern South America temperature (Past Global Changes) and SAM reconstructions for much of the last millennium, with the main feature being a decrease in wind strength ca. AD 1450 that coincides with a decrease in temperature at many sites around the Southern Hemisphere and transition to a more negative SAM phase. The combination of a modern climatological framework for understanding Macquarie Island's current climate together with modelling and palaeoclimatological reconstructions of the westerlies, demonstrates that changes recorded at Macquarie Island are representative of wind, rainfall and temperature across the mid- to high-latitudes of the Southern Hemisphere.

O-3184

## Holocene sediment records from World Heritage-listed K'gari/Fraser Island lakes (subtropical eastern Australia) highlight their sensitivity to drying

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### Abstract

Lakes are some of the most biodiverse, yet vulnerable, ecosystems on the planet. In Australia, the driest inhabited continent on earth, permanent lakes are relatively rare. By contrast, K'gari or Fraser Island, the largest sand island in the world, has a large number of permanent lakes and represents one of the few lake districts on the continent. The lakes of K'gari/Fraser island are remarkable because many are perched above the regional water table where an impermeable layer separates them from the sand below. They are one of the reasons why the island is listed as a UNESCO World Heritage site.

Holocene sediment sequences have now been analysed from at least six lakes on K'gari/Fraser Island. It appears that there was marked aridity on the island from c. 8000 to 5000 ka BP. Some lakes dried completely at a time previously thought to be characterised by humid climates in the Australian subtropics. Interestingly, in some sequences there is little to no physical evidence of drying which is recorded as a hiatus in the accumulation of highly organic, acidic, lake sediments.

The mid-Holocene dry phase recorded on K'gari/Fraser Island contrasts with evidence from North Stradbroke Island, a similar sand island which also has perched lakes, approximately 150 km to the south. As a result, there is strong potential to infer the Holocene regional climatology of the Australian subtropics at small spatial scales from these records.

Lastly, our study highlights a largely unrecognised vulnerability of lakes on K'gari to drying and indicates a need to better understand their hydrology and response to projected future climate change.

O-3185

## Antarctic ice sheet surface mass balance over the last millennium: a comparison between climate models and ice-core reconstructions

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### Abstract

Improving our knowledge of the spatial and temporal variability of the Antarctic Ice Sheet (AIS) Surface Mass Balance (SMB) is crucial to reduce the uncertainties of past, present and future Antarctic ice sheet contribution to sea level rise. Here, we show that the Global Climate Models (GCMs) simulate relatively well the current AIS SMB, but also the temporal variations over the last two centuries, including the large positive SMB trend since around 1960 AD as shown in ice cores data. The climate models suggest a strong regional positive correlations between AIS surface temperature and SMB, which is not evident in the reconstructions. Additionally, this correlation is stronger than that between delta O 18 and surface temperature at regional scale, which suggests that SMB can be used to reconstruct surface temperatures. When constraining the isotope-enabled model results with SMB and delta O 18 observed in the ice cores through a data assimilation procedure, the resulting surface temperature reconstruction outperforms the reconstruction based on the statistical method from PAGES2k, which is based on only delta O 18 (Stenni et al. 2017). Indeed, the correlation between the observed surface temperatures (1958--2010 CE) and our reconstruction is 0.73 against 0.57 for the statistical reconstruction. This is particularly true for the East Antarctica, where the observational uncertainties are large. This confirms that the use of other proxies and not only the delta O 18 allows improving the reconstruction, but also the relevance of data assimilation which allows to consider different proxies. Finally, we present an AIS SMB reconstruction over the last two centuries showing 1) large variability in SMB trends at regional scale; 2) large SMB increase (0.82 Gt year<sup>-2</sup>) in West Antarctica over the last decades, which is consistent with the recent reconstruction of Medley et Thomas (2018).

O-3186

## Long-term demise of Subantarctic glaciers modulated by meridional shifts in the Southern Hemisphere Westerlies

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### Abstract

*The recent accelerated loss of land ice and ice-shelves on the Antarctic Peninsula demonstrates a high sensitivity with respect to regional and large-scale climate drivers. To place the recent observed changes in the context of past natural shifts, it is paramount to reconstruct and reproduce past long-term glacier variability in the subantarctic zone and establish linkages to potential climate drivers. Here, we present a new high-resolution reconstruction of the extent of three cirque- and tidewater glaciers on South Georgia (SG, 54°S, 36°W). The reconstructions, which cover the past 14 000 years, combine lake multi-proxy lake sediment analyses with cosmogenic nuclide exposure dating. The analysis documents a dynamical behavior with glaciers on South Georgia shrinking since the Antarctic Cold Reversal (ACR, 14.5-12.8 Ka) and throughout the Holocene, in phase with glaciers on the Antarctic Peninsula and in part with Patagonia. Post ACR Equilibrium-Line-Altitude (ELA) variations correspond to a gradual warming of 1-1.5 °C, in accordance with recent ice core reconstructions. We hypothesize that orbital forcing and recent CO<sub>2</sub> changes and ozone depletion have caused an intensification of the Southern Annular Mode (SAM) which contributed to summer warming, the retreat of the subantarctic glaciers during the Holocene, and to the recent complete disappearance of Hodges Glacier on South Georgia, respectively.*

O-3187

## Non-linear ice sheet behaviour in the Ross Sea driven by oceanic variability during the Holocene

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### Abstract

Many outlets of the Antarctic ice sheet are experiencing terminus retreat, dynamic thinning and mass loss. This ice loss is predicted to accelerate for several regions of Antarctica in response to oceanic warming. Crucially, the observational record is short, restricting our ability to understand complex and non-linear responses. Longer-term records are therefore required to better understand patterns, mechanisms and drivers of ice sheet retreat, and to distinguish trends from decadal-scale variability.

We investigated the Holocene history of outlet glaciers in the western Ross Sea. Today, this region has the coldest continental shelf waters and so these marine-terminating outlets should be relatively insensitive to changes in ocean temperature. New cosmogenic-nuclide (<sup>10</sup>Be) surface-exposure data from Mawson Glacier, collected in elevation transects above the modern ice surface, reveal that rapid thinning occurred at ~6–8 ka. This is broadly coeval with new ages of grounding-line retreat at ~6 ka, as well as rapid surface lowering recorded at nearby Mackay Glacier at ~7 ka. Our data also show that a moraine formed near to the modern ice margin of Mawson Glacier at ~0.8 ka, which, together with other ice elevation data, indicates that glacier terminus positions likely oscillated during the Late Holocene. We then used time-dependent ice-flow modelling to evaluate the mechanisms of outlet glacier change in this region. We find that 1) the accelerated thinning of outlet glaciers resulted from local grounding-line retreat through overdeepened basins irrespective of the forcing applied, 2) the glaciers were unaffected by increased accumulation and/or glacial isostatic adjustment, and 3) ocean temperature variability during the Holocene can best explain the recorded outlet glacier history.

Our work demonstrates that non-linear ice sheet retreat was typical of Antarctica's marine-based margins during the last deglaciation, and that glaciers in the western Ross Sea were closely coupled to oceanic and topography-induced perturbations near their termini throughout the Holocene.

O-3188

## Reconstruction of precipitation changes over the last 800 years in NE Patagonia: the varved Lake Jeinimeni record (46.5°S, Chile)

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### Abstract

For the last decades, paleoclimate studies in Patagonia have emphasized a high Holocene variability, strongly controlled by the intensity and latitudinal position of the Southern Westerly Wind (SWW). In this study we analyze the sedimentological and geochemical record of Lake Jeinimeni to document environmental and climate variability over the last centuries in North East Patagonia. At Present the lake setting is characterized by cold and steppic conditions with less than 300 mm by year of precipitation, mainly as snow. The core LJe14B (46°50'S, 72°00'W, 161 cm) was drilled in 2014 with an UWITEC gravity corer at a water depth of 60 m. The sediment is purely terrigenous with a low organic matter content (mean 2.5%) of allochthonous origin (mean C/N 16.7). Visual description, scopix radiographies and thin section observation evidence that the sediment is finely laminated, made by light brown clayey silts and fine sands with 17 centimetric coarser layers and 2 glass shard-rich tephras. <sup>210</sup>Pb and <sup>137</sup>Cs data demonstrate that the upper 17 cm of the core covers the last century with an average sedimentation rate of 1.3 mm/yr. The 2 tephras are consistent with recent eruptions of the Hudson volcano in 1991 and 1972AD, respectively. All chronometers are consistent with the annual deposition of the background fine sediment. A total of 766±60 varves are counted within 150 cm of sediment, the bottom part of the core being not investigated since scopix radiographies do not evidence any laminations. The 17 massive coarse layers were considered as one event and were therefore removed from the age model. A multivariate statistical analysis done on the core scanner XRF data allows to decipher 3 groups of samples. The first group, close to Principal Component (PC)1 axis, corresponds to argillaceous Al-rich layers. The second is distributed along PC2 axis and co-varies with Zr and Rb. It coincides with the plurimillimetric sandy-layers observed in the core and probably represents flood-like events related to snow melting. The third group of samples is made by the pluricentimetric sandy and gravely layers that interrupt the background fine sedimentation. They correspond to massive erosional events due to watershed perturbation. The evolution of PC1/PC2 ratio probably record flood-like events, bringing to the lake variable detrital supplies according to the precipitation rate. Our study site, the Lake Jeinimeni, allows to document environmental and climate variability in Patagonia over the last centuries. By combining sedimentological and geochemical proxies, the varved lacustrine sequence reveals recurrent coarse detrital supplies attributed to floods. The time-series record will be compared with regional paleoclimate reconstructions derived from Patagonian archives to decipher between local and regional climate influences. This research is funded by WBI-Chile cooperation project and Fondecyt 1120765.

O-3189

## A 14,200 year sea-surface temperature reconstruction from the western Indian sector of the Southern Ocean

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### Abstract

The temperature of the Southern Ocean is dependent on factors including the temperature of the atmosphere and upwelling water, shifts in the position of the Antarctic Circumpolar Current and the southern westerly winds, and the amount of heat transported northwards by the Atlantic Meridional Overturning Circulation (AMOC). Over recent decades, a slowdown of the AMOC has led to heat accumulating in the subsurface of the Southern Ocean, while surface waters poleward of 50°S have cooled, particularly in the Pacific sector (Armour et al., 2016; Jones et al., 2016). Given the scarcity and short length of Southern Ocean temperature records (Jones et al., 2016) palaeoclimate reconstructions can be used to investigate if the observed patterns are outside the range of natural variability and how temperature has varied in response to past changes in the climate system.

We present a diatom-based sea-surface temperature reconstruction from core KH-10-7 COR1GC, sampled from the western Indian sector of the Southern Ocean (54°16.04'S, 39°45.98'W), which was produced using the Modern Analogue Technique. The record spans from 14.2 to 1.0 ka BP (calibrated kiloyears before present) and has an average resolution of 60 years, allowing an improved understanding of the millennial-centennial variability since the deglacial. The record shows that temperatures varied in parallel with atmospheric temperatures over Antarctica, supporting synchronous changes in ocean and atmospheric temperatures across the southern high latitudes. Temperatures were low during the Antarctic Cold Reversal and gradually increased during the Younger Dryas (13-11.8 ka BP) to reach higher and stable values during the early Holocene (11.8-8.7 ka BP). Subsequently, cooler and variable conditions prevailed. The results support that during the Younger Dryas a slowdown in the AMOC along with rising atmospheric CO<sub>2</sub> levels caused the inferred warming of the Southern Ocean. A cool interval at 8.2 ka BP may be a southern hemisphere response to the '8.2 event' seen in records primarily in the northern hemisphere.

O-3190

## An overview of the IntCal19 radiocarbon calibration curve

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### Abstract

The IntCal19 radiocarbon calibration curve has been constructed from carefully screened <sup>14</sup>C and calendar age data using a newly developed Bayesian framework. New data include <sup>14</sup>C measurements of the U-Th dated Hulu cave speleothem back to 54ka cal BP, late glacial tree-rings from New Zealand and Europe, and thousands of decadal and single year tree-rings from around the world. It also includes the extension and revision of the Lake Suigetsu varve counts. In addition, floating series of glacial age tree-rings have been wiggle-matched to the <sup>14</sup>C calibration data. A GCM ocean model has been used to estimate marine reservoir age changes over time. The new curve compares well to other independently dated records such as wood buried by the Campanian Ignimbrite. IntCal19 provides more robust atmospheric <sup>14</sup>C values and uncertainties than IntCal13 particularly for calendar ages older than 12ka cal BP.

O-3191

## Statistical methodology for the IntCal19 radiocarbon calibration curves: bespoke Bayesian splines with errors-in-variables

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### Abstract

A high-quality radiocarbon calibration curve requires not only precise and accurate calibration data but also a rigorous and reliable statistical approach to create the calibration curve and uncertainty bands. The available calibration data have several unique features that we need to both recognise and incorporate in the curve development. These include features such as:

- the radiocarbon measurements may relate to single-year tree-rings or annual sediment layers while others represent 5-20 years;
- for older time periods, the calendar ages of our calibration data are estimates with associated uncertainties (e.g. U/Th dating, varve counting, or climate tie-pointing to otherwise dated archives);
- calendar ages may even be unknown (e.g. a floating series of tree-ring <sup>14</sup>C measurements);
- offsets may exist between sets of radiocarbon measurements in different materials, due to reservoir ages or dead carbon fractions which may also be unknown.

If we ignore these aspects of the data then the final curve would be neither robust nor accurate and would underestimate the variability. However, at the same time we also wish to have a method that is neither so complex nor slow to run that it does not allow us to investigate the robustness of the curve to individual data points, data sets or modelling assumptions.

In this talk we present the new methodology used for the creation of the IntCal19 calibration curves. Our approach aims to address all the features described above while also enabling us to investigate the sensitivity of the curve to changing assumptions. The curve itself is estimated using Bayesian regression splines with the addition of bespoke modelling to incorporate the uncertain calendar ages, blocking and offsets. Curve creation is performed within an MCMC sampler using parallel tempering to improve mixing.

O-3192

## The evolution of past marine radiocarbon reservoir ages according to simulations

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### Abstract

Marine radiocarbon records are important constituents when reconstructing the atmospheric radiocarbon history prior to the continuous tree-ring period. However, marine radiocarbon records are frequently fragmentary in space and time, and their reservoir age (i.e., their isotopic depletion compared to the atmosphere expressed as radiocarbon age) is only weakly constrained through observations. Ocean radiocarbon cycle circulation models can provide a valuable tool to assess the evolution of past reservoir ages. Here, we present results of reservoir age simulations contributing to the construction of the most recent radiocarbon calibration curve, IntCal19, applying the LSG ocean general model forced with various climatic background conditions and with atmospheric radiocarbon changes according to the Hulu Cave speleothem record. We discuss the spatiotemporal evolution of reservoir ages during the past 54000 years. As an update of previous work (Butzin et al., 2017, doi:10.1002/2017GL074688), we find reservoir ages varying between 500 and 1400 <sup>14</sup>C years in the low- and mid latitudes and reservoir ages exceeding 3000 <sup>14</sup>C years in the polar oceans. Our results are broadly in line with available marine radiocarbon reconstructions, with the caveat that these records typically originate from continental margins, marginal seas, or tropical lagoons which are not properly resolved by our model. This problem will be overcome by the next generation of radiocarbon-equipped ocean circulation models featuring global multiresolution meshes.

O-3193

## Reanalysis of the atmospheric radiocarbon record from Lake Suigetsu for radiocarbon calibration

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### Abstract

Terrestrial plant macrofossils from the lake sediment record of Lake Suigetsu, Japan, taken in 2006 (SG06) provide the only quasi-continuous direct atmospheric record of radiocarbon covering the last 50 ka cal BP (Bronk Ramsey et al. 2012). New high precision data are now available on U-Th dated speleothems covering the same time range (Cheng et al. 2018). In addition a new varve-based chronology has also been published for SG06 based on extended microscopic analysis of the sediments and improved algorithms for interpolation (Scholaut et al. 2018). Here we reanalyse the radiocarbon dataset from Suigetsu based on the new varve counting information and the constraints imposed by the speleothem data so that the Suigetsu dataset can be used to help in the construction of the next IntCal calibration curve. Comparison of the speleothem and plant macrofossil records provides insight into the mechanisms underlying the incorporation of carbon into different types of record and the relative strengths of different types of archive for calibration purposes.

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O-3194

## Trees on ice: Anchoring floating tree-ring chronologies on ice core timescales to improve radiocarbon dating calibration

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### Abstract

The radiocarbon calibration curve, IntCal, is a key dating tool in paleosciences. It provides a chronological framework for a wide range of disciplines studying environmental and cultural changes during the past 50,000 years which is crucial for our understanding of their dynamics. Tree-rings directly record atmospheric  $^{14}\text{C}$  at their time of growth and can be absolutely dated via dendrochronology making them ideal archives to build a calibration curve. However, these high quality records are only continuously available back to  $\sim 14,000$  years before present. Prior to this, IntCal relies on  $^{14}\text{C}$  data from archives that do not provide the same quality in terms of timescale and (in the case of marine and speleothem records) do not directly reflect atmospheric  $^{14}\text{C}$ . However, occasionally trees beyond the current continuous record are being discovered and these “floating” tree-ring records can provide snapshots of past atmospheric  $^{14}\text{C}$  variability. The challenge lies in establishing their absolute chronology.

Ice cores have become invaluable tools for linking “floating” tree-ring chronologies to an absolute timescale.  $^{10}\text{Be}$ , a cosmogenic radionuclide produced in a similar way as  $^{14}\text{C}$ , is stored in the ice and provides a unique comparison record. Pattern-matching of floating  $^{14}\text{C}$  records to ice core  $^{10}\text{Be}$  can thus guide us in establishing a timescale for the tree-ring records, characterize past atmospheric  $^{14}\text{C}$  variability and test and improve the radiocarbon dating calibration curve.

We will show examples of how ice core  $^{10}\text{Be}$  records can be used to link floating tree-ring chronologies to an absolute timescale over the entire range of the radiocarbon dating method, and discuss the implications for the radiocarbon dating calibration curve.

O-3195

## Tree-ring $^{14}\text{C}$ data across the ITCZ over South America and Central Africa: filling the gaps in atmospheric post-AD1950 $^{14}\text{C}$ curves

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### Abstract

Radiocarbon ( $^{14}\text{C}$ ) dating allows us to better understand the human past and the carbon cycle. The technique's success relies on very precise measurements of  $^{14}\text{C}$  activity in carbonaceous material remains. Independently-dated biological materials that exhibit annual layers, such as tree rings, are necessary for a precise reconstruction of the atmospheric  $^{14}\text{C}$ , as radiocarbon ages do not represent exact calendar dates. Ongoing efforts to optimize the  $^{14}\text{C}$  timescale have produced calibration curves back to 50 kyrs BP. Nevertheless, several gaps still remain. While it is well established that during the Holocene atmospheric  $^{14}\text{C}$  signatures have varied between the Northern Hemisphere (NH) and Southern Hemisphere (SH) through the inter-hemispheric offset, there is still little data to better define intra-hemispheric offsets for the last 70 years. The intra-hemispheric offsets define the  $^{14}\text{C}$  geographical division known as zones NH1, NH2, and NH3 for Northern Hemisphere, and SH1-2 and SH3 for Southern Hemisphere. Currently, the  $^{14}\text{C}$  geographical divisions, zones SH1-2 and SH3, are basically defined using data from eastern SH sites (New Zealand, Australia, and Indonesia). Consequently, the  $^{14}\text{C}$  boundary between zones SH1-2, SH3, and NH3 over South America and Africa at lower latitudes are defined based on the mean position of the Inter Tropical Convergence Zone (ITCZ). To overcome a dearth of suitable  $^{14}\text{C}$  records at lower-latitudes, we selected six tree species across the Amazon basin and Central Africa (i.e., Ecuador, Peru, Bolivia, Brazil and Cameroon). The main goal of this project is to extend the observational record by developing annually-resolved atmospheric post-AD1950  $^{14}\text{C}$  data using cellulose material from dendrochronologically-dated tree rings across the ITCZ mixed band. These newly developed datasets will be used to model observed  $^{14}\text{C}$  gradients of each species/site for backtracking air-mass parcels to better constrain the new global atmospheric  $^{14}\text{CO}_2$  global distribution map. Additionally, we will develop isotopic synoptic maps based on both  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  tree-ring series to examine spatial and temporal patterns of carbon cycle changes that can influence  $^{14}\text{C}$  spatial distributions. The project showcase will be discussed and preliminary results will be presented.

O-3196

## Testing and improving the $^{14}\text{C}$ calibration curve with independent records

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### Abstract

Connecting calendar ages to  $^{14}\text{C}$  ages (i.e. constructing a calibration curve) is mainly based on  $^{14}\text{C}$  samples that can also be dated via independent methods. However, comparison of  $^{14}\text{C}$  data to other records such as cosmogenic radionuclide data from ice cores can provide tests of the quality of the  $^{14}\text{C}$  data and its calendar age determinations. Here we will discuss how such additional information can aid the identification of uncertainties in  $^{14}\text{C}$  records and the improvement of the calibration curve.

The direct incorporation of such information into the calibration curve is challenging as it delivers only partial information (e.g. the placement of a floating tree ring sequence within a section of non tree ring data) possibly leading to an inhomogeneous calibration record. We will discuss how this issue will be addressed in the upcoming IntCal update. Furthermore, we will investigate how floating tree ring sequences on ice core time scales agree with the new  $^{14}\text{C}$  data from measurements on U/Th-dated speleothems from Hulu cave in China and discuss unresolved differences that are possibly related to our limited understanding of carbon cycle influences on the atmospheric  $^{14}\text{C}$  concentration during the last glacial period.

O-3197

## The glacial history of NW Greenland during the last 50,000 years

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### Abstract

Knowledge about the glacial history of the Greenland Ice Sheet and its dynamic response to past climate variability is important to put the current changes into context. However, there are areas in Greenland where only little knowledge about past ice marginal fluctuations are available. One of these areas is NW Greenland, an area where ice sheet models show deglaciation sometime during Early Holocene, but limited field studies have been carried out.

In this study we aim at illuminating the glacial history of NW Greenland, combining results from three study areas; Melville Bay, the Qaanaaq area and Inglefield Land. We use <sup>10</sup>Be and in-situ <sup>14</sup>C exposure dating of boulders on moraines and bedrock as well as radiocarbon dating of reworked marine molluscs and subfossil plants.

Radiocarbon ages of reworked marine molluscs and subfossil plants show a smaller than present day ice extent during MIS3 between 42.2 to 30.6 cal ka BP as well as during late Holocene from 3.7 cal ka BP until 1.0 cal ka BP being in accordance with other findings from northwest and northeast Greenland (Farnsworth et al. 2018; Larsen et al. 2018).

<sup>10</sup>Be ages of boulders on moraines and bedrock show a large scatter of ages from 11 ka in Melville Bay to 93 ka in Inglefield Land, yielding low erosion rates and <sup>10</sup>Be from previous exposures in several of the samples. Thus, in-situ <sup>14</sup>C measurements will be carried out in order to constrain the glacial history in areas affected by inheritance. The trend so far points towards the areas away from fast flowing ice being the most affected showing the importance of ice bed properties when using a method as exposure dating.

Overall, preliminary results from our three study areas show a dynamic glacial history but also highlights difficulties when using a method as exposure dating in NW Greenland, possibly due to a cold based less erosive ice. With the new age constraints, we expect to gain further knowledge about the overall glacial history of NW Greenland, one of the least explored parts of Greenland. We will discuss the new age constraints in relation to existing climate records as well as already published glaciation ages from NW Greenland.

O-3198

## Disintegration of a local ice cap: patterns of ice recession during the Last Glacial-Interglacial Transition in the Wicklow Mountains, Ireland

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### Abstract

We present a geomorphological assessment of the extent and dynamics of glaciation in the Wicklow Mountains, Ireland, during the Last Glacial Interglacial Transition (LGIT; ~ 20 – 11 ka BP). Until now, work in the area has focused upon a local ice cap which was confluent with regional ice at the Last Glacial Maximum (LGM; ~ 25 ka BP), but little information exists on subsequent ice retreat in response to climate amelioration during the LGIT. Our contribution investigates ice dynamics during and after the transition from an ice cap to topographically restricted mountain glaciation. We identify that initial ice cap recession was characterised by rapid retreat and large-scale disintegration. The geomorphological record indicates that ice masses only stabilised once they were topographically constrained within valleys. We also recognise the establishment of three distinct landsystems in the Wicklow Mountains following the fragmentation of the LGM ice cap: (1) the large north-eastern sector of the region hosted a mountain icefield with multiple outlet glaciers; (2) a small plateau icefield existed in the central sector, with several outlet glaciers; and (3) several individual valley glaciers persisted in the south-western sector. Each of these landsystems record sustained retreat and subsequent stabilisation during the LGIT, prior to the Younger Dryas. Two-dimensional reconstructions of ice dynamics indicate variations in recession patterns throughout the region. Based on our ice margin reconstructions and the limited published dates for the region, we suggest that following the retreat of regional ice after the LGM, the local ice cap was relatively stable until the start of the LGIT (~20 ka BP). Following this, ice experienced sustained thinning and ice margin retreat until ~ 17 ka BP. By this point, ice was topographically restricted and the three aforementioned landsystems were established. A period of ice margin stabilisation occurred before further persistent retreat until ~ 15 ka BP, by which ice had retreated into the upper reaches of valleys. It is likely that the plateau icefield and most of the mountain icefield had disappeared by ~15 ka BP, when the outlet glaciers of both landsystems had detached from their central accumulation areas and experienced sustained retreat. Following this, some small cirque glaciers experienced minor readvance before ice recession continued. The geomorphological record indicates that limited cirque glaciation was re-established during the Younger Dryas.

O-3199

## Glacial Lake Agassiz varves document Laurentide Ice Sheet retreat during the Younger Dryas and rapid formation of an end moraine

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### Abstract

Numerous efforts to understand glacier response to abrupt climatic events naturally focus on moraines. An often employed assumption is that moraines formed at stationary glacier configurations, but for a more comprehensive understanding we need continuous and high-resolution records of retreat, re-advances, and standstills, which glacial varves uniquely provide. The reliability of varves as chronometers hinges on cross correlating many sites and independent age control.

We present such a varve record from glacial Lake Agassiz that is both reproducible across multiple sites and independently dated. This 1200 varve-year time series documents Laurentide Ice Sheet (LIS) margin retreat during the late Younger Dryas (YD) at around 23 m/yr. In addition, the varves span a prominent end moraine (the Hartman), which is typical for those on the Canadian Shield, being composed of sand and gravel and deposited by sub-aqueous discharge along the ice margin. The Hartman moraine was created during general ice retreat and formed within a time window of less than 200 years. A 45-year period of thicker varves within this period is our favored interpretation for the duration of moraine building. The moraine dates to the YD/Holocene transition (ca. 11,600 cal yr BP). This varve time series begins 7-km north of an older moraine, the Eagle-Finlayson, but our record does not yet span this older moraine, so its timing and period of formation remain poorly constrained.

This Lake Agassiz varve record is similar to that from the Baltic Ice Lake in southern Finland, which documents steady ice retreat north from the Salpausselkä I moraine and formation of the Salpausselkä II moraine near the end of the Younger Dryas. Similar to the Eagle-Finlayson and Hartman moraines, the Salpausselkä I and II moraines are ice-marginal, sub-aqueous deposits of sand and gravel. Cooler temperatures during the latter half of the YD stadial were not enough to stop ice retreat along the LIS bordered by Lake Agassiz, nor the FIS ice margin bordered by the Baltic Ice Lake. The similar timing and mode of formation between the moraines in Lake Agassiz and the Baltic Ice Lake suggests that they may have similar climatic forcing mechanisms. Our ability to test potential teleconnections between the LIS, FIS, and ice core records during the late glacial, particularly as they relate to abrupt climate change, would be greatly improved by developing additional well-dated and cross-correlated varve thickness data sets from North America.

O-3200

## A spatially-restricted Younger Dryas plateau icefield in the Gaick, Scotland

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### Abstract

Producing three-dimensional palaeoglaciological reconstructions of discrete ice masses has been the focus of many glacial geomorphological studies in the Scottish Highlands over the past 15 years or so. Despite this, understanding of the extent, style and timing of Quaternary glacier fluctuations in Scotland remains incomplete. This is exemplified by the enigmatic and contentious Gaick (or Gaick Plateau), a dissected upland plateau in the Central Grampians. Previous studies of the glacial sediment-landform assemblages in this area have resulted in widely-differing and conflicting interpretations, although the 'generally-accepted' model is one of extensive plateau icefield glaciation during the Younger Dryas (~12.9–11.7 ka). We present the results of renewed, systematic geomorphological and sedimentological investigations in the Gaick. Using a glacial landsystems approach, morphostratigraphic principles and 'glacierisation threshold' analysis, we establish that the area experienced only spatially-restricted plateau icefield glaciation during the Younger Dryas. Our glacierisation threshold analysis shows that topographic variations from west to east across the area, combined with a steep projected increase in the regional equilibrium line altitude (and a concomitant decrease in precipitation), would have precluded the development of an icefield across the whole area. Our revised interpretation contrasts starkly with the widely-held view that the Gaick was covered by an extensive plateau icefield during the Younger Dryas. We use the geomorphological evidence, together with surface profile modelling, to produce a three-dimensional reconstruction of a ~42 km<sup>2</sup> Younger Dryas plateau icefield. This newly-reconstructed icefield is then used to derive palaeoclimatic variables for the Younger Dryas and assess regional climate trends across Scotland during that period.

O-3201

## The dynamic response of debris-covered Himalayan glaciers to Late Holocene climate change

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### Abstract

Glaciers in the monsoon-influenced central Himalaya last advanced during the regional Little Ice Age around 500 years before the present day. The dynamic behaviour of many of these large mountain glaciers during and after this period was strongly influenced by the accumulation of supraglacial rock debris supplied from rapidly eroding hillslopes. Rapid debris export during late Holocene advances created topographic barriers to further glacier expansion, causing debris-rich glaciers to expand vertically rather than horizontally. Supraglacial debris accumulation during the subsequent period of negative mass balance caused extensive glacier tongues to be preserved at lower elevations than would be possible for clean-ice glaciers, as in regions with active tectonics such as the Himalaya, debris layers are commonly thicker than a few centimeters and substantially reduce ablation by insulating the glacier surface from the atmosphere and incoming solar radiation.

Understanding the response of these large mountain glaciers to climatic change therefore requires quantifying the feedbacks between ice flow, debris transport and mass balance. We used higher-order numerical modelling of ice flow and debris transport to unravel the behaviour of the world's highest glacier, Khumbu Glacier in Nepal, during the Late Holocene and through the present day, to investigate how supraglacial debris influences the response of Himalayan glaciers to climatic change and to predict their future evolution. Numerical modelling was evaluated against observations of past glacier geometries from moraine positions, remotely sensed data spanning the last 50 years, and present day mass balance and dynamics from field monitoring as part of the EverDrill high-elevation debris-covered glacier drilling project. Results from this numerical modelling predict glacier mass loss of only 10% by 2100 CE and illustrate the differing behaviour of debris-covered glaciers compared to clean-ice glaciers.

O-3202

## **A decade of glacier and landscape change: high resolution monitoring at the British Geological Survey Glacier Observatory, Virkisjökull-Falljökull, SE Iceland**

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### **Abstract**

The BGS Observatory at Virkisjökull-Falljökull has carried out continuous survey and monitoring since 2009, in order to characterise processes ongoing in the glacier catchment in response to changing climate. Multi-year datasets include: meteorology; glacier, proglacial and groundwater hydrology; glacier flow and surface ablation; glacier seismicity; annual LiDAR surveys; and multiple GPR, meltwater chemistry, structural glaciology, dye-tracing, ablation, and mapping survey campaigns. Thus we believe this is one of the broadest scope, multidisciplinary projects of its kind.

Our key findings relate to processes of deglaciation, in terms of glacier ablation, flow and reorganisation, and meltwater production, storage and transport, plus the impacts of deglaciation on landscape evolution, and surface and groundwater hydrology. Our data also help to parameterise new glacier-hydrological modelling.

Project highlights include:

The transition from proglacial debris-covered ice zone to ice-marginal lake has seen the ephemeral development of classic proglacial geomorphology, followed by equally rapid geomorphological degradation. We propose this model of proglacial evolution is now common across Iceland and evidence of similar transitions can be seen in the glacial geological record worldwide.

The upper active section of Falljökull still flows, but has detached from, and is being thrust over, its stagnant lower section. The reduction in active length of Falljökull over recent years has allowed rapid re-equilibration to regional snowline rise. Globally other steep outlet glaciers may respond similarly to mass balance changes by rapidly adjusting their active length in response to recent atmospheric warming.

Ice and snowmelt dominate summer riverflow, but significant flow also occurs in winter due to glacier icemelt and rainfall. The influence of groundwater discharge increases during winter and forms a small (15–20%) consistent source of baseflow to the river. Storms give rise to similar hydrological responses across all seasons reflecting a highly efficient permanent glacial drainage system.

Large volumes of proglacial groundwater storage are actively recharged by local precipitation and strongly influenced by individual precipitation events. Significant glacial meltwater influence on groundwater occurs within 500m of the outlet river, where there is active recharge from river losses. Predicted future changes in glacier



coverage and precipitation are likely to increase the significance of groundwater storage in proglacial aquifers for water resources and maintaining environmental flows.

Numerical modelling of glacier-hydrological processes, ground-truthed with river discharge and ablation data have indicated that meltwater volume and river discharge are highly influenced by changing glacier hypsometry. Although the river flow regime characteristics (flow magnitude, timing and variability) are sensitive to climate change, the response is moderated by melt and glacier-hydrology processes. This has consequences for uncertainty quantification in glacial meltwater modelling projections.

We would now like to build on our many collaborations borne from this project, and explore new research partnerships based on a decade of data.

**O-3203**

## **Advances in Deglaciation - A mechanism for glacier mass-loss in Svalbard**

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### **Abstract**

Glaciers respond to a shift from cool to warm climate by various forms of mass loss (melting, calving) and general ice-marginal retreat. This response has been widely observed in modern systems and has also been reconstructed from past deglaciations. An under-studied mechanism of glacier mass-loss in a changing climate exhibits an opposite ice-marginal response to warming. On a short timescale, glacier ice margins re-advancing rapidly, yet unsustainably, resulting in a pronounced draw-down of ice throughout the system. Unlike a traditional advance associated with positive mass balance this re-advance results in significant volumetric loss. While to an extent this process can be observed at present, the palaeo-record of such a process is harder to disentangle owing to limited palaeo-climate records and fragmented reconstructions.

Widespread, asynchronous glacier re-advances during the Late Pleistocene and Holocene have been identified around Svalbard. Glacial deposits are contemporaneous with reconstructions of warm water and air masses arriving to the region and the time-transgressive deglaciation of the Svalbard-Barents Sea Ice Sheet. We propose that unsustainable glacier re-advances were a key and previously un-acknowledged mechanism for net mass-loss and the degradation of the former ice sheet. Conceptually, this process does not exhibit a constant rate nor synchronous mode of mass loss, but potentially a more effective means of ablation given an extended period of time, as climate shifts from glacial mode to inter-glacial mode.

O-3204

## Late Quaternary Caspian Sea evolution recorded through clay minerals, Nd isotopes and palynology

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### Abstract

We present the results of clay mineral, Nd and palynological analyses applied to sediments from the Caspian Sea. Analyses were performed on two sediment cores that were collected in the middle basin (SR-9418 GS20, water depth of 479 m and Sh7, water depth of 749 m) during a cruise that took place in 1994 as a part of the multidisciplinary study of the Caspian Sea, conducted by a Russian-French team, and a cruise of the Shirshov Institute of Oceanology in 2010. Sediments were already studied for sedimentological, magnetic, geochemical and biological parameters (Chalié et al. 1997; Jelinowska et al., 1998,1999; Boomer et al., 2005; Leroy et al., 2000,2007,2010,2013,2014; Pierret et al., 2012; Tudryn et al. 2013,2014;2016). Both cores present Late Pleistocene and Early-Mid Holocene sediments. The late Pleistocene part of both cores consists of detrital rich and carbonate poor material while Holocene sediments are dominated by carbonaceous mud.

Our results show that during the last deglaciation, the Caspian basin collected meltwater and fine-grained sediment from the southern margin of the Scandinavian Ice Sheet via the Volga River. It induced the deposition of characteristic chocolate-colored illite-rich sediments (Chocolate Clays) that originated from the Baltic Shield area according to Nd data (Tudryn et al., 2016). This supply started probably at ~22 cal kyr BP, led to the Early Khvalynian transgressive stage(s) and Chocolate Clays deposition in the now-emerged northern flat part of the Caspian Sea and in its middle basin, and it stopped at ~13.8 cal kyr BP. The strong contribution from Volga river sources to the sediment is also indicated by pollen analyses (very low pollen concentrations with high occurrence of *Pinus* and reworked grains). Pollen assemblages detected then the Allerød and the Younger Dryas, and the dinocyst assemblages the subsequent Mangyshlak.

After the Chocolate Clays deposition and until 3.0 cal kyr BP, smectite became the dominant clay mineral in the sediment from the middle basin of the sea. Simultaneously,  $e_{Nd}$  values increased and stayed high during the Holocene indicating the major change of the sediment sources in this basin. Such values are comparable to those obtained for today's sediments deposited by Amu-Darya in the Aral Sea. The highest  $e_{Nd}$  values were recorded between 9 and 4 cal kyr BP and are similar to those obtained for today's sediments transported from Alborz Mountain by Sefidrud Rivers into the southern basin of the Caspian Sea.

O-3205

## Late Pleistocene and Holocene Paleoclimate Problems of the Northern Caspian Region

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### Abstract

The Northern Caspian region located far from the key areas with well-developed sequence and known types of global climate events. The main paleoclimate factors in the region are with sharply continental conditions, trade winds moves from Turkestan, Siberian glacial, Arctic and even Mediterranean. The local impact on paleoclimate events also affected by rapidly changes of the Caspian Sea level.

We studied paleoclimate events, reconstructed from paleo landscapes, and find a number of important features. These include a sharp change of vegetation landscapes, often without transitional stages, an unusual composition of plant communities for paleoclimate optima and minima, as well as unique latitudinal zonality of natural zones. Different types of hyperzonal landscapes predominance were the special feature of the local paleoclimate. Sometimes we fixed natural zonality, close to the meridional one, associated with radical change of the atmospheric air currents direction.

The dynamics of natural events are frequently correlate with extreme natural events of a catastrophic type. Some of them turn out to be concentrated in the form of unique episodes associated with natural events. Sand and dust storms are the main among natural disasters, as well as high-speed changes in the Caspian Sea level, and relief transformations, mud volcanism, gravity and seismic-gravity processes, powerful quick ground processes associated with extremely high pressures groundwater, and some hydrological disasters. The Late Glacial hydrological disasters in the Volga Valley, unlike other Eastern Europe river systems, destroyed almost all pre-Neolithic archaeological monuments. We also find some places with local extreme environmental events, with significant hydrogen sulfide gas emissions. This may cause partial mortality of large mammals.

O-3206

## What are the drivers of Caspian Sea level change during the Quaternary period?

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### Abstract

The Caspian Sea, one of the world's largest lakes and located in a closed basin, experienced extreme water level changes ranging from tens to hundreds meters on various time-scales during the Quaternary period. Numerous studies have suggested that the water level variations of this region have depended on both geophysical processes, affecting the opening and closing gateways with the marine realm, and hydro-climatological processes, resulting in water balance changes. However, there are conflicting ideas concerning the relative importance of different potential drivers of past sea level variability, as well as the mechanisms/routes by which they impacted basin connectivity and sea level variation. In this study, firstly we focus on reviewing the potential drivers of sea level change and secondly we study the impacts of hydro-climatological processes and catchment dynamics on water level. Climate model simulations from a global coupled ocean-atmosphere-vegetation climate model, HadCM3, are used to drive a hydrological model to examine lake level change. We explore catchment water balance variability as well as changes in catchment size over the last 120 thousand years. Hypothetical scenarios of runoff source area are investigated to understand the impact of extinct river systems and pro-glacial melt water pulses on lake levels and connectivity. By this method we will explore and constrain the drivers and sources of runoff that control the sea level variations of Caspian Sea.

**Keywords:** Sea Level change, hydroclimate processes, hydrological modelling, catchment dynamics.

O-3207

## The Black Sea level during the period of the catastrophic river runoff

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### Abstract

The remnants of the palaeo-channels much larger than the modern ones are widespread in the floodplains of lowland rivers in the Black Sea basin on the East European and Pannonian plains. Palynological studies of palaeo-rivers alluvium make it possible to locate the climatic and hydrologic region-analogues of the landscapes at the time of their development, from 16 to 19 ka BP. These analogues allowed reconstruction of the former surface runoff of the large Late Glacial rivers, as well as the total volume of flow to the Black Sea from the East European and Pannonian plains, using the transform functions. The mean annual water yield from this territory for several thousand years was up to 700-800 km<sup>3</sup> and reached 2800 km<sup>3</sup> per year for a few decades during the extreme runoff stage. This huge river runoff was the main factor of the Black sea level rise in that period. The flow velocity calculations, lithological composition of deposits and morphology of the Bosphorus and Dardanelles straits shows that these canals were cleaned of loose sediments by this powerful flow, and the basement rocks were exposed. There is an uncertainty in the position of the highest rock sill, as the maximum rock surface altitude is similar in the Dardanelles and in the Bosphorus (about -75...-80 m). We assume that the rock sill in the Dardanelles was formerly higher than at present (about -70 m), and was lowered down to its modern position by the powerful flow through the canal. When the ocean level was lower than the rock sill in the Dardanelles, the level of the Black Sea was controlled by flow hydraulics on this sill. The spillway flow theory was used to calculate the water level on the rock sill using discharge, critical velocity of rock erosion initiation and cross-section geometry. At the stage of the maximum discharge (the "hydrocratic" transgression of the Black Sea), sea level was about -62...-64 m. Later on, with diminishing discharge it decreased to -66...-67 m. Since about 14 ka BP, when the ocean level rose above the altitude of the Dardanelles rock sill, the new stage of the "eustatic" transgression has begun. The level of the Black Sea was then controlled by the ocean level and remained close to it ever since.

This study was funded by Russian Federation program "The Evolution and Transformation of Erosion-Channel Systems under Changing Environment and Human impact."

O-3208

## MIS5 in the Marmara Sea: palynological reconstructions of climate and water parameters

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### Abstract

The Marmara Sea is the ultimate western connexion of the Pontocaspian to the Mediterranean Sea. It has had a complex history of connections both with the latter and with the Black Sea. During periods of isolation, it was fully Pontocaspian with a brackish environment. During periods of connexion to the Mediterranean Sea through the Dardanelles, the Sea of Marmara water body experienced a more or less pronounced stratification, as during the Holocene. Palynology has been studied in two sedimentary sequences with a special focus on sapropel intervals attributed to MIS5. At those times, the Marmara Sea was stratified, and the bottom water, presumably of higher salinity, experienced episodes of anoxia.

The dinocyst assemblages in the sapropels are dominated by *Pyxidinopsis psilata* and *Spiniferites cruciformis* and clearly differentiate the sapropels from the truly marine phases. The terrestrial pollen shows a clear alternation of steppic landscape (*Artemisia*) and oak forests, corresponding to the substages of MIS5. This confirms the proposed age-depth model. Moreover, warmer periods, likely during MIS 5a and 5c, appear to coincide with peaks of organic carbon content in the sediment.

O-3209

## Late Quaternary climate and environment reconstruction of Lake Urmia basin (Iran)

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### Abstract

The ongoing changes affecting Lake Urmia are revealed by the lake water level decrease by more than 7 m in the last 15 years, desertification and formation of dust storms. This drop has been attributed to rainfall declining by ~10% and to anthropogenic causes mainly the construction of numerous dams on rivers feeding the lake and abusive groundwater pumping. Nevertheless, the exact roles of natural and anthropogenic factors that influence the state of the lake are still not identified. Indeed, the lack of the detailed record of environmental evolution in the past limits the understanding of actual and future processes and as a consequence, the capability to develop integrated management of this water resource.

The Franco-Iranian project initiated by bilateral Gundishapour program (2016/2017), aims to obtain a high temporal resolution records of past environmental and climate changes in the Lake Urmia area for the whole Holocene. Preliminary results integrating the interpretation of environmental data in the vicinity of our lacustrine cored sequences are done with reference to modern hydrogeochemical and geological systems in relation with the establishment of a reliable <sup>14</sup>C time-scale indispensable for palaeoclimatic reconstructions using various proxies at a global scale (Tudryn et al., in prep.).

During the fieldworks, several sediment cores (5-14 m long) have been obtained from recently dried out part of the lake close to Urmia city and sampling of the lake, wells and river waters has been done. Preliminary analyses were done on part of sediments and waters at laboratory UMR 8148-GEOPS. Sediments are composed by an alternation of sands and finer-silty and clayish fractions. Analyses for total mineralogy, clays, carbonates, magnetic properties, organic carbon, either contents and isotopes <sup>13</sup>C<sub>org</sub> and microscopic observations show important changes of the biological activity, sources of detrital material and transport energy, conditions of lake water evaporation and during early diagenesis. All these parameters are in relation with both lake water level fluctuations and precipitation variations over the lake watershed at local to regional scales through time. Ongoing analyses for <sup>14</sup>C AMS dating on rests of plants will allow the establishment of the accurate chronology for observed changes.

O-3210

## Lake Burdur (Turkey) environmental changes during the Late Quaternary inferred from the lake deposits: preliminary results

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### Abstract

Lake Burdur is located in Isparta region (Anatolia, Turkey). As it is closed, sensitive to the rapid climate changes reservoir, it belongs to large Eurasian lakes that are good climatic archives. Moreover, its geographical position allows the studies of the pale climate variations not only at local scale, but also at regional scale that integrates Mediterranean-Marmara-Black-Caspian seas area. Lake Burdur occupies the lowest part of the Burdur basin that was formed during Tertiary extensive tectonic phase as a graben. During the last 40 years water level of the lake lowered significantly (~ 15 meters), as well as the groundwater table in the area. This was attributed to climatic variations, human activity and/or seismic activity; nevertheless, exact impacts of these on actual lake evolution were not yet established. Indeed, the lack of the detailed record of environmental evolution in the past, limits the understanding of actual and future processes in the lake area.

The recently initiated Franco-Turkish project aims to obtain high temporal resolution records of past environmental and climate changes in the Lake Burdur area for the Late Pleistocene (from Last Glacial Maximum) and the whole Holocene. The process will integrate hydrogeological, hydrological and lake sediments studies.

During the fieldworks realized in 2017/2018, two continuous sediment cores (~20 m long) have been obtained from recently dried out part of the lake close to the Burdur city. Preliminary analyses were done on sediments at Research and Application Laboratory for Geothermal Energy, Groundwater and Mineral Resources (Isparta, Turkey) and in laboratory UMR 8148 – GEOPS (Orsay, France). Sediments are mostly composed of silty and clayish fractions, some levels that are rich in brownish organic material indicate the low water level or even dried state of the lake with soil development. First analyses for total mineralogy, specific carbonates, clay and magnetic minerals, organic carbon and microscopic observations show changes in sources and transport energy of detrital material, biological activity in the lake and conditions during the early diagenesis in sediments. These results provide a comprehensive record of changes in water level of the lake related to water resources availability, conditions in the lake itself (salinity, biological productivity), but also of changes in the catchment basin indicating variation of vegetation cover and erosion intensity. Ongoing analyses for <sup>14</sup>C AMS dating on rests of plants will allow the establishment of the accurate chronology for observed changes.

O-3211

## The International Science Council as the Global Voice for Science and the role for Quaternary Science

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### Abstract

Humanity has become a defining geological force that has re-configured the global ecology in ways that are inimical to many of the natural processes that have created and sustained the biosphere, atmosphere and hydrosphere, and that form the life support system for the planet's inhabitants. Science faces a major challenge to identify pathways to sustainability in this system that in a technical sense is complex, involving convergent, coupled issues of climate change, environmental degradation, poverty, social conflict, corruption and inequality.

However, the setting into which scientific understanding plays is also changing. Although society needs science more than ever, it is arguably less inclined to listen to its voice, partly because of deep socio-economic shifts and partly because the tools of the digital revolution have been disruptive in unanticipated ways. The worldwideweb for example, notwithstanding its democratic potential, has proved indifferent to falsehood and honesty, becoming a powerful enabler of "alternative facts." We have a threefold challenge: a scientific challenge in understanding the complexity of the Earth system, including its human inhabitants; a political challenge in articulating policy options for pathways to sustainability in ways that respect the needs of policymakers; and a social challenge in bringing scientists and non-scientists together as collaborating knowledge partners able to create actionable knowledge that has credibility, practical relevance and the socio-political legitimacy without which political action stymied.

It is largely in response to such issues, and the vital need to bring the natural and social sciences together in addressing them, that the International Science Council (ISC), of which INQUA is a member, has been created, with the mission to act as the global voice for science. ISC has inherited the role of the International Council for Science (ICSU) as the formal representative body for science in the UN system, and is acting boldly to ensure that the voice of science is heard in the international political arena. ISC has identified four major strategic challenges for its current planning period: *sustainability and the SDGs, the digital revolution, science in policy and public discourse, and changing science systems*. INQUA and Quaternary scientists have a significant role to play in all these domains: in creating high resolution temporal narratives about the nature and consequences of human intervention in the Earth system; in ensuring that Quaternary science data can be effectively integrated to explore related complex phenomena, particularly in specific sustainable development goals; in engaging in open transdisciplinary discourse; and in easing the path towards more efficient interdisciplinary science. The presentation will give specific examples where greater engagement from Quaternary science is needed.

**O-3212**

## **Quaternary sciences document the reality, magnitude and threat levels of current planetary climate warming**

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### **Abstract**

Evidence documenting anthropogenic climate warming comes in abundance from virtually every branch of the natural sciences. Were judgment rendered in a U.S. court of law, the standards of “beyond a reasonable doubt” (criminal case) and “preponderance of the evidence” (civil case) have clearly been met and dramatically surpassed. Significant contributions to our understanding of current climate change have been made by researchers in the atmospheric, oceanic and geological sciences.

The concept of uniformitarianism developed by James Hutton in the late eighteenth century asserts that the universality of fundamental principles and natural laws in space and time validate the application of current process explanations to processes of the past (the familiar “the present is the key to the past”). Similarly, results and relationships of the past serve to constrain and elucidate those of the present and future. Insights from the geological record have been invaluable in interpreting current data trends; paleoclimatic studies indicate that climate models are more likely to underestimate than to overestimate long-term change.

Of great concern to climate scientists are the accelerating rates of change of current climate change parameters and the processes they document. Equally concerning as the increasing severity and frequency of extreme climate-related events. The recent IPCC report (November, 2018) emphasized the urgency of immediate policy action to reduce greenhouse gas emissions as the most effective means of mitigating global warming. In the words of UN Secretary-General Antonio Guterres, “This report by the world’s leading climate scientists is an ear-splitting wake-up call to the world. It confirms that climate change is running faster than we are – and we are running out of time.”

As we Quaternary scientists and educators acknowledge the validity of the science and express concern for victims of the impacts, our obligation to warn and to support action becomes compelling. Because of our special knowledge and experience, we bear special responsibility. It is incumbent upon us to speak up and demand policy change!

**O-3213**

## **Mapping Sea-Level Change in Time, Space, and Probability**

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### **Abstract**

As recorded instrumentally and reconstructed from geological proxies, sea levels have risen and fallen throughout Earth's history, on timescales ranging from minutes to millions of years. Sea-level projections depend on establishing a robust relationship between sea level and climate forcing, but the vast majority of instrumental records contain less than 60 years of data, which are from the late twentieth and early twenty-first centuries (1–3). This brief instrumental period captures only a single climate mode of rising temperatures and sea level within a baseline state that is climatically mild by geological standards. Complementing the instrumental records, geological proxies provide valuable archives of the rates of sea-level response to past climate variability, including periods of more extreme global mean surface temperature

We review the current methodologies and data sources used to reconstruct the history of sea-level change over geological (Pliocene, Last Interglacial, and Holocene) and instrumental (tide-gauge and satellite altimetry) eras, and the tools used to project the future spatial and temporal evolution of sea level. We summarize the understanding of the future evolution of sea level over the near (through 2050), medium (2100), and long (post-2100) terms. Using case studies from Singapore and New Jersey, we illustrate the ways in which current methodologies and historical data sources can constrain future projections, and how accurate projections can motivate the development of new sea-level research questions across relevant timescales.

O-3214

## Wildfire risk at different elevations: contextualizing modern fire activity through a paleo-perspective

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### Abstract

Anthropogenic-induced climate change is progressively increasing drought severity across many regions of the northern hemisphere including western North America. Over the last 30 years, prolonged droughts coupled with declines in winter snowpack and/or earlier spring runoff have created hazardous wildfire conditions through mid- and high-elevations across the U.S. Rocky Mountains (Westerling, 2016). With projections suggesting a continued increasing trend in global temperatures, wildfire risk is also expected to increase. Examining long-term paleoecological records are important for investigating whether fire activity at mid- and high-elevations is unprecedented in time and space, as well as for investigating potential climatic drivers and ecosystem responses. Here, we investigate wildfire activity across the U.S. Rocky Mountains over the last 1,500 years to contextualize past fire activity across various elevations using 37 sedimentary charcoal records. Our results show that at present, more biomass burning has occurred at mid-elevations in the northern Rocky Mountains compared to the southern Rocky Mountains. However, prior-to the Medieval Climate Anomaly (MCA) ~1350 cal yr BP, wildfire activity occurred through both mid- and high-elevation throughout the U.S. Rocky Mountains. Because climatic conditions during the MCA were similar to those seen at present, this time period could serve as a potential analog for future wildfire activity (Carter et al., 2018). Thus, investigating ecosystem response prior-to the MCA could inform land managers potential responses to future climate change and subsequent changes in fire regimes. Thus, investigating ecosystem-level responses prior-to the MCA could provide a means for land managers to evaluate responses to future climate change and subsequent changes in fire regimes.

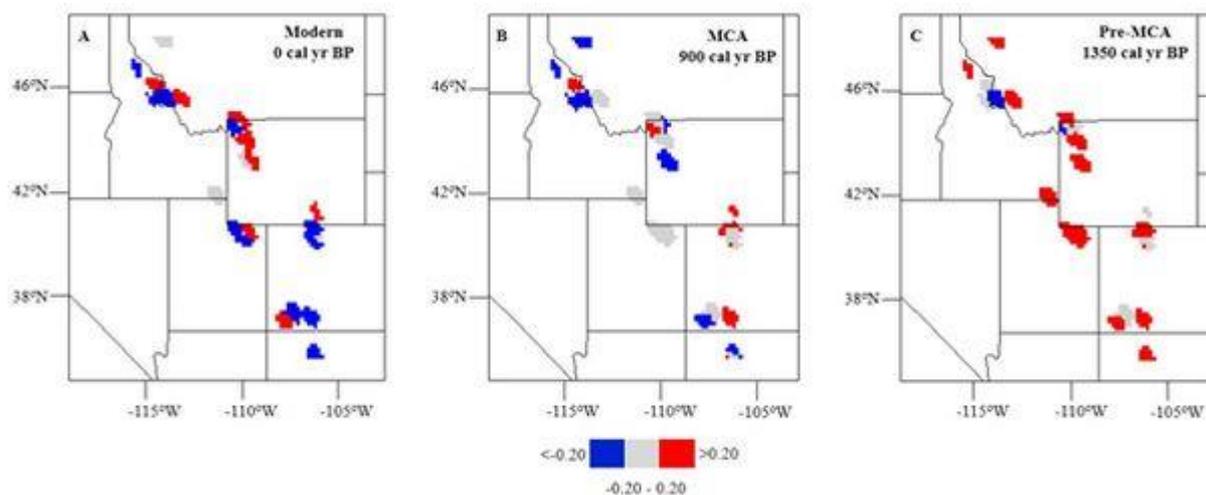


Figure 1. Trends in wildfire activity across the US Rocky Mountains during the A) the 20th century, B) 900 cal yr BP, and C) 1350 cal yr BP. Red indicates positive trends in burning; Gray indicates neutral trends; Blue indicates negative trends in burning.

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**O-3215**

**Building resilient hydrologic systems for the future using lessons from past societies: from Ancient Rome to the Maya Lowlands**

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**Abstract**

In 2018 the University of Texas at Austin launched an ambitious multi-disciplinary, multi-year project, Planet Texas 2050. The goal of this research is to build resilient human, environmental, and urban systems for Texas and beyond in the face of increasing environmental and health challenges, including climate change, drought, flooding, and severe weather scenarios. An important component of this research is studying past societies to provide both social and landscape analogues for the current Texas environment. Our research includes projects tracing ancient water management structures and strategies, ranging from Roman aqueducts to ancient Maya wetland agriculture. This paper presents the results from our 2018 and 2019 hydro-geoarchaeological field seasons in Italy and the Maya Lowlands of Central America. Results include documentation of little-known Roman aqueduct sections of the Aqua Traiana that still serve the broader City of Rome water system, and ancient Maya water management infrastructure in the Maya Lowlands.

O-3216

## Recent advances in the palaeoflood hydrology of alluvial rivers

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### Abstract

Riverine flooding is a widespread, commonly occurring, and costly hazard, with 2018 global economic losses to floods estimated to exceed \$10 billion. Conventional assessments of flood hazard (i.e., the probability that a flood of a given magnitude will occur) are based on statistical analyses of instrumental streamflow data, but these assessments assume geomorphic and climatic stability, and are prone to large uncertainties when estimating the probability of an extreme flood. Recent advances in palaeoflood hydrology now allow for the development of event-scale and quantitative reconstructions of past floods on alluvial rivers where populations and infrastructure are concentrated. Here, we present a series of recent and on-going projects from North America and Europe that use and apply palaeoflood records developed from floodplain lakes to reevaluate flood hazard with the long view provided by Quaternary science. We demonstrate how these palaeoflood records are developed, and how they can be integrated with statistical models, palaeoclimate data, and Earth system models to improve assessments of flood hazard. These examples form the basis for our argument that alluvial palaeoflood hydrology be more regularly incorporated into conventional assessments of flood hazard made by public and private entities.

O-3217

## The application of Holocene alluvial stratigraphy to address streambank erosion and reservoir sedimentation in the Midwestern U.S.A.

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### Abstract

Reservoir sedimentation is a significant problem in many parts of the world and has important implications for the sustainability of water supplies, flood protection, and aquatic habitats. In the Midwestern USA, streambanks have been identified as the primary contributor to total watershed sediment yield. In much of this region, deposits of fine-grained Holocene alluvium comprising streambanks have been assigned to a single lithostratigraphic unit, the DeForest Formation.

Stratigraphic relationships and the erodibility of the different members of the DeForest Formation were investigated in northeastern Kansas. Distinct differences in erodibility, measured in terms of critical shear stress by a submerged jet-test device, were observed between the different members. The most erodible member is the Camp Creek Member while the most resistant is the Gunder Member. Variability in erodibility between and within the different members is attributed to the magnitude of post-depositional soil-forming processes, including the presence of buried soils, as well as the inherent natural variability in the different parent materials. A weak positive correlation was found between percent clay and critical shear stress. Resistance to erosion by fluid flow was found to be significantly greater where clay contents exceed 28%.

Although the Camp Creek Member was the most erodible, it always occurs, stratigraphically, as the uppermost member. Bankfull stage indicators suggest that bankfull discharges rarely attain elevations sufficient to erode Camp Creek Member deposits. Therefore, other members of the DeForest Formation can exert some control on the rate of bank erosion by hydraulic flow. Furthermore, given the observed differences in lithology, soil development, and erodibility, the susceptibility to mass wasting processes also is likely to vary between the different members and is a focus of current research. Therefore, Holocene alluvial stratigraphic relationships have important implications for the nature of streambank erosion in the Midwestern USA as well as in other alluvial settings worldwide. These relationships can be used to locate areas more prone to streambank erosion that may serve as mitigation targets in order to reduce rates of reservoir sedimentation.

O-3218

## Paleo Dune Development on the Canary Islands: A Relationship to Atlantic Heinrich Stadials and Events?

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### Abstract

The internal structure and repetitive pattern of paleo dunes on the Canary Islands provide insight into the climatic dynamics of the North East Atlantic (NEA) during Heinrich Events (HE) and Heinrich Stadials (HS). Here we present an explanation of the dune development that could simultaneously solve the mystery of the jointly occurring HEs and HSs.

The paleo dunes show a systematic 3-phase sedimentary sequence starting with the deposition of marine biogenic sand and a certain amount of Sahara dust. The second phase shows a much higher dust content. Jointly appears a dense community of a few gastropod species and bee nests. The final phase is an indurated layer of maximum dust content that seals the sequence and, the cycle repeats. Optical stimulated luminescence (OSL) dating on some of the indurated layers reveals age ranges that match with the timeline of NEA HEs, suggesting that the Pleistocene ice-ocean-atmosphere dynamic in the NEA region played an essential role in the sequential development of the dune deposits.

I.e., the initial phase of the dune development needs a dry shelf area that makes biogenic sands susceptible to wind transport. This is when sea level drops as a consequence of growing Pleistocene ice shields. The climate of the NEA during this phase is relatively mild (in glacial terms) with little dust transport from the Sahara to the islands. The extension of the North Atlantic ice-sheets onto the shelves results in an increasing iceberg production which subsequently freshens and cools the NEA surface water including the overlying atmosphere. This enhances the temperature contrast between the polar and tropic region and thus, wind speeds. Consequently, transport of micaceous dust from the Sahara increases and, because the wetter westerly zone moves further south there is now sufficient precipitation allowing vegetation on the dunes which nourishes gastropods and bees. We suggest that this phase with cooler NEA surface waters and a cooler-wetter atmosphere is a HS.

Somewhere during this phase southern warmer sub surface waters advance towards the grounding lines of northern ice margins causing rapid melting that weakens the contacts between basal rocks and the ice. The ice sheets rather synchronously start collapsing, thus generating a HE. Consequently, even colder NEA surface water extends much further to the south, pushing the zone of westerly winds, too. The dust now contains elevated amounts of kaolinite from the desiccated subtropical-tropical regions of Africa. The HE ends when the interstadial oceanic circulation resumes. Then a new sequence starts. Thus, there seems to be no direct link between HEs and HSs but an indirect link to somewhere in the global south-north energy seesaw.

O-3219

## $\delta^{18}\text{O}$ record comparisons among Siberia stalagmite, Hulu Cave stalagmite, NGRIP2 and GISP2 ice cores during 33-60 Ka

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### Abstract

A 23-cm long stalagmite (K6) from Kyok-Tash Cave (51°43'43" N, 85°39'23" E, 890 m a.s.l.) in south Altai Mountain of Siberia, Russia, was dated by <sup>230</sup>Th/U method, spanning from 59.42 ka to 33.76 ka. Up to date, a total of 1404 samples were measured  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ . This high-resolution stalagmite  $\delta^{18}\text{O}$  record has compared with the  $\delta^{18}\text{O}$  records of GISP2 ice core (The Greenland Summit Ice Cores, 1997), NGRIP2 (North Greenland Ice Core Project members, 2004) and Hulu Cave stalagmite (Wang et al., 2001). The comparison shows that between 33 ka and 44 ka, all records have good comparisons, indicating heavier  $\delta^{18}\text{O}$  peaks in stalagmites (drier climatic conditions) corresponding to cold episodes (lighter  $\delta^{18}\text{O}$  peaks in ice core, e.g., H4); and vice versa. However, between 44 ka and 60 ka, K6 record compares well with GISP2 record, but not good with NGRIP2 and Hulu records. Since the Hulu record provided excellent chronology for age tuning of ice core records (the GRIP2001/ ss09sea timescale, Johnsen et al., 2001), the chronology of NGRIP2 record between 40 ka and 60 ka shifted 1-3 kyrs older than GISP2 record. This chronology tuning assumes that the forcing factor of Hulu  $\delta^{18}\text{O}$  record should be single (i.e., amount effect or moisture source effect) and keep constant through time, and the climatic correlation between Asian summer monsoon and high latitude temperature (cold vs dry or weak summer monsoon) should remain unchanged. The K6 record shows multiple factors to influence stalagmite  $\delta^{18}\text{O}$  in the south Altai region. For example, the K6  $\delta^{18}\text{O}$  record does not show strong enrichment during H5 event (no matter it was center at 45.5 ka or 48 ka), and strong depletion during DO14 event. We suspect that more winter precipitation with lighter  $\delta^{18}\text{O}$  might obscure the amount effect (dry) during H5, whereas increased summer rain with heavier  $\delta^{18}\text{O}$  balanced the wet effect during DO14. Between 60 ka and 44 ka the Siberian High might not be very strong, so the climatic discrepancies between south Altai and Asian monsoon regions were larger especially during interstadials. After 44 ka, the Siberian High became stronger, so that similarities of Hulu and K6 records were more. More <sup>230</sup>Th/U dates will be obtained to refine the chronology of K6 record.

O-3220

## Dust and Flood Events during Heinrich Events - Evidence from a new annual resolution record from the maar lake of Auel

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### Abstract

Two new overlapping sediment cores have been drilled from the infilled maar lake of Auel in the west Eifel volcanic field and document all stadials and interstadials of MIS2/3. The high sedimentation rate of 2 mm/a (caused by riverine input, dust deposition, and high biogenic productivity) allows annual resolution analysis with 0.5 mm  $\mu$ XRF logging and 1.0 mm organic carbon logging. The two new 102 m long records are dated by a combination of <sup>14</sup>C/tephrachronology/ice core tuning/varve counting. Average varve thickness has been determined for each stadial/interstadial and corroborates the tuned Bayesian age model.

High Corg, Si/Al and P characterize varved interstadials, which reveal an almost identical structure as the Greenland interstadial  $\delta^{18}O$  record. Ti/Al documents fluvial runoff into the maar lake by erosion of Al-rich clay particles from the soils of the catchment during all stadials from GS17 to GS2. Eolian particles are best detected by Ca/K, which documents the abundance of limestone detrital grains in the dust fraction. Pollen complement the analysis and document the distinct vegetation of each stadial, interstadial and Heinrich event.

Heinrich 5 caused a massive deterioration of the early MIS3 trees of spruce and hornbeam and was characterized by highest Ti/Al values indicating intense stadial precipitation (rain or snow). It started with a time of strong lake level drop and reworking of older wood particles.

Heinrich 4 revealed strong precipitation only during its first phase, which occurred about 200 years hundred years after the Campanian Ignimbrite, which is visible in the Auel records as a 1 mm thick cryptotephra with agglutinated greyish glass shards. The centuries before the onset of GI8 had seen only some precipitation, but no Ca-rich dust. These centuries mark the time when grass pollen started to dominate the vegetation.

Heinrich 3 occurred immediately before GI4. It has seen the erosion of large amounts of clay into the lake (most probably as winter smelt), but also severe dust intensity. In this respect it is very different to the earlier Heinrich events.

Heinrich 2 is a short Ti/Al maximum in the section of continuously high glacial dust, which started at 26,000 and intensified at 23,400 yrs b2k. The clay rich layers of this time are characterized by Ranunculaceae pollen.

Heinrich 1 immediately before the 14,700 yr b2k warming reveals in contrast no clay and no pollen at all, but a pronounced Ca-rich dust maximum of about 500 year duration.

Accordingly, each Heinrich event had a unique climatic and environmental structure. H5 - H2 were associated with precipitation (probably winter snow fall), H3 - H1 with severe dust and thus aridity.

O-3221

## **Abrupt environmental change during Heinrich stadials, inferred from biological and non-biological variables in sediments of neotropical Lake Petén Itzá, Guatemala**

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### **Abstract**

Evidence of environmental changes triggered by Heinrich events (HE) are preserved in marine sediment archives around the world. Few studies, however, have determined the ultrastructure of each event or detailed its impact on freshwater ecosystems. Changes in abundances of fossil species assemblages are generally used as indirect information on the magnitude of climate and environmental impact. However, determining the magnitude and velocity of ecological change by applying multivariate methods on fossil counts, in both, aquatic and terrestrial ecosystems can provide a more accurate quantification of the impact.

Continental environmental information during Heinrich Stadials (HS) is limited in the northern Neotropics, because very few lakes in the region deposited sediment during the last glacial. One exception is Lake Petén Itzá, in the lowlands of northern Guatemala. The lake is deep (165 m) and large (100 km<sup>2</sup>), and its sediments contain information on the climate and environment of the past 400 ka. This closed-basin lake is especially sensitive to changes in the balance between evaporation and precipitation (E/P), and the sediment record can be used to infer past E/P and lake level. Extremely arid periods are marked by gypsum precipitation, and most layers deposited during HS.

Multiple biological (ostracodes, diatoms, pollen) and non-biological (geochemistry, mineralogy) sediment data from long cores PI-6 and PI-2 reveal different responses among HS 5a-1 as recorded by the aquatic ecosystem. For instance, HS5 and HS3 were characterized by prevailing dry conditions that subsequently became more humid; HS2 was predominantly humid, but became arid; HS4 and HS1 displayed fluctuating dry-humid conditions, and HS5a was mainly arid and displayed high lake conductivity. HS1 has been identified as the coldest and driest so far, where lake levels dropped 50-60 m. Presence of tropical ostracode species assemblages during HS indicates that water temperatures did not decline dramatically, and were only 1-3°C lower than modern lake temperatures. Geochemical and mineralogical analyses showed, however, that gypsum precipitation not only occurred during HS in lake Petén Itzá, but also during Greenland Stadials (GS) GS 4-8 and GS 14. HE are typically seen as episodes of rapid climate change that had profound, often negative effects on aquatic communities. Our record, however, shows that biodiversity during HE was higher than during other times. Significant changes in precipitation and lake level favored the establishment of numerous microhabitats and created greater environmental heterogeneity.



Our combination of biological and non-biological variables in sediments of Lake Petén Itzá revealed that northern neotropical lakes were sensitive to cold climate pulses originating from the North Atlantic (HE and GS), and the predominant climatic condition was dry and cold as a response of a more southern position of the ITCZ and a slowdown of the ocean's thermohaline circulation.

O-3222

## Orbital-to-millennial scale climate variability during Marine Isotope Stages 5 to 3 in NE Spain

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### Abstract

The climate during the last glacial cycle was characterized by abrupt millennial-scale changes superimposed on long-term orbital control. The understanding of the terrestrial response in Europe to those abrupt events has increased during the last decade, but is still sparse. Previous studies on the Iberian Margin and in the Mediterranean Sea emphasize the sensitivity of this area to climate change in the North Atlantic realm. Unfortunately, speleothems and lacustrine sediments from southern Europe covering this time period are discontinuous and difficult to date, with the exception of few lacustrine sequences such as Lago Grande di Monticchio, anchored by tephra datings.

Here we present a stalagmite record from Ejulve cave, northeastern Iberia, covering the period between the end of Last Interglacial and Marine Isotope Stage (MIS 3) with an outstanding chronology based on U-Th dates. In contrast to many other speleothems from European caves which preferentially formed during warm/wet periods and commonly stopped growing when the climate turned cold/dry, this record is continuous and hence provides exceptional insights into the terrestrial mid-latitude response to forcing mechanisms across several climate transitions. Our results support previous studies showing a late demise of the Last Interglacial in southern Europe at  $108.3 \pm 0.3$  kyr. During MIS 5,  $\delta^{18}\text{O}$  is controlled by orbital pacing, with periods of low precession of boreal summer peaks characterized by wet conditions. In contrast, during MIS 4 and 3,  $\delta^{18}\text{O}$  is decoupled from precession and co-varies with  $\delta^{13}\text{C}$ , suggesting a common control of both isotopes by enhanced degassing of drip waters during dry periods.  $\delta^{13}\text{C}$  shows a positive correlation with Mg/Ca, reflecting water availability, vegetation productivity and soil microbial activity in the catchment of the cave's drip water. Rapid changes in the hydrology and the vegetation cover occurred during the Heinrich Stadials (HS) and the marine cold events C26 to C23, as well as Dansgaard-Oeschger (D-O) cycles.

Interestingly, two periods with a marked "W-shape" pattern are recognized as the response of the  $\delta^{13}\text{C}$  to HS-6 and D-O 18 on the one hand, and to HS-5a and D-O 15 on the other hand and are interpreted as intra-Heinrich event variability alternating between cold/dry and mild/humid. The phases of cold/dry conditions are in concordance with a reinforcement of the northeasterly trade winds over the Iberian Margin and cold conditions in the subtropical Atlantic during HS-6 and HS-5a, while the mild/humid episodes occurred during the warm phases of D-O 18 and 15. These oscillations document the significant impact of rapid climate oscillations of last glacial cycle on the terrestrial environment on the Iberian Peninsula and provide new insights into the fine-scale climate variability (intra-Heinrich events) that will serve to better understand the mechanisms triggering these oscillations.

O-3223

## Are Heinrich events reflected in the central Iberian loess record?

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### Abstract

On the Iberian Peninsula terrestrial archives that shed light on palaeoenvironmental conditions during the last glacial period are very rare. Due to the proximity of the North Atlantic a coupling between marine processes and terrestrial environments is suspected, but still difficult to verify.

Based on extensive stratigraphic work and abundant luminescence dating (OSL) the upper Tagus loess record proved to be a valuable environmental record for the late Pleistocene. Multiple phases have been identified that point to brief and vigorous loess deposition related to gusty winds under generally dry conditions. For the last 35 ka, we found a strong coincidence in time between phases of loess deposition in central Iberia and the occurrence of Heinrich Stadials (HS) that have been identified in marine records along the Iberian margin. The origin and genesis of the loess deposits indicate cold temperatures during HS-3, HS-2 and HS-1, while grain-size patterns suggest maximum wind strengths during HS-3, followed by HS-2 and HS-1. Moreover, based on  $\delta^{13}\text{C}$  values of *n*-alkane compounds extracted from loess samples we can conclude that HS-3 was the driest period during the last glacial, while aridity was less pronounced during HS-2 coinciding with the so called last glacial maximum.

Our results are well compatible with the timing of palaeoglacier dynamics in central Iberian mountain ranges and allow to draw a picture of last glacial palaeoenvironmental and palaeohydrological conditions in the Iberian interior that appear to be strongly correlated with marine dynamics relating to the occurrence of Heinrich events respectively Heinrich stadials.

However, a still open question belongs to contrasting dynamics during the early to middle marine isotope stage 3, when loess deposition falls in between HS-5 and HS-4 and is absent during HS-4, which is, however, recorded most strongly in many marine records.

O-3224

## Sub-millennial scale variability between Heinrich events 4 and 3 in the long terrestrial paleoecological archive of Lake Fimon (north-eastern Italy)

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### Abstract

Marine Isotopic Stage 3 (MIS 3, ca. 60-30 ka BP) is regarded as one of the most unstable period of the Late Pleistocene as far as climate is concerned, closely interwoven with the late human evolution history. During MIS 3, episodes of massive iceberg discharge into the North Atlantic (Heinrich events [HEs]) enhanced sea surface temperature (SST) cooling at mid- to low-latitudes (Darfeuille et al., 2016) inducing rapid vegetation changes in S-Europe and in the Mediterranean area (Fletcher et al., 2010).

To contribute to the discussion about the influence of HEs on European vegetation dynamics, we present a new high-resolution record from NE-Italy (Lake Fimon, southern Alpine foreland) covering the HE3-HE4 interval. This area is well-known as it provides both a Late Pleistocene palaeoecological record (Pini et al., 2010) and several Middle to Late Palaeolithic sites yielding evidence of Neandertal and AMHs occupation (Fumane cave and Broion shelter; Peresani et al, 2008, 2016; Peresani et al., in press).

The published paleoecological record from Lake Fimon, the resolution of which was too low to reconstruct in detail the history of terrestrial and aquatic ecosystems between 41 - 30 ka cal BP, was reconsidered. The core was resampled to achieve a resolution of ca. 1 sample/80 yrs between 41 - 36 ka cal BP and ca. 1 sample/120 yrs between 36 - 30 ka cal BP. Changes in pollen-algae-spores %, pollen-slide- and macrocharcoal concentrations, and geochemical proxies help to decipher the effects of climate variability on vegetation.

Despite the pollen record points to a general persistent afforestation, HE4 and HE3 intervals are identified by significant drops of the dominant tree taxon, *Pinus sylvestris/mugo*. Such variations are mirrored by upland herbs expansion, including xerophytes and Compositae Asteroideae, indicating phases of climate deterioration. A general low frequency and intensity fire regime, possibly influenced by moist conditions characterizing this geographical area, is punctuated by some fire episodes occurring during periods of possibly enhanced drier conditions related to HEs.

The evolution of the sedimentary basin in relation to HEs can be summarized as follow. A shallow lake persisted during HE4; afterwards, paleoecological and geochemical data indicate blooms of planktonic algae (*Pediastrum*, *Gloeotrichia*, *Scenedesmus*), expansion of submerged macrophytes (*Ceratophyllum demersum*) and detrital carbonates increase. These evidences suggest that the lake threshold rose before HE3, possibly due a clastic supply from an external fluvio-glacial river. The subsequent development of a Cyperaceae-dominated littoral belt suggests



reduced level excursions. According to calibrated radiocarbon ages, the mire development lasted ca 3000 years (31-27.5 ka cal BP), until the building of a subsequent fluvio-glacial dam at the LGM onset.

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O-3225

## The role of the marine ice cliff instability in past, present and future rapid ice sheet disintegration

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### Abstract

Ice sheets wax and wane in response to climate forcing. Climate forcing alone, however, is not sufficient to explain the rapid demise of ice sheets. For example, during the last glacial period the Laurentide Ice Sheet sporadically discharged vast armadas of icebergs through the Hudson Strait into the North Atlantic Ocean during so-called Heinrich Events. More recently, we have observed punctuated ice sheet decay during the unexpectedly catastrophic disintegration of ice shelves on the Antarctic Peninsula and during the retreat of marine terminating glaciers surrounding the Greenland Ice Sheet. Recent attempts to understand the interplay between ice flow, fracture and climate forcing at the root of rapid ice sheet demise have led to the hypothesis that ice sheets can rapidly collapse through a process called the 'marine ice cliff instability'. The marine ice cliff instability is based on the idea that the finite strength of ice places a limit on the maximum ice cliff height possible at the ice sheet calving front. When buttressing ice shelves are breached exposing a thick calving cliff, catastrophic ice sheet disintegration can occur. However, the marine ice cliff instability remains a new and untested hypothesis. Here, we examine modern and past evidence that informs the theoretical and observational basis for the marine ice cliff instability to show that the observations of Antarctica, Greenland, Svalbard and Alaskan glaciers are broadly consistent with the 'upper bound' on ice cliff height suggested by theory. We further show that invoking a maximum cliff height can help explain large-scale patterns of modern glacier advance and retreat and—subject to idealized forcing—Heinrich Events. In all of our simulations, ice sheets evolve to a state where they are vulnerable to small perturbations. Small perturbations associated with modest changes in ocean forcing (or other factors) at the calving front can then trigger sustained rapid retreat and drawdown. Surprisingly, however, applying the model to project the fate of Pine Island and Thwaites Glaciers, in the Amundsen Embayment section of modern West Antarctica, we find that rapid uplift associated with the low mantle viscosity inferred in the region has a strong stabilizing effect that can not only arrest ice sheet retreat, but also leads to subsequent re-advance. This suggests that regional solid Earth structure may play a larger role than previously recognized in century time scale projections of sea level rise and climate change.

O-3226

## Combining coupled ice sheet - sea level modelling and palaeo data to understand the mechanisms and timing of ice sheet change

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### Abstract

Modeling paleo ice sheet and sea level changes has classically been approached by either (i) modeling the response of a single ice sheet to past climate changes with a dynamic ice flow model, or (ii) inferring ice cover history through inputting prescribed ice cover changes into a glacial isostatic adjustment model, predicting geographically variable global sea level changes, and comparing to palaeo sea level records. More recently, coupled ice sheet – sea level models have been developed that simultaneously predict dynamic ice sheet evolution in response to a changing climate and global sea level changes as well as considering the feedbacks that arise between these systems. These coupled models represents a new tool for self-consistently capturing regional ice sheets and their contributions to nearfield and farfield sea level changes globally, allowing for comparison to a wide range of ice age datasets. I will present the results of recent work combining coupled modeling and palaeo data to give insight into the timing, magnitude and mechanisms of past ice sheet evolution and associated sea level changes. I will also discuss the potential for inter-hemispheric teleconnections between ice sheets through sea level change. Specifically, results will highlight how, by combining coupled modeling with iceberg-rafted debris records and relative sea level data, we can assess the influence of sea level changes associated with Northern Hemisphere ice sheets on the evolution of the Antarctic Ice Sheet during the last glacial cycle.

O-3227

## Fully coupled simulation of the Northern Hemisphere climate and ice sheets during the Last Glacial Maximum with CESM/CISM2.1

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### Abstract

We present preliminary results of a project aiming to produce the first transient fully coupled climate/ice sheet simulation of the last deglaciation using the newly released Community Earth System Model 2.1 (CESM2.1). The main goal of the project is to investigate the role played by the different feedbacks and dynamical processes in controlling the deglaciation of the Northern Hemisphere ice sheets. The new model setup now includes interactive coupling between atmosphere, ocean, sea-ice and land components with a dynamic Ice Sheet Model (Community Ice Sheet Model 2.1, CISM2.1). Additionally, a one-way coupling between the ocean model (POP2) and CISM2.1 has been added in order to explicitly calculate ocean melting rates under the ice shelves.

Here, CESM-CISM2.1 is used to produce the first fully coupled 1° climate – 4 km ice sheets simulation of the Northern Hemisphere at the Last Glacial Maximum (LGM, 21 ka). The Earth System Model is forced according to the protocols of the Paleoclimate Modelling Intercomparison Project 4 (PMIP4), whereas the input paleobathymetry and ice sheet reconstruction are generated using a different global Glacial Isostatic Adjustment (GIA) model than in PMIP4. The recently updated empirically-constrained Eurasian Ice sheet reconstruction (developed as part of the BRITICE-CHRONO project) and the Greenland - North American ice sheets chronologies taken from Lecavalier et al., 2014 are combined and used as input for the GIA model.

A key feature of the CESM2.1 model setup is the bi-directional coupling between the land and ice sheet model, where the surface mass balance (SMB) and near-surface air temperature fields are computed at multiple elevations and then downscaled to the active ice sheet regions. Additionally, using the new one-way coupling from the ocean to the ice sheet model, the simulated depth-varying ocean temperature and salinity are used to force CISM2.1 during run-time. The simulated climate and ice sheets will be evaluated against a range of published empirical constraints. We encourage input from the community for further possibilities for model-data comparison and integration.

O-3228

## Using Antarctic ice sheet palaeo-thinning rates to constrain numerical ice sheet model outputs.

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### Abstract

Geo-chronological data can constrain past configurations of ice sheets and act as empirical tests of modelled deglaciation scenarios. One technique that has been widely applied is cosmogenic exposure dating with the resulting ages conventionally used to define the timing of deglaciation for a particular site. Numerical model outputs can be compared to such data and scored accordingly. However, the spatial distribution and contiguity of geological data and model outputs are fundamentally different. This requires assumptions to be made about how well a point geological measurement represents larger scale ice-sheet configuration changes. Additionally, systematic uncertainties related to the dating technique add additional but unquantifiable uncertainty to each measurement meaning future refinements in the dating technique can affect existing model-data comparisons. The potential to compare ice sheet model output to *rates* of change has advantages over individual measurements. Rates reconstructed with a single nuclide (i.e.  $^{10}\text{Be}$ ) will be broadly insensitive to systematic uncertainties and rates can be reasoned on glaciological grounds to be representative of ice sheet change on scales similar to, and greater than, grid resolutions commonly used in modelling.

We present a collation of cosmogenic exposure ages from exposed nunataks in Antarctica that have been used, or have the potential to be used, to constrain rates of thinning of the Antarctic Ice Sheets since the Last Glacial Maximum. We present thinning rates, modelled by Monte Carlo linear regression analysis, from 23 sites across Antarctica. Palaeo-thinning rates are spatially variable with high rates appearing to correlate to areas of contemporary rapid changes. On centennial timescales past thinning rates are comparable to modern day observations implying that modern day thinning has the potential to persist for centuries in numerous parts of Antarctica. The thinning rate data set is the first Antarctic-wide collation of past ice sheet thinning rates and provides an empirical starting point for model-data comparisons. We outline our approach to utilising this data-set to score an ensemble of modelled Antarctic deglaciation scenarios to improve understanding of the evolution of the Antarctic Ice Sheet throughout the last glacial cycle which has important implications for understanding its present-day contribution to sea-level change.

O-3229

## Numerical reconstruction of the Rhine glacier advance across the Swiss lowlands at the LGM using PISM to Elmer/Ice downscaling

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### Abstract

The flow of ice and basal conditions during past and future glacial advances in the Swiss lowlands are aspects to consider for assessing how glacial erosion may affect the long-term safety of proposed deep geological repositories for high-level radioactive wastes in Switzerland. We develop a high-resolution fully coupled thermo-mechanical three-dimensional transient ice flow model of the Swiss lowlands solving the Stokes and energy equations using Elmer/Ice for the period leading to the Last Glacial Maximum (LGM). A key difficulty to set up the model resides in the initialization which is difficult to constrain for the period just prior to the LGM (unknown ice extent, ice thickness and temperature). To overcome this difficulty, we run a sequence of two models of different complexities at different spatial and temporal scales. First, we run PISM (the Parallel Ice Sheet Model), a simplified shallow-ice shallow-shelf ice sheet model, over the entire western and central Alps from the last interglacial to the LGM. Then, we use the three dimensional full-Stokes ice flow model Elmer/Ice, initialized with ice thicknesses, temperatures, and ice extent obtained from PISM at a couple of thousand years before the LGM. The Elmer/Ice model is run forward in time up to the glacial maximum, giving a much more detailed and physical picture of the dynamics of the Rhine Glacier than the one given by PISM. We compare modeled ice extent at the LGM with moraine position, computed ice flow paths with evidence of striae and other ice flow indicators, basal conditions (temperate vs frozen bed) with features of past glacial erosion, and evidence of subglacial and ice-marginal meltwater channels with subglacial water flow paths computed from hydraulic potentials. Of particular interest are the basal conditions over the proposed deep geological repositories. We compute the duration of ice cover and the sliding distance (a first order estimate of glacial erosion) over these areas and develop criteria for estimating the potential for glacial erosion there.

O-3230

## Model simulation of the British-Irish Ice Sheet using BRITICE-CHRONO age assessments; non-steady and asymmetric retreat, ice shelves and collapse events.

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### Abstract

The BRITICE-CHRONO consortium of researchers has been a six-year project to constrain the timing of retreat of the last British-Irish Ice Sheet (BIIS) by a systematic dating programme focused on the marine-to-terrestrial transition. From two research cruises (18,000 km of geophysical data and 377 vibro- and piston cores), along with numerous investigations of stratigraphic sections on land we collected samples for dating from 914 sites from which 639 new geochronometric ages have been derived (336 radiocarbon, 156 luminescence and 157 cosmogenic). Organised into eight key transects from the shelf break to tens of kilometers onshore the pattern and pace of retreat has been compiled into an ice sheet wide reconstruction of ice extent at one thousand year times steps. We then forced ice sheet numerical models to comply with these ice extents, yielding simulations of ice sheet change which incorporate known ice sheet physics pertaining to grounding lines, ice shelves, ice streams, and glacio isostatic adjustment and sea level. This empirically-constrained simulation of the last British-Irish Ice Sheet will be presented and used to address the following hypotheses. 1) that the marine-influenced sectors collapsed rapidly (<1000 years) and that once onshore the ice sheet stabilised and retreated more slowly; 2) that the main ice catchments draining the BIIS retreated synchronously in response to external climatic and sea-level controls.

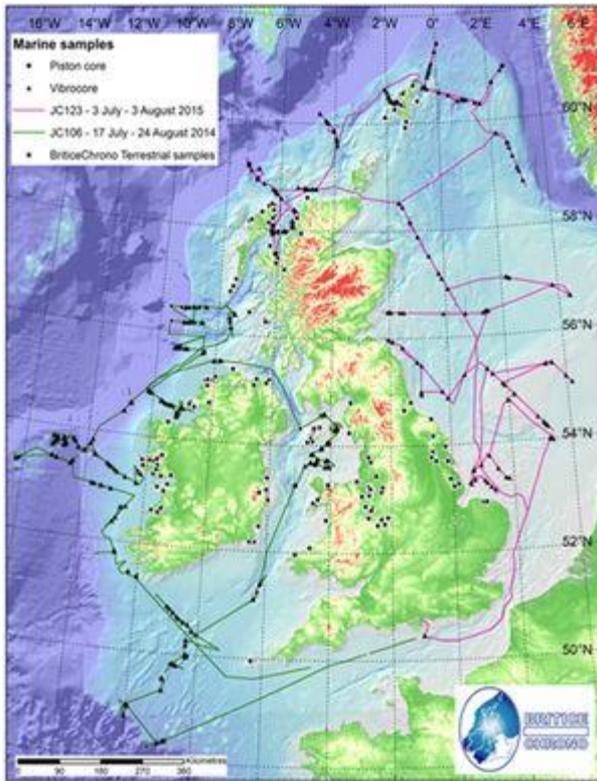


Fig 1. Summary of the BRITICE-CHRONO sample locations (n=914) used for deriving material for dating ice advance and retreat.

O-3231

## Modelling the generation, evolution, and pattern of ice stream flow over Britain and Ireland with the BISICLES ice sheet model

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### Abstract

Ice stream evolution is a major uncertainty in projections of the future of the Greenland and Antarctic Ice sheets. Basal processes and properties, like bed strength and meltwater availability, determine how ice streams flow. These are most commonly estimated in ice sheet models from inversions of surface velocity observations. However, basal properties evolve over a variety of timescales. Such feedback processes are not represented when basal sliding parameters are inverted, making them unsuitable for modelling ice streams over centennial and millennial timescales. An alternative is to incorporate these basal sliding feedbacks into a state-of-the-art ice sheet model, and to test the model on palaeo ice sheets. The palaeo-record provides snapshots of ice stream evolution, with a particularly well constrained ice sheet being the British-Irish Ice Sheet (BIIS).

We implement a new basal sliding scheme coupled with thermomechanics to BISICLES, a higher-order ice sheet model, to simulate the evolution of the ice streams of the BIIS. We find that the simulated location and spacing of ice streams matches well with the empirical reconstruction of ice stream flow (figure 1). Locations of troughs and calving margins are found to be a major control on the ice streams of the BIIS, whilst geothermal heat flux distribution was found to be a significant control offshore of western Ireland. We show that the empirical palaeo record is an essential test of the skill of ice sheet models, particularly when simulating the location, spacing, and migration of ice streams through centuries and millennia, since the extensive empirical record of the BIIS has allowed for the calibration of model parameters. We also demonstrate how model simulations can inform empirical evidence, with our model results stimulating further evaluation of the empirical record, including mapping offshore subglacial bedforms in regions of simulated ice streaming.

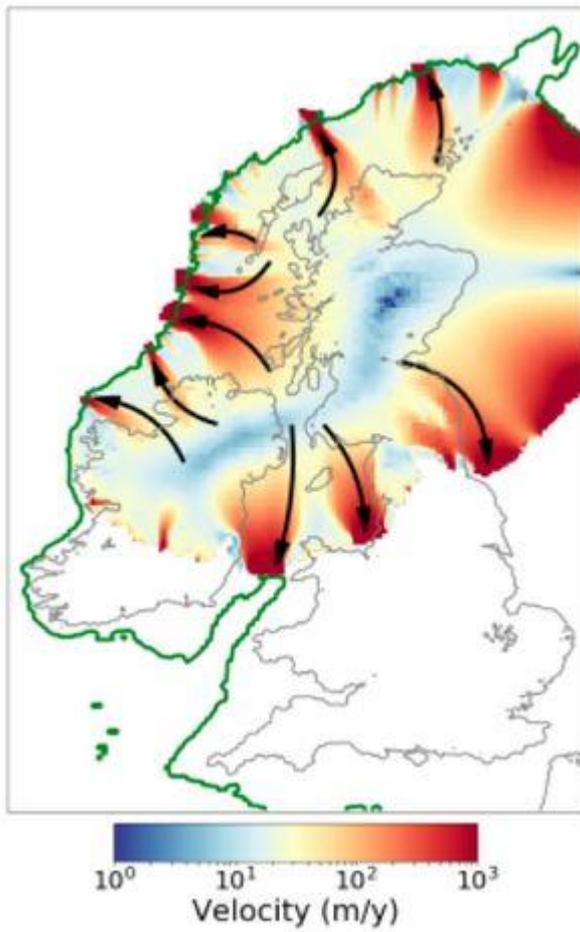


Figure 1: Simulated ice streams of the British-Irish Ice Sheet using a new basal sliding scheme in the BISICLES ice sheet model. Black arrows show locations of key empirically reconstructed ice streams.

**O-4001**

## **Pre-Columbian polyculture agroforestry systems on Amazonian Dark Earths**

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### **Abstract**

The highly modified soils generally located along the bluffs of the Amazon River and its major tributaries, known as Amazonian Dark Earths (ADEs), are arguably the most compelling evidence of human transformation of tropical environments in the Americas. Although soil scientists have made major progress in the understanding of the genesis of these archaeological sites, very little was known until recently about the land use practices carried out on these soils in pre-Columbian times. This presentation summarises and presents new combined archaeological, archaeobotanical, palaeoecological (lake and terrestrial) and climate data on land use on ADEs across Amazonia resulting from the University of Exeter's PAST project from Santarem (Lower Amazon), the Middle-Purus Madeira River (Central Amazonia) and Versalles (Bolivian Amazon). We provide new insight on agricultural practices, fire regimes, land cover and vulnerability to climate change of these past systems. We briefly discuss, their legacy and its implications for management and conservation efforts on Amazonian sustainable futures under current threat from climate change and development.

O-4002

## Widespread mid-Holocene population decline in South America: identifying thresholds and impacts

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### Abstract

Quantifying the impacts of climate change on prehistoric societies is crucial for understanding the adaptive pathways taken by humans in response to stress. While archaeologists in South America have identified periods of regional abandonment during the mid-Holocene (8200 to 4200 calendar years before present), the extent to which local patterns and ‘archaeological silences’ can be generalised and linked to large-scale trends has remained unclear. We present and integrate archaeological and palaeoclimatic data to show that multiple, sustained phases of population collapse occurred coeval with the mid-Holocene transition at the scale of the entire South American continent.

Employing a large and spatially extensive database of radiocarbon dates for the interval 12000 – 2000 cal BP as a proxy for relative prehistoric population levels, we are able to show to multiple demographic contractions dating to the mid-Holocene. Placing summed probability distributions of calibrated radiocarbon dates within a robust statistical framework, we are able to model the duration and relative severity of demographic decline. Outlier analysis of a selection of precipitation proxies with full latitudinal coverage of South America suggests that the frequency of anomalous climatic events may be a better predictor of Neotropical demographic downturns than the absolute magnitude of climate change (i.e. aridification). We note the increasing visibility of domesticated and managed plant resources starting in the early Holocene, and adds to the body of evidence that their importance was amplified after 8200 cal BP, possibly in response to flux in wild resource bases.

Together, these data allow us to place our findings in the context of previous work on the ‘Archaic Gap’ and ‘archaeological silences’ of the Middle Holocene in South America and greatly enhance archaeological knowledge on this topic. Variation in the distribution and configuration of complex social formations, diversified resource bases, and large-scale anthropic modifications to the environment in South America by European Contact may ultimately be rooted in conditions established and propagated following the mid-Holocene population bottleneck. More broadly, our results shed light on the limits of forager adaptive resilience in the face of abrupt climate change, and raise questions about what thresholds may constitute “sufficient” climatic or environmental variability, and the time frame over which it must occur, to trigger responses from human societies.

O-4003

## Comparing human population growth rates between hunter-gatherers and complex agrarian societies: from competition to cooperation feedback processes

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### Abstract

The modern sciences of economics, human demography, and population dynamics started with Malthus, who suggested that populations grow geometrically as food resources expand at an arithmetic rate. Concerned for the unprecedented human population growth after the Industrial Revolution, demographers and population ecologists - 200 years after the publication of Malthus's book- have found a common conceptual framework for unfolding the feedback relationship between human demography, global climate and natural resources sustainability. Now it is well-documented that past hunter-gatherer and complex agrarian societies experienced demographic boom and bust cycles, or even collapsed. Despite of some recent studies on the collapse of human societies, the problem still remains poorly understood. So, to make strong cases for collapses in pre-historic societies, we combine the principles and elements of Population Dynamic theory and procedures to evaluate the impacts of climate variability and/or internal societal variables on the resources supply, and how these effects propagated into the demography. **In particular, we are interested in comparing the population dynamic patterns of boom and bust cycles between simple hunter-gathered and complex agrarian societies that have inhabited the Americas over the last 8,000 years.** Hence, this study pretends to provide a detailed comparison for history of pre-Hispanic collapses through the recompilation and analysis of paleodemographic data. In addition, to delineate a comparative analysis of population dynamics for detecting converges and divergences in the collapsing process among pre-Hispanic agrarian societies that differ either in socio-political complexity or environmental settings.

O-4004

## PEOPLE3K: Shifts in coastal upwelling drive cultural and demographic changes in hunter-gatherers of northern Chile during the mid-Holocene

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### Abstract

Shell middens are human refuse mounds left behind by coastal dwellers and are found throughout coastal northern Chile, where they span more than 9000 years. Early to mid-Holocene shell middens accumulated from the discarded remains of terrestrial plants and shellfish discarded by local coastal hunter-gatherer cultures known as the Chinchorro. These shell middens can accumulate very quickly with one midden accumulating 3 m in 500 years. By radiocarbon dating samples of marine and terrestrial origin along a given stratigraphic horizon, shell middens can be used to estimate local (or regional) marine reservoir departures from the global marine <sup>14</sup>C calibration curve ( $\Delta R$ ). These departures are due to shifts in upwelling as different water masses have different apparent <sup>14</sup>C ages. Our well-replicated  $\Delta R$  chronology is based on 102 <sup>14</sup>C AMS dates and spans more than 9,000 years. The record was developed from several different shell middens located along 100 km of coastline in northern Chile.  $\Delta R$  records were remarkably stable during the early to mid-Holocene and averaged  $\sim 270$  yrs implying very stable upwelling and highly productive marine ecosystems which coincided with an exponential increase in coastal populations as reconstructed from a regional Summed Probability Distribution (SPD) of archaeological <sup>14</sup>C-dates.  $\Delta R$  values are highly variable between 6.5 – 6.3 ka and 5.4 – 4.7 ka, with oscillations in  $\Delta R$  exceeding 1000 yrs. This implies strong environmental fluctuations associated with variable upwelling conditions possibly tied to changes in the long-term behavior of El Niño-Southern Oscillation (ENSO) and the South Pacific High (SPH). These variations were coeval with one of the largest coastal population collapses in northern Chile during the mid-Holocene. Conditions stabilized after 4.7 ka until 2.4 - 2.0 ka when large excursions again occur in our regional  $\Delta R$  record and coincide with the near extinction of coastal hunter-gatherers and increased interactions with agricultural societies along coastal northern Chile. Such changes were likely driven by large-scale climate change (such as regional ENSO or SPH variability) and may be one of the key factors behind most large-scale demographic changes and coastal resource use seen in the remarkable coastal hunter-gatherer societies that inhabited northern Chile.

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**O-4005**

## **Contributions of IRSL and $^{14}\text{C}$ geochronology and sediment geochemistry to the issue of initial settlement in the New World**

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### **Abstract**

Early archaeological sites from central Alaska (USA) have been dated using Optically Stimulated Luminescence (OSL) in order to document the arrival, adaptation and dispersal of early human groups in America. Eolian sediment samples (loess) from stratigraphic profiles in several localities have been systematically dated using this method and compared to the radiocarbon ages for the different human occupations. The interpreted geochronology suggests a human occupation of the area at the end of the Upper Pleistocene, which is in good agreement with the regional archaeological framework.

A relation can be made between the sedimentation rates and the territorial occupability patterns of the early human groups present in central Alaska. This relationship is implicitly related to paleo-environments as well as climate changes, since the accumulation rates of eolian sediments can be directly correlated with the glacial context of the region, and thus with the environmental processes of the past.

Geochemical analyses have been conducted on material sampled from the chronostratigraphic profiles in order to characterize the evolution of paleo-environment through the end of the Pleistocene and the Holocene periods.

A measurement protocol for the luminescence dating method with infrared stimulation (IRSL) has been developed to obtain accurate and reliable results for the minerals extracted from these late glacial loess sediments. The low temperature LPH-IRSL (Low preheat IRSL) protocol thus allows in this case the establishment of a detailed geochronological framework for the Central Alaska region, contributing to better refine the initial settlement in the New World.

O-4006

## Non-linear soil evolution trajectories from the Holocene to the Anthropocene

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### Abstract

Soils have a substantial role in the environment as they give back several ecosystem services as food supply and carbon storage. But agricultural practices can modify soil properties and soil evolution processes, threatening these services. These modifications are poorly studied and resilience/adaptation times of soils to disruptions are unknown on pedogenesis time scale.

Lake sediment sequences can be used as continuous archives of long soil evolution. The study of four lake-catchment systems from the western North Alps inquires both soil evolution and the development of human activities throughout the Holocene.

The compared multiproxy analysis of sedimentary sequences of Lake La Thuile (875 m, Bauges), Lake Bénit (1450 m, Barge), Lake Gers (1540 m, Giffre), Lake Verney (2088 m, Italy, Petit Saint-Bernard Pass) and the soils of their catchment, allowed to decipher the interactions between agro-pastoral system, erosion and soils. Our main objective is to determine whether human became, over the Holocene, the overriding factor of the pedogenesis and what are the ecosystem responses to disruptions, in terms of resilience and sustainability.

The comparison of paleoenvironmental reconstructions, derived from lacustrine archives evidenced a progressive development of soils during the first part of the Holocene, associated with substrate decarbonation, acidification then podzolization of soils in the Holocene Climate Optimum. The second part of the Holocene is characterized by regressive pedogenesis, in response to agro-pastoral activities development, mainly around the Roman and Medieval periods, along with erosion increases. Environmental disruptions triggered colluviation movements and a regression of soil weathering, leading to a multiplication of (non-linear) soil evolution trajectories and a higher soil diversity in the Anthropocene.

The soils developed until first human settlements present a higher capacity of resistance to erosion than soils developing thereafter. Resilience processes appear to be dominated by the establishment of new agroecosystem equilibrium states and attest of the deep modifications performed on mountain environments for several millennia. These modifications are recorded by the soils and triggered the expression of aftereffects on current land use. Interactions within the critical zone form a dynamic whole linked together by human who appears as the main pedogenetic factors in the Anthropocene.

O-4007

## Cyanobacteria secondary metabolites: New proxies for past environmental change

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### Abstract

We present a new proxy for past climatic and environmental variability: cyanobacteria secondary metabolites (CSMs). Cyanobacteria are ubiquitous, tolerating climatic (e.g. temperature) and environmental (e.g. nutrient) variability more successfully than other organisms. This adaptability has made cyanobacteria one of the longest existing life-forms, with geologic evidence showing their existence since the Archaean (~3.5 billion yr. BP). Freshwater cyanobacteria produce a number of unique CSMs (e.g. microcystin, nodularins, moturporin). These species-specific secondary metabolites are easily identifiable and clearly distinguishable from those produced by other organisms.

CSMs archived in lake sediment cores reflect varying diversity in populations of freshwater cyanobacteria through time. A 2000 year old sediment core has been extracted from the dairy-surrounded Lake Kopureherehere, lower North Island, New Zealand. The record encompasses pre-human New Zealand, Polynesian arrival (ca. 800 yr BP), Māori settlement, European arrival (ca. 200 yr BP) and modern land-use intensification. Samples from the core have been analysed for CSMs by MALDI, gas chromatography mass spectrometry and high-performance liquid chromatography mass spectrometry. The mass spectrometry results are compared with our database of CSM molecular weights, and are used to identify the corresponding cyanobacteria species.

Human-driven changes in land-use are characterised by pollen, charcoal and stable isotopes ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values). These proxies show significant changes in vegetation through time, corresponding with human activity on the landscape. Results indicate that cyanobacteria respond to human-driven changes in landcover (e.g. vegetation) during the late Holocene. Our findings suggest that our new method for reconstructing past lake health is successful.

O-4008

## Decadal-scale progression of Dansgaard-Oeschger warming events

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### Abstract

During the last glacial period, the Greenland ice core records show a succession of rapid, millennial-scale warmings, called Dansgaard-Oeschger (DO) events. Their widespread environmental impact is documented in proxy records throughout the Northern Hemisphere. A range of different mechanisms have been proposed that can produce similar warming in model experiments, however the progression and ultimate trigger of the events still remains elusive. Especially the spatio-temporal progression of environmental changes at the onset of the warm events can yield valuable insight into possible trigger mechanisms. However, because of their fast nature, this progression is challenging to reconstruct from paleoclimate data due to the limited temporal resolution achievable in many archives and cross-dating uncertainties between records.

In the presented study we present new high-resolution multi-proxy records of sea-salt (derived from sea spray and sea ice over the North Atlantic) and mineral dust (derived from the Central Asian deserts) aerosol concentrations over the period 10–60ka from the Greenland NGRIP and NEEM ice cores. We use these records in conjunction with local precipitation and temperature proxies from one of the cores to investigate the progression of environmental changes at the onset of the warming events at annual to multi-annual resolution.

Our results show on average a small lead of the changes in both local precipitation and terrestrial dust aerosol concentrations over the change in sea-salt aerosol concentrations and local temperature of approximately one decade. This suggests that, connected to the reinvigoration of the Atlantic Meridional Overturning Circulation and the warming in the North Atlantic, both synoptic and hemispheric atmospheric circulation changed at the onset of the DO warmings, affecting both the moisture transport to Greenland and the Asian monsoon systems. Taken at face value, this suggests that a collapse of the sea-ice cover was not the initial trigger for the DO events.

O-4009

## Synchronous timing of abrupt climate changes during the last glacial: evidence from the compilation of speleothem records

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### Abstract

Speleothems are a key tool for improving our understanding of the global expression and timing of abrupt climate changes during the last glacial period. Precise and accurate uranium-thorium dating enables high-resolution and precisely constrained chronologies of the events to be assembled. The wide geographic distribution of speleothems permits the expression of the events in various climate regions to be examined. Numerous speleothem records have been published, yet until now, the incidence, timing or expression of stadial-interstadial changes in these records has not been rigorously compared.

Here we compile 64 published speleothem records to assess the degree of global synchrony in the timing of the onset of interstadials. All records were standardised by recalculating the uranium-thorium ages using the latest decay constants and performing an optimal correction for detrital thorium. Depth-age relationships were then remodelled using a Bayesian Monte Carlo based age-modelling technique to produce a revised chronology for each record from which the onset of interstadial conditions were identified. Statistical methods were then employed to compare the timing of events between records.

We show that climate changes associated with abrupt high-latitude warming were synchronous to within a few decades to a century across the Europe-Mediterranean, Asian monsoon and South American monsoon regions, indicating that high-latitude climate changes were rapidly transmitted to the tropics. Strong evidence for such synchrony permits us to combine the speleothem event timings to produce exceptionally precise estimates for the onset of interstadials. We compare the combined speleothem event timings to the timing of interstadials in the GICC05 chronology. We do not detect any systematic ice-core-to-speleothem age difference that could be linked to either background climate state, or interstadial duration, amplitude and rate of warming, although there is a tendency for GICC05modelext to be slightly older between 75-70 kyr BP and slightly younger between 111-104 kyr BP. These comparisons strongly support the accuracy of the GICC05 (including GICC05modelext) chronology, but suggest that the quoted uncertainties are too conservative. Our study provides unprecedented chronological information on the timing of climate changes during stadial-interstadial transitions, with important ramifications for understanding regional synchrony, and for refining the ice-core chronology.

O-4010

## A new 200ka reference record for precipitation isotopes based on Gibraltar speleothems

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### Abstract

Gibraltar, located at the gateway between the Atlantic and the Mediterranean marks a climatologically important position at the southern limit of Atlantic storm tracks. We present a near-continuous multi-proxy speleothem record spanning the modern day to 200 ka. The record is anchored to a chronology based on over 200 high precision U-Th ages and the stable oxygen and carbon isotope records sampled by micromilling provide decadal to sub-decadal time resolution. Eight years of cave environmental monitoring precede this study and provide critical evidence for the main meteorological and environmental controls on proxy variability and speleothem capture of western Mediterranean terrestrial climate.

Records from the recent past and cave monitoring clearly show that  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  in modern speleothem calcite are controlled by seasonal within-cave processes dependent on external temperature and water balance. The older Gibraltar record shows variations in  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  on timescales from multi-decadal to multi-millennial which we compare with independently dated records including long marine core sequences and the Greenland ice core record. The radiometrically dated Gibraltar speleothem chronology provides a precise reference record to correlate with other proxy records, and we can demonstrate remarkable correspondence with the timing of change in Greenland temperature for much of the last glacial period. However, we note that periods in which the rates of change of Gibraltar water isotopes and Greenland temperature are more complex and provide evidence of other regional climatic influences. Trace elements provide evidence for other aspects of environmental change such as aridity, vegetation activity, and colloidal transport processes from the soil into the cave system.

The Gibraltar speleothem record provides a new precisely dated reference record for comparison with previously published datasets and for mapping isotope gradients across the Mediterranean and Europe over glacial-interglacial intervals.

O-4011

## A new speleothem record of the penultimate deglacial: insights into spatial variability and centennial-scale instabilities of East Asian Monsoon

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### Abstract

Shandong peninsula is climatically dictated by East Asian monsoons and bordered by the Bohai Sea and Yellow Sea in East Asia, two marginal seas with less than 100 meters water depth at present time. As continental ice sheets built up and sea level fell down, the coastline shifted southeast, and likely shifted 800-1000 km during the last glacial maximum when sea level was ~120m lower than at present time. This tremendous shift of coastline could have substantial impacts on the climate at Shandong peninsula. Here, we present a high-resolution and precisely dated speleothem isotope record from the Shangxiaofeng Cave and reconstruct the history of precipitation  $\delta^{18}\text{O}$  spanning the penultimate deglaciation in Shandong peninsula, northern China.

The results of the  $\delta^{18}\text{O}$  analysis reveal two outstanding features. Firstly, our  $\delta^{18}\text{O}$  record magnitude of the glacial-interglacial change (~0.7‰) is significantly smaller compared to those (1.4-2.4‰) of the  $\delta^{18}\text{O}$  record from Southern China (Dongge, Sanbao and Yangkou caves). Assuming that all  $\delta^{18}\text{O}$  records mainly reflect precipitation isotope composition changes above the caves, the glacial-interglacial  $\delta^{18}\text{O}$  difference between the various Chinese caves could be related to changes in atmospheric circulations, changing effect of altitude between the various caves and climate mean states, and particularly large-scale changes in regional land-sea coverage due to sea level changes. The latter leads to disappearance and expansion of Bohai and Yellow seas during glacial and interglacial episodes, respectively, and likely affect the isotope composition of precipitation.

Secondly, the SD1  $\delta^{18}\text{O}$  record of the penultimate deglaciation documents the instabilities which show the abrupt shifts center at ca.134.5ka, 132.8ka and 131ka BP, coincident with so called "H11 complex" identified from marine sediments. We also identified a brief excursion with enriched  $\delta^{18}\text{O}$  centered at 128.3 ka BP and last ca. 400 years, implying a Younger-Dryas-type event during the penultimate deglaciation.

Taken together, our study highlights that hydroclimate imprints of the East Asian Monsoon changes during the penultimate glacial-interglacial cycle were spatially heterogeneous and centennial-scale monsoonal hydroclimate instabilities are inherent features of deglacial climate transition.

O-4012

## Climate change since the Last Interglacial at Orakei Basin, northern New Zealand

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### Abstract

The terrestrial southern mid latitudes are underrepresented in palaeoclimate research, which causes a gap in our understanding of regional complexities of global past climate compilations. We present a new pollen record and associated mean annual air temperature (MAT) reconstruction from Orakei Basin, northern New Zealand that can help fill this gap. The crater contains ~85 m of lacustrine sediments and peat, which accumulated between the Last Interglacial and the Early Holocene, when the crater rim was breached by the ocean. The age-depth model for the core is based on tephrostratigraphy, radiocarbon dating, luminescence dating on feldspars, paleomagnetic variation and Beryllium-10 variation.

We compare the Orakei Basin record to the numerous fragmentary terrestrial records from New Zealand, to the Okarito Pakihi pollen record in southern New Zealand (Newnham et al., 2007), to speleothem, glacial geomorphic and marine records from the region (Williams et al., 2015), the LR04 marine stack (Lisiecki and Raymo, 2015), and to ice core records from Greenland and Antarctica. Paleomagnetic excursions, such as the Laschamp event (~41 ka), and volcanic ash layers such as the Kawakawa/Oruanui tephra (~25.4 ka), can act as anchor points in these comparisons.

The Orakei Basin record shows five distinct phases comparable to Marine Isotope Stages (MIS) 5 to 1. The broad similarity of the Orakei MAT trend to the MIS and other records from New Zealand implies all were driven by northern high-latitude summer insolation, consistent with the Milankovitch orbital forcing hypothesis. Several patterns superimposed on the general trend stand out: firstly, MIS 4 is a brief cool period, which is different from the observation that glaciers were more extensive in New Zealand's Southern Alps during MIS 4 compared to MIS 2, possibly due to the seasonal distribution of energy from solar insolation. Secondly, MIS 3 displays an earlier warm phase followed by a progressive cooling trend which might be correlated to decreasing local summer insolation intensity. Thirdly, glacial conditions of MIS 2 appear consistent with the early onset of the Last Glacial Maximum in the southern mid latitudes, which was likely driven by regional insolation intensity. Together, these results point out the importance of considering regional-to-local drivers of climate changes superimposed on global reconstructions.

Future planned work on this core includes increasing the resolution so abrupt climate change events (such as Dansgaard-Oeschger cycles or Antarctic Isotope Maxima) can be identified, and developing a chironomid record, from which summer air temperatures can be reconstructed, allowing a look into past seasonality.

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O-4013

## Evaluating existing discrete-depth $^{14}\text{C}$ dating practices in deep-sea sediment archives.

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### Abstract

For a number of decades, radiocarbon ( $^{14}\text{C}$ ) dating has been readily applied to deep-sea sediment archives. The material that is typically  $^{14}\text{C}$  analysed from these archives is the calcareous tests of foraminifera. The  $^{14}\text{C}$  method, however, has traditionally required at least 1 mg of carbonate material, meaning that researchers have typically had to pick tens to hundreds of individual specimens from a single discrete core interval (typically 1 cm of core depth) and pool these into a single subsample for analysis. Such pooled samples are not heterogeneous in  $^{14}\text{C}$  age, and  $^{14}\text{C}$  measurements of pooled samples only report the mean  $^{14}\text{C}$  activity and machine measurement error, thus concealing the true intra-sample  $^{14}\text{C}$  age heterogeneity (i.e., the full analytical error). Failure to consider the effects of  $^{14}\text{C}$  age heterogeneity of pooled samples can lead to downcore  $^{14}\text{C}$  age artefacts caused by the interplay between post-depositional vertical mixing of foraminifera (bioturbation), the dynamic  $\Delta^{14}\text{C}$  history of planet Earth, and the fact that  $^{14}\text{C}$  is a radioisotope (i.e., younger foraminifera specimens within a pooled sample contribute exponentially more to the mean  $^{14}\text{C}$  activity of a pooled sample).

Here, a newly developed model (the **sediment accumulation simulator** - SEAMUS) is used to evaluate the baseline accuracy of  $^{14}\text{C}$  dating in deep sea sediment cores, by simulating the deposition and bioturbation history of single foraminifera within the deep sea sediment archive, using established understanding of  $\Delta^{14}\text{C}$  history and bioturbation processes. To represent such a baseline scenario, we consider 'best case scenarios' involving constant sediment accumulation rate, constant bioturbation depth, constant foraminiferal species abundance and constant  $^{14}\text{C}$  reservoir age. The simulation results indicate that even such 'best case scenarios' can exhibit large  $^{14}\text{C}$  age artefacts (> 100  $^{14}\text{C}$  yr) in pooled samples, particularly during periods of dynamic  $\Delta^{14}\text{C}$  history (such as the Younger Dryas and the Laschamp event) and in the case of lower sediment accumulation rates (< 10 cm/ka). Furthermore, such  $^{14}\text{C}$  age artefacts are greatly amplified during the  $^{14}\text{C}$  calibration process, producing large calendar age artefacts (> 200 calendar years), even in the case of higher sediment accumulation rates (> 40 cm/ka).

These findings highlight the pressing need to develop an improved  $^{14}\text{C}$  calibration algorithm for deep sea sediment cores, whereby a bioturbation *a priori* is implemented. Furthermore, these findings also highlight the importance of single foraminifera  $^{14}\text{C}$  analysis for furthering our understanding of the palaeoclimate signal in deep sea sediment cores.

O-4014

## Volcanic synchronization of abrupt climate change in Greenland and Antarctic ice cores during the last glacial period

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### Abstract

The sections of Greenland and Antarctic ice cores covering last glacial period have previously been synchronized primarily by their common records of gas concentrations and cosmogenic isotopes. Here, we apply annual layer counting and matching of volcanic peak patterns to synchronize the onsets and terminations of Greenland Interstadials (GI) in Marine Isotope Stage 3 (MIS3, 25-60 ka). Based on the identification of more than 50 significant bipolar volcanic events throughout MIS3, most abrupt climate events can be synchronized between the two Hemispheres at decadal precision. Layer counting has been performed in the Greenland NGRIP and the Antarctic EDML ice cores using high-resolution records of chemical impurities, dust, and visual grey scale intensity. The time scales obtained from layer counting are not always in agreement with existing ice core chronologies. Volcanic peak patterns have been identified in all available acidity records from the Greenland GRIP, GISP2, NGRIP, and NEEM and the Antarctic EDML (Atlantic sector), EDC (East Antarctic plateau), and WDC (West Antarctica) ice cores. The obtained volcanic synchronizations within Greenland and within Antarctica are in agreement with existing volcanic synchronizations. The bipolar volcanic synchronization is supported by cosmogenic record patterns at several of the major GI onsets and it is in accord with the cosmogenic synchronization at around the geomagnetic Laschamp event (41 ka). The bipolar volcanic synchronization is offset from the NGRIP-WDC methane synchronization by up to 150 years, generally pushing the Antarctic record towards older ages at the GI onsets. The general Antarctic response to a GI onset is a direct warming at the EDC and WDC sites that peaks within a century and a less significant cooling at the EDML site, possibly attributed to a northward shift of the southern hemisphere westerly winds. This pattern is, however, not consistent among all GI onsets and in particular the weaker GI events show deviating Antarctic response patterns. Several of the sharp Greenland climate transitions in MIS3 are associated with periods of strong volcanism suggesting that volcanism may work as a trigger of abrupt climate change. Other abrupt transitions are not associated with volcanism and many strong volcanic events do not show a response in the climate records. Overall, the bipolar volcanic synchronization gives strong support for the suggested bipolar seesaw mechanism.

O-4015

## Reconstructing palaeoenvironments in South Africa's Cape Floristic Region: a palynological approach

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### Abstract

The Cape Floristic Region (CFR) is a key focus area within southern Africa due to its botanical importance in terms of high levels of biodiversity as well as its rich cultural and archaeological heritage. The area is highly sensitive to cycles of regional and global environmental change, and records obtained from the region may provide valuable information regarding past climate variability. Prior to the last decade, few high resolution palaeoenvironmental records were recovered from the region, and therefore its environmental history was previously poorly understood. This presentation summarises some of the most important findings that have emanated from several pollen records generated over the last few years and outlines current and future directions for palynological research in this region.

The records presented are derived from unique natural archives found within the CFR and include pollen results from rock hyrax middens and coastal lowland wetland deposits that cover various portions of the Holocene, the last glacial and, in the case of one record, the last interglacial. These records document the nature and timing of past vegetation shifts and can be used to infer distinct changes in rainfall amounts and seasonality. They have improved our understanding of how different subregions (e.g. interior vs. coast) of the CFR have responded to past climate changes. Assessed in conjunction with other proxy evidence, the variability within the records suggest that the underlying drivers of climate change in this important region of southern Africa are associated with high latitude Southern Hemisphere climate dynamics (e.g. the position of the Subtropical Front and the westerlies storm track). However, more crucially, they also indicate that there is a larger degree of complexity than previously thought and highlight a series of avenues for future research.

O-4016

## Changing vegetation patterns in Border Cave, KwaZulu-Natal, South Africa, ~ 250 000 to ~ 43 000 years ago

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### Abstract

The location of this study is the Border Cave environment near the Maputaland centre of endemism in northern KwaZulu-Natal. The topic is to investigate vegetation change through time (from approximately 250 000 years (ka) ago to 43 ka and the possibility that Miombo Woodland existed before approximately 150 ka when micromammals from the palaeofaunal record included taxa that prefer a drier environment than today. Relicts of Miombo woodland still exist in northern South Africa, for example in the Soutpansberg. The method used is anthracology, which is recording anatomical features of charcoal by means of reflected light microscopy and digital photography while using the IAWA code, the InsideWood online database and modern wood charcoal reference collections. The materials studied are archaeological charcoal pieces recently excavated through the long sequence of Brown Sand (BS) and White Ash (WA) Members numbered from 6BS to 1WA. In these Members lithic technology changed from early to late Middle Stone Age, then Early Later Stone Age. The charcoal identifications show that the woody taxa represent a vegetation profile within the modern day range. There are some differences in the presence of taxa between Members 3BS (~64ka) deciduous vegetation is more strongly represented than evergreen in contrast to 2BS (~49ka) where evergreen vegetation is more strongly represented than deciduous vegetation, with seemingly little difference in eight Members. Bushveld genera are more strongly represented than forest in the Members except for Member 4WA (~115ka) and 2BS (~49ka). The vegetation profile over a long period does not suggest much change through time, that is, Lebombo Bushveld and Summit Sourveld probably persisted throughout the sequence. A comparison may be made between other archaeological sites in KwaZulu-Natal, for example, Sibudu where a mosaic of vegetation communities included evergreen forest and patches of open savanna.

Keywords: archaeological charcoal, environment, late Pleistocene, Quaternary, vegetation communities

**O-4017**

## **Tropical-extratropical rainfall systems interaction in the Southern Atacama Desert since 17ka**

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### **Abstract**

The southernmost part of the Atacama Desert (24-27°S; SAD) lies in the transitional area between the tropical and extra-tropical rainfall systems linked to the South America Summer Monsoon (SASM) and the Southern Westerlies Wind Belt (SWWB), respectively, providing a unique chance to trace their interactions in the past.

It has been largely hypothesized about the source of the rainfall associated to the different wet phases recorded in the SAD since 17ka, mainly based on the temporal and spatial patterns recorded in the different kind of archives and/or proxies. This led to some inconsistencies attributed to the different temporal and spatial scales in which palaeoclimatic archives/proxies capture the past climate variability. Furthermore, the geographic complexity of the regional climate such as variation in the sources and/or mechanisms delivering the precipitation in space over the entire SAD, made the picture in time even more complicated.

In order to trace the past palaeoclimatic dynamics at the southern Atacama Desert and then, the interaction of tropical/extra-tropical interaction of the rainfall systems since the Late Pleistocene, this paper analyzed the changes in the fossil midden pollen assemblages (same archive/proxy) in time and space aided by a modern regional vegetation-pollen-climate calibration set.

Rodent midden pollen series at 24.5°S show extremely humid conditions during the Late Pleistocene (14-10.8ka) coinciding with the Central Atacama Pluvial Event II (CAPE II) which gradually turned into extremely dry at 8.5ka which lasted until 2ka. Then, a climatic amelioration towards slightly wetter conditions occurred up to the present interrupted by a dry phase between 1.4-1.0ka. At 26-27°S, pollen assemblages preserved in fossil rodent middens reflect humid conditions between 17-13ka which gradually turned into extremely dry ones around 10ka peaking up to 9ka. During the Mid-Holocene and up to 3.3ka drier than present conditions prevailed followed by a wet phase up to 2.2ka and a dry period between 1.0-0.6ka. At 0.6ka, an increase in humidity was recorded followed by a trend to drier conditions similar to the present.

Extremely humid conditions during the Late Pleistocene and early Holocene followed by severely arid phases prevailed both at 24.5°S and 26-27°S suggesting the intensification and posterior weakening of both, tropical and extra-tropical rainfall systems. Amelioration of dry conditions occurred into the Late Holocene which was characterized by alternating dry and wet phases at the centennial scale. The increase of humidity and occurrence of wet phases at 26-27°S indicate that the extra-tropical rainfall system intensified during the Late Holocene, particularly after 3.3ka and ca. 0.6ka whereas the tropical rainfall system behaved similar to the present.  
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O-4018

## Southern Hemispheric Westerlies and global climate variability – the sediment record of Laguna Azul (southeastern Patagonia, Argentina)

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### Abstract

Multiproxy climate reconstructions are scarce for southern South America but urgently needed to improve our understanding of spatio-temporal patterns of past and future climate conditions. The presented radiocarbon-dated lacustrine sediment record from Laguna Azul (52°05' S, 69°35' W, 100 m a.s.l.) provides high-resolution data of hydroclimatic variability for southern-most South America. The investigated crater lake is located 25 km north of the Magellan Strait and was formed by volcanic activities in the Quaternary Pali-Aike Volcanic Field during the Late-Glacial. Prevalence of Southern Hemispheric Westerlies (SHW) controls the regional climate in the rain shadow of the Andes. This determining factor results in cool-temperate (6–7 °C mean annual temperature), semiarid (200–300 mm annual rainfall), windy and highly evaporative conditions with Magellanic steppe as the resulting biome. The catchment area (0.24 km<sup>2</sup>) of Laguna Azul is restricted to the inner crater walls and small in relation to the lake's water surface (0.15 km<sup>2</sup>). Today, the water body is stratified (dimictic, holomictic) with a well-developed metalimnion during southern summers and classifies as mesotrophic to eutrophic. The obtained multiproxy-sediment record documents a millennial-scale Holocene variability of SHW overprinted by centennial-scale variations between warm/dry and cool/wet phases during the Meghalayan. These climatic fluctuations influenced water-column stratification as well as lake levels with feedbacks on lakeshore erosion, algal communities, trophic conditions, bottom-water oxygenation and authigenic mineral formation. The lacustrine history started with cool/wet climatic conditions at the onset of the Greenlandian (11,600–10,100 cal BP) followed by an extended dry period (10,100–8300 cal BP) related to intensified SHW with development of a shallow lake, ectogenic meromixis, strong anoxia, methanogenesis and high salinity. During the Northgrippian (8300–4000 cal BP) the influence of SHW weakened resulting in less arid conditions and development of a deep freshwater lake. For the Meghalayan (4000 cal BP until present-day), regional temperature decreased in accordance with the onset of the Neoglacial and was accompanied by intensified SHW reaching full strength after 3000 cal BP. Superimposed on the multi-millennial SHW variability, Laguna Azul experienced century-long warm/dry spells contemporaneous with La Niña-like ENSO conditions around 2200 and 1000 cal BP as well as during the 20<sup>th</sup> century. Less arid and colder conditions occurred between these warm/dry periods. The most pronounced of these episodes are synchronous with the northern hemispheric "Dark Age Cold Period" and the "Little Ice Age". While centennial climatic fluctuations appear at the same time for Southern and Northern Hemispheres, millennial-scale variability is linked to SHW dynamics provoking distinct climatic differences between luv- and lee-sides of the Andes.

O-4019

## Patagonian glacier-climate changes during the Holocene based on $^{10}\text{Be}$ (and $^{14}\text{C}$ ) dating

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### Abstract

Mountain glaciers respond sensitively to changes in Earth's atmosphere such that records of their history serve as a useful proxy for past climates. The record of glacier behavior around Patagonia reflects former climates that affected the cryosphere at the middle to high latitudes of the Southern Hemisphere. Recently, in situ  $^{10}\text{Be}$  cosmogenic nuclide dating, combined with detailed geomorphic mapping, has been applied to Holocene-age moraines in southern and central Patagonia. We summarize at least three areas where we are focusing: there are in the drainage areas of Lago Argentino and Lago Viedma, and around the San Lorenzo massif. On the one hand, the findings indicate, in general, an early Holocene warm period with reduced glacier extents. This finding is strongly supported by other proxies, which collectively indicate a swath of warmth from the middle to high latitudes. On the other hand, observations so far indicate that smaller glaciers do register relatively brief cool periods that punctuated the generally warm early Holocene interval. By 8,000-6,000 years ago, climatic conditions favored cooling and recurrent glacier expansions for much of the remaining Holocene. At least one temporal exception of limited glacier expansion occurred from 4,000 to 2,500 years ago, which agrees with other proxy records for a relatively warm dry period. Several advances occurred during the Little Ice Age interval in Europe; however, in all areas we have worked in Patagonia – these are generally not the largest expansions of the Holocene.

We compare  $^{10}\text{Be}$  (and  $^{14}\text{C}$ ) glacier chronologies with recent reconstructions of SAM-like conditions since Late Glacial time, based on other proxy types including of past vegetation changes. Positive and negative SAM-like conditions are associated with warm/dry and cool/wet climates in central/southern Patagonia, which are favorable for reduced and expansive glaciers, respectively. We conclude that millennial and centennial intervals of generally reduced ice – from the middle to high latitudes – occur when positive Southern Annular Mode (SAM)-like conditions are persistent. We infer these intervals are times of weakening and/or poleward expansion of the Southern Hemisphere westerlies, and they are associated with reduced sea ice. Conversely, persistent negative SAM-like conditions, increased sea ice, and perhaps equator-ward focus of the westerlies are favorable for glacier expansions in Patagonia.

O-4020

## Coupled atmosphere-ocean temperature changes in southwest Pacific during the Antarctic Cold Reversal

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### Abstract

The thermal bipolar seesaw [Stocker and Johnsen, 2003] is the leading hypothesis to explain the millennial-scale temperature changes of the last glacial termination, which are of opposing sign between the polar ice cores. However, the spatial extent and temporal structure of these events outside of the high latitudes and thus, the climatic mechanisms responsible, remain poorly constrained. Here we address this shortcoming with quantitative constraints on the timing and magnitude of atmospheric and sea-surface temperature changes during the Antarctic Cold Reversal from the New Zealand region. Our new glacier-based air temperature reconstructions and foram-derived sea surface temperature record exhibit coldest temperatures within centuries of the onset of this millennial-scale event, followed by gradual warming prior to 13 ka. Placed in the context of Antarctic ice cores and the thermal bipolar seesaw hypothesis, our evidence for centennial-scale response at this far-field, southern mid-latitude location challenges the Stocker and Johnsen [2003] hypothesis by suggesting a teleconnection to the North Atlantic that is not modulated by their proposed Southern Ocean heat reservoir. Coupled atmosphere-ocean mechanisms operating north of the Antarctic Circumpolar Current, as indicated by recent climate modelling, provide a physical framework that may reconcile the different climate response times of the southern mid- and high-latitudes during the Antarctic Cold Reversal.

### References

Stocker, T.F., Johnsen, S.J., 2003. A minimum thermodynamic model for the bipolar seesaw. *Paleoceanography* 18 (4), 1087, doi:10.1029/2003PA000920.

**O-4021**

## **Tracking the last glacial termination in the Southern Alps of New Zealand**

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### **Abstract**

In the Southern Alps, application of surface-exposure dating using in-situ produced terrestrial cosmogenic nuclides (SED) over the past decade or so has produced comprehensive chronologies for moraine sequences in several major east-draining mountain valleys (Darvill et al. 2016 - Quaternary Science Reviews (QSR) 149: 200-214). A regional-scale glacial geomorphologic map published for the central sector of the Southern Alps (Barrell et al. 2011; GNS Science Monograph 27), together with well-resolved SED moraine chronologies, provide an invaluable framework for reconstructing past glacier extents and deriving paleoclimate estimates via glaciological modelling. Spanning from Marine Isotope Stage 4 through to Termination 1 (~18 ka), the moraine sequence geomorphology and SED chronology of the Pukaki and Ohau valleys (Putnam et al. 2013a – QSR 62: 114-141; Kelley et al. 2014 - Earth and Planetary Science Letters (EPSL) 405: 194-206; Schaefer et al. 2015 – QSR 114: 52-60; Doughty et al. 2015 - Geology 43: 407-410) afford substantive evidence for at least 8 major episodes of terminal and/or lateral moraine formation at or near full-glacial ice extent. Shulmeister et al. 2019 (QSR 206: 1-20) recognise an additional episode of glacier expansion from luminescence-dated glaciogenic sediments, making a total of at least 9 major cold-climate episodes during the last glaciation.

In the Pukaki and Ohau valleys, as well as in the Rakaia valley (Putnam et al. 2013b – EPSL 382: 98-110), terminal moraines were formed at ~18 ka, followed by rapid ice recession that, by ~17 ka, had seen each glacier trunk downwaste by at least several hundred metres, with implied terminal recession of as much as 40% of the overall glacier length. Similar recession is also indicated by SED ages from the Rangitata valley, where glacier downwasting of at least 300 m was in progress at ~17.7 ka (Barrell et al. 2019 – QSR 203: 141-150). The glacial moraine record implies an atmospheric warming of several degrees during the ~18 to ~17 ka interval. The paleoenvironmental impacts of this change are reflected to varying degrees of resolution in other New Zealand (NZ) terrestrial paleoclimate proxies (Barrell et al. 2013 – QSR 74: 4-20) and registered most crisply at a lowland pollen record site (Vandergoes et al. 2013 – QSR 74: 215-229) where subalpine shrub and grass taxa were replaced by full lowland temperate rainforest over that ~1 kyr interval. At about the same time, the Subtropical Frontal Zone shifted poleward to the south of NZ (Bostock et al. 2015 - Paleoceanography 30: 824-844), while substantial glacier recession and resurgence of temperate forest vegetation occurred in western Patagonia (Moreno et al. 2015 – QSR 122: 233-249). These findings highlight that the last glacial termination in the austral mid-latitudes was rapid, sustained and of at least pan-Pacific extent.

O-4022

## Gone to seed? Organic residue analysis shows the earliest prehistoric Saharan pottery was used for plant processing

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### Abstract

North Africa is one of the earliest known centres for pottery production across the world. These earliest African ceramics, technologically advanced and extremely well made, were found at Ounjougou, Mali (c. 9400 cal BC) and at other sites in the mountains of the Central Sahara (Algeria, Libya, Chad and Niger), the Eastern Sahara (Sudan) and the Nile Valley (Egypt).

Despite the late domestication of plants in Africa, archaeological and archaeobotanical evidence from early and middle Holocene sites across north Africa revealed considerable assemblages of exceptionally well-preserved plant and vegetal macro-remains. Together with the adoption of appropriate technology, such as pottery and grinding stones, this suggests sustained and systematic exploitation of significant varieties of wild plants by the hunter-gathering groups living in the region.

Here, we use a combined archaeological, molecular and isotopic approach to identify extensive processing of plant material within ceramic vessels from early Holocene sites across north Africa. Biomarkers such as *n*-alkane distributions and sequences of long-chain fatty acid distributions demonstrate that different species of plants, such as wild grasses and aquatic plants, were processed in the vessels. The high P/S ratios of some of the residues, and comparison to archaeological propagules, also confirm that oil was likely processed in the vessels, perhaps from boiling of seeds within the pots to extract the oil. These data confirm that the gathering and processing of a wide variety of plants, including grains/seeds, leafy and aquatic plants, played a significant role in the diets and subsistence practices of Holocene prehistoric groups.

**O-4023**

## **The ceramic technology practiced at Dolni Vestonice, ca. 26,000 B.P., compared to some others in Eurasia**

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### **Abstract**

The archaeological site of Dolni Věstonice I, dated by radiocarbon and stratigraphy to 26,000 B.P., lies along the northeast side of the Pavlov Hills near the Dyje River in the Moravian basin, now in the Czech Republic. Dolni Věstonice I is known for ceramic figurines of animals and humans and for small slabs, spherical balls and pellets of fired clay that number about 5760. Together with the nearby sites of Dolni Věstonice II, Pavlov I and II, Předmosti and Petřkovice, dated between 28,000 and 24,000 B.P., the ceramic inventory totals over 10,000. A domed and banked hearth, with 2300 ceramic fragments in and near it, was excavated in 1979. It was used to fire at least some of the figurines and other ceramics. A second horseshoe-shaped kiln, excavated in 1951-1952 was found in a hut upslope from the habitation site. It was made in layers of the same Aeolian loess as the figurines. Some other large fired-loess fragments that we have called structural ceramics, may have been used as a small, elevated working space or support platform, possibly placed near a hearth.

This paper aims at reporting the raw materials and production technologies, and the implied knowledge of ceramic materials, processing and properties, that developed at Dolni Věstonice to produce ceramics, and at making comparisons to the ceramic and pigment technologies at other Pavlovian sites in Moravia. Other comparisons are made to sites to the east; such as, Kostenki I-1 (ca. 22,000 B.P.) on the Don River and Maina (ca. 15,000 B.P.) in the Yenesei River basin, Russia, and Zazaragi (ca. 18,000 B.P.) near Sendai, Japan. Each of these sites has clay resources with dissimilar properties. Another comparison is made to the ceramic balls from Mas d'Azil (ca. 14,000), French Pyrenées. This inhabited and decorated cave is above a river that connects two valleys.

At each site, humans developed ceramic technology to make figurines and/or ceramic balls and pellets using clay and water processed using knowledge of forming, drying and firing. Some of these clays also were suitable for use as pigments, and some we have documented were used as both pigments and ceramics. The inhabitants at each site could have used the readily available plastic clays to make pots, as I have done at Dolni Věstonice, Kostenki, Maina and Mas d'Azil to demonstrate that it can be done. Although the inhabitants had the know-how or craft practice, they did not have a need for moveable ceramic pots, the idea of a pot, or a natural model upon which to base such an innovation. The closest archaeological features are the stationary skin-lined pits or depressions near hearths used for cooking with preheated, so-called "boiling stones."

**O-4024**

## **The emergence of ceramics in Southwest Asia**

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### **Abstract**

In Southwest Asia, early ceramics are generally associated with sedentary farming communities. This is unlike many other parts of Asia, where ceramics were first manufactured by hunter-gatherers. Radiocarbon evidence indicates that sustained production of ceramic containers—pottery—began at several sites in Anatolia, Upper Mesopotamia and the northern Levant around 7000 BC or slightly later, although there are indications that very small-scale production of pottery sometimes occurred at even earlier dates. In other regions (e.g. the southern Levant, Cyprus) pottery does not become common until centuries later. This paper examines regional variability in Southwest Asian ceramic production in terms of its timing, technology, use and contexts. It considers the reasons for the early adoption of pottery in some parts of the broader region and why, in other areas, adoption was delayed despite probable knowledge of the materials and methods needed to make pottery. It also considers the legacy of early archaeological studies of southwest Asian pottery for our general understanding of the emergence of ceramics. For example, Gordon Childe's concept of a 'Neolithic package' promoted a close association between the emergence of farming and pottery, which can no longer be supported for many parts of Asia.

O-4025

## Ceramics in the desert: Mongolian pottery in context

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### Abstract

The regular use of pottery technology in Mongolian archaeological sites is largely coincidental with major shifts in land-use and the adoption of other food processing technologies such as grinding stones. Decorative styles show strong connections with contiguous regions of northern China, suggesting cultural connections across the arid belt of Mongolia and north China, with similar technologies but various approaches to land-use. Radiocarbon dating, site distribution, and statistically significant trends in raw material reduction strategies between environmental settings all show that these technological changes are coincidental with a decline in residential mobility and a wetland-centric mode of land use. This shift corresponds to a middle Holocene Climatic Optimum and the “greening” of the Gobi Desert. Similar shifts in land-use, relative to their environmental contexts, occurred across northern China and Mongolia at the same time and may have been instrumental to the rise of agricultural economies in less arid parts of China. In the Gobi Desert, this period represents a prolonged phase of a wetland-centric hunting and gathering-based economy. Based on recent excavation and geoarchaeological research in eastern Mongolia, it is probable that wetland use was closely tied to wet phases and that individual wetlands were abandoned, or there were overall changes in land-use, as a result of aridification. Despite the emphasis on wetlands and the fact that residue analysis of pottery from other regions of Northeast Asia demonstrates their importance in processing aquatic foods, faunal analysis of archaeological sites and preliminary organic residue analysis on vessels from the Gobi Desert suggest an overwhelmingly terrestrial focus. This presentation will summarize previous findings on chronology and site distribution, as well as present new data, including chronometric dates, stratigraphic sequences, fauna, and organic residue analysis, all of which reveal the context of pottery use in the Gobi Desert.

O-4026

## Environmental conditions of early ceramics appearance in the Late Pleistocene – Early Holocene (the Transbaikal region, South Siberia)

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### Abstract

Early ceramic assemblages of the Transbaikal region were dated by AMS and OSL (Konstantinov, 1994; Razgildeeva et al, 2013; Hommel et al., 2017; Tsydenova et al., 2017). The obtained results demonstrated their Late Pleistocene – Early Holocene ages. New AMS dating of the early ceramic layer from the Krasnaya Gorka site also gave reasons to define the age of assemblage as the Late Pleistocene - Early Holocene. There is another opinion, that regional ceramic could not appear as early due to the cold climatic conditions. Hence, the Studenoe 1 (layers 8–9) and Ust'-Menza 1 (layers 5–8) age estimations were regarded as incorrect and Atlantic period of Holocene has been supposed (Konstantinov, 2016). However, the most recent paleoenvironmental data indicates the colder conditions, than expected earlier and does not propose the Atlantic age (Razgildeeva et al., 2011). In addition, the results of pollen analyses indicate that the climatic changes in the Late Pleistocene - Early Holocene of the Baikal region correspond to the general climatic scale [Bezrukova et al., 2011; Bezrukova, 2012]. The regional climate becomes more humid and mild around 14.5–12.5 cal. kyr BP, what is corresponding to the European Allerød interstadial. The warmest paleoenvironmental conditions have been recorded around 13.5 cal. kyr BP [Bezrukova, 2012; Reshetova, Bezrukova, 2016]. The most recent dates from the early ceramic sites correspond to this period.

O-4027

## Starch grain evidence reveals early pottery function cooking plant foods in North China

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### Abstract

Early pottery sherds excavated in northern China date back to more than 11,000 cal a BP, and are presumed to have been used as cooking vessels. Pottery invention in different geographic areas is believed to have been driven by different factors including, but not limited to, architecture, culinary use, resource intensification, and/or social/symbolic elaboration. Studies of the function of early pottery are fundamental in gaining an understanding of why ancient people began to use ceramic vessels. In both northern and southern China, the presence of scorch and soot marks on the exterior surfaces of ancient sherds has led to the hypothesis that pottery was used for cooking food. Other functions may have included the extraction of bone marrow and grease, raw food preparation and storage, the brewing of alcoholic beverages, and use in social roles such as feasting. Notably, these functions have remained hypothetical due to the lack of residue analyses of the early pottery from these regions. Here we report ancient starch grains recovered from carbonized residues adhering to the bases of flat-bottomed vessels excavated from the Zhuannian site dating more than 10,000 cal a BP in the North China Plain. This evidence demonstrates that early pottery was being used to cook cereal grains, particularly millets, and acorns in terms of using the dichotomous key we set up. Because millets were in the process of domestication at this time, we propose that pottery invention in northern China may have been related to early farming activities.

O-4028

## Watershed Event or Piecemeal Process: Exploring Behavioural Adaptations Surrounding Early Pottery Use in Northeast Asia

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### Abstract

Inquiries focusing on addition of ceramic production within the behavioural and technological systems of hunting-gathering-fishing societies of Late Pleistocene Northeast Asia are only recently developing. We compare the timing of ceramic adoption as well as its role in behavioral adaptations to changing environments roughly 14,000-10,000 <sup>14</sup>C BP (Bølling-Allerød-Younger Dryas) from sites in Transbaikal Russia, Russian Far East, northeastern China, and Hokkaido. Our analysis revolves around identifying reorganization of behavioural adaptations in terms of settlement patterns, sedentism and storage, subsistence, extractive technology, and human reciprocity that overlay both environmental destabilization from 14,000 to 10,000 <sup>14</sup>C BP and timing of ceramic vessel adoption. Specifically, we will compare site locations and features, fauna exploited, stone and organic tools, symbolic representations, and ceramic construction and styles. As adoption of pottery is not uniform across time or geographic locations within the region, we will elucidate some factors that prompted foraging people to use pottery under some circumstances but not others.

O-4029

## Investigating the mid-Holocene tectonic geomorphology of northern Crete and Late Bronze Age Santorini tsunamite candidate based on a multiproxy approach

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### Abstract

The Late Bronze Age (LBA) tsunami and the A.D. 365 tsunami are supposed to have affected the northern coasts of Crete. However, near-coast sedimentary archives have been rarely investigated in this area, and sedimentary archives including palaeotsunami fingerprints are still unknown. The main objective of our research was to search for appropriate tsunami sediment traps in order to gain detailed insights into the Holocene palaeotsunami history of northern Crete. We found an excellent fine sediment archive near Pírgos, located to the west of Rethymnon. Based on a multi-electrode geoelectrical survey and an 11-m-deep sediment core, we analysed the eventgeochronostratigraphical

record by means of sedimentological, geochemical, geochronological, geomorphological, and microfossil investigations. The Pírgos record revealed a thick unit of homogeneous mud of a lagoonal environment starting ~6000 years ago. The lagoon was affected by five high-energy events, leaving layers of allochthonous sand. Microfossil analyses of these layers revealed a mixed foraminiferal assemblage including species from brackish habitats but also displaced and transported species from open marine and deep-water environments. Considering sedimentary characteristics, the local wave climate of the Cretan Sea, and the overall geomorphological setting, we interpret these layers as related to extreme wave events (EWE). Based on a local radiocarbon age-depth-model, we identified one EWE layer as a reliable candidate for the LBA Santorini tsunami. Another EWE layer is most probably associated with the A.D. 365 tsunami. This EWE ended abruptly the lagoonal conditions at Pírgos because of the 1.64 m coseismic uplift at the site. The Pírgos lagoon existed between the first half of the 6th mill. B.C. and (at least) the end of the 2nd mill. B.C. We found that the area around Pírgos has continuously subsided over 3000 or so years, reflecting constant tectonogeomorphological conditions dominated by the nearby subduction zone between the Aegean and African plates

O-4030

## The identification and characterisation of the Storegga Slide Tsunami in the southern North Sea using a multiproxy approach

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### Abstract

Doggerland is a landmass occupying the area currently beneath the North Sea, which was inundated during the early Holocene, separating the British landmass from the rest of Europe. The Storegga slide was a major submarine landslide, which triggered a Tsunami that has been identified in sediments in the northern North Sea, northeast coastlines of the British Isles and across the north Atlantic. The extent and impact of this tsunami and its role in the final inundation of Doggerland is unknown as to date no direct evidence for this event has been recovered from the southern North Sea. In this paper, we present multi-proxy palaeoenvironmental (diatom, pollen and mollusc) and sedimentary ancient DNA (sedaDNA) data from a core recovered from an off-shore palaeo-river system identified using seismic survey and dated using Optically Stimulated Luminescence. The character and chronology of a distinct lithostratigraphic unit within the core, indicates the impact of the Storegga Tsunami. Seismic tracking of this unit across the palaeo-river system implies that the effects of the Tsunami reached the southern North Sea, but effects were probably localized and possibly limited by the dominant woodland vegetation and topography. We hypothesise that clear physical evidence of the Tsunami event are thus likely to be restricted to specific contexts, such as incised river valley systems.

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O-4031

## Wadden Sea Geoarchaeology- Reconstructing a drowned coastal landscape around the medieval trading centre Rungholt (North Frisia, Germany) by multi-proxy analyses

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### Abstract

In the 12<sup>th</sup> to 14<sup>th</sup> cent. AD, the Wadden Sea of North Frisia (Schleswig-Holstein, Germany) - today protected as UNESCO World Heritage - represented an extensively cultivated landscape, where natural coastal marsh- and fenlands were widely embanked, drained and cultivated by Frisian settlers. At that time, the tidal flats around the marsh island Hallig Südfall belonged to the historical Edomsharde district and its main settlement Rungholt. During medieval and early modern times, vast areas of this settled marshland were drowned by extreme storm surges like the 1. Grote Mandrenke in 1362 AD. Within days, hundreds of square kilometres of cultivated marshland were turned into tidal flats and permanently lost to the sea.

In the present-day Wadden Sea, remnants of the medieval coastal landscape are still preserved beneath younger sediments. Where currents or waves erode the sediment cover, relics of marshland become exposed and remains of dikes, drainage ditches, terps and even plough marks emerge from the tidal flats. However, due to the tides, hard accessibility of many areas and unfavourable weather conditions archaeological investigations in the tidal flats are still a rather difficult task. So, until today, rather little is known about the appearance coastal North Frisian in late medieval times.

For the first time in North Frisia, a broad research approach based on geoarchaeological, geophysical and geomorphological investigations now aims at (i) reconstructing the historical landscape around sunken Rungholt, (ii) evaluating the impact of storm surges on the medieval marshland by identifying traces of such events in the Wadden Sea and (iii) deciphering the complex interactions between man and environment.

So far, geophysical investigations by means of magnetic, seismic and electrical resistivity prospection, revealed distinct evidence of former settlements including remains of dykes and dwelling mounds. Geomorphological investigations based on vibracoring, direct push (DP) sensing and a detailed multi-proxy analysis of sediment cores, retrieved from the tidal flat zone around Hallig Südfall and from the Hallig itself, allowed to elucidate major environmental changes that considerably altered the coastal landscape since medieval times. By combining results from detailed sedimentological, micropalaeontological, geochemical analyses with geophysical and geochronological data, we were able to identify remains of a late medieval palaeosol associated with the medieval marshland and differentiate between settled and unsettled areas. For the first time for North Frisia, we also provide geological evidence of marshland destruction by the Grote Mandrenke in 1362 AD. Altogether, the Wadden Sea turned out to be a promising archive for geoarchaeological prospection.

O-4032

## Late Holocene coastal change in northwest Ireland

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### Abstract

Coastal sediments in northwest Ireland have the potential to explain much about climate and sea-level changes in the last few millennia, but accommodation space for preserved depositional sequences is limited and at times, compromised. Previous efforts to establish relative sea-level contexts and characterise late-Holocene coastal evolution here have necessarily focused on intertidal freshwater peats (i.e. evidence of lower than present sea-level) and raised beaches (i.e. evidence for high stands). It is clear that the far north (e.g. Malin Head) experienced a distinct high-stand c. 6000 yr BP, but evidence of this farther south/west, suggested in glacioisostatic modelling has yet to be forthcoming.

North of Burtonport (County Donegal, northwest Ireland), bedrock headlands and an archipelago of small offshore islands have provided accommodation space pockets where sediment sequences formed during the mid- to late-Holocene, some of which have been preserved. Here, a weathered granite bedrock surface just below the level of mean high water neaps is overlain by beach gravels topped by an organic-rich peat containing in situ *Pinus* stumps (at about mean high water). Above this is a 2 m thick exposure of peaty sediment bounded by undulating erosional unconformities, topped by a palaeosol (20 cm thick) and 60 cm of recent dune sand. The central portion of peaty sediment comprises distinct packages (20-80 cm thick) where organic-rich sediments are interbedded with laterally continuous sandy layers (<1 cm thick) that generally increase in thickness upwards at the expense of the organic layers.

Following a multi-faceted approach including magnetic susceptibility, particle size analysis, geochemistry and microfossil assemblages (diatoms), the sequence is explored for evidence of marine forcing and environmental. Five samples were also removed for AMS <sup>14</sup>C dating, which firmly place the entire sequence in the late Holocene. Results point to a complex sequence of changes in coastal physiography and depositional context during a period of higher than present sea level. Marine influence, evidenced by the increased presence of multiple species of brackish diatoms and distinct cyclicity in organo- to minerogenic accretion, appears to have peaked at 2.7 m OD, >1.5m above the contemporary mean high water springs, but notably within the maximum surge level of recent years. The sequence places some control on late-Holocene sea-level change, but importantly provides clear indication of coastal response within a complicated setting to marine forcing over a 3000 year period.

O-4033

## Rapid and sustained tidewater glacier advance during era of Norse settlement in Greenland

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### Abstract

Tidewater glaciers (TWGs) exert a major control on the short- and long-term mass balance of the Greenland Ice Sheet (GIS) and have experienced widespread retreat over the last century. However, in many cases inferences on their dynamics, prior to this, are poorly constrained due to a lack of observations and paucity of mapped or mappable deglacial geomorphology. Especially lacking is evidence associated with TWG *advance* during the Little Ice Age (LIA, AD c. 1300 to 1850). Such data are crucial for numerical model calibration and validation in order to more confidently forward model ice sheet dynamics and projection future sea-level rise. Therefore, empirical data constraints from the palaeo-record, that span such timescales (decadal to millennial), are essential.

To address this, we present a unique reconstruction of advance and retreat at a major Greenlandic tidewater spanning the last millennium utilising a multi-proxy approach (geomorphological, sedimentological and archaeological evidence). We demonstrate the rapid advance of Kangiata Nunaata Sermia (KNS) by 15 km ( $\sim 113 \text{ m a}^{-1}$ ) from AD  $1076 \pm 84$  to  $1230 \pm 44$ , approaching to within 5 km of its Little Ice Age maximum (LIA<sub>max</sub>). This provides the first evidence that sustained rates of tidewater glacier advance are similar to the dramatic rates of retreat observed across Greenland over the last century (Kjeldsen et al., 2015). The advance occurs during a period of atmospheric cooling indicated by independent climate proxies (Vinther et al., 2010; Von Gunten et al., 2012). New evidence confirming the contemporaneous occupation of a Norse farmstead, proximal to the advancing calving front, also suggests that iceberg production rates during advance were lower compared to the retreat dominated behaviour of KNS over the last c.200 years (Lea et al., 2014a; 2014b). Sedimentary and geomorphological evidence reveals that KNS was subsequently stable near to its LIA<sub>max</sub> configuration for approximately 500 years despite significant climate variability. For the first time, these findings provide key context for how climate can impact calving behaviour, driving both rapid advance and of tidewater glaciers over centennial timescales during the Norse era.

**O-4034**

## **UAV photogrammetry and 3D scan data for topographic mapping and monitoring of coastal areas**

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### **Abstract**

Coastal areas experience change via marine processes and other natural and anthropogenic causes. These changes to coastal geomorphology must be assessed on a range of temporal and spatial scales to understand the evolution of these environments, particularly in the context of projected climate change yielding increased sea-levels and storm frequency. Commercial survey grade unmanned aerial vehicle (UAV) and 3D scan equipment, data processing and analysis tools are available to coastal managers, engineers and researchers.

This study, undertaken as part of the CHERISH project, analyses the use of photogrammetry via UAVs and 3D scan data from scanning total stations in Irish coastal locations to produce orthoimage mosaics and digital surface models. These products extend and complement acoustic bathymetric data from the Irish national seabed mapping programme (INFOMAR) in mapping coastal regions. Preliminary results indicate that combining relevant techniques to produce seamless onshore-offshore maps can provide high-resolution information about emergent and submergent coastal geomorphology on a range of scales for use in coastal mapping, monitoring and management.

O-4035

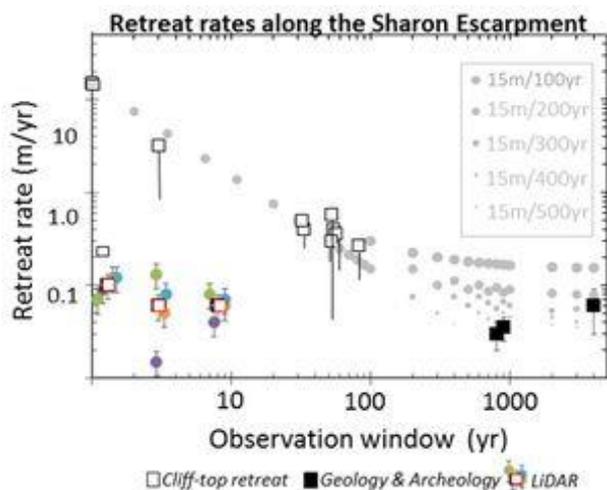
## Do Higher 20th Century Cliff-top Retreat Rates Necessarily Imply Recent Acceleration in Sea-cliff Erosion?

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### Abstract

Inland retreat of sea cliffs in response to post LGM (last glacial maximum) sea-level rise is an ongoing process that affects coastal environments and communities worldwide. Here, we examine a globally recurring pattern where reported sea-cliff retreat rates since the 20<sup>th</sup> century often appear to exceed longer-term millennial-scale ('background') rates, which rarely exceed ~0.1 m/yr. Focusing on Israel's 30-km-long Mediterranean 'Sharon' sea-cliff as a case study we demonstrate that such apparent increase in rates may also reflect a widely acknowledged sampling bias in geologic rate estimates inferred from observation time windows ( $T_{obs}$ ) shorter than process episodicity. We show that this possible bias leads to an ambiguity in conventional rate estimates obtained by averaging observed retreat distances over  $T_{obs}$ , and that as a result despite ubiquitous and robust observations of cliff retreat since the 20<sup>th</sup> century (e.g., aerial photographs) recent/current retreat rates for many of the world's episodically retreating sea cliffs remain effectively unknown. To address this limitation in our current ability to detect and quantify recent changes in sea-cliff retreat rates we use a sediment-budget approach that builds on repeat LiDAR surveys to measure the continuous wave-driven volumetric erosion of collapsed material from the cliff base as an effective upper-bound constraint for the m/yr rate of episodic retreat of the cliff itself. We find that while conventional m/yr rate estimates for retreat of the Sharon sea-cliff since the 20<sup>th</sup> reach values of up to several m/yr the LiDAR-constrained retreat rates for the same period are comparable to the cliff's background retreat rate of 0.03-0.07 m/yr since the mid Holocene and thus indicate no recent acceleration in retreat. This new ability to unambiguously constrain sea-cliff retreat rates through annual-decadal scale measurements of the coastal sediment budget directly impacts the global-scale push to quantify, better understand and ultimately predict the response of sea cliff erosion and retreat to recent/projected changes in environmental conditions such as sea-level, climate, near-shore ocean dynamics and anthropogenic influences.



Sea-cliff retreat rates inferred from annual-decadal observations of cliff-top retreat are artefactually high because retreat episodicity has a time-scale of several hundred years. Instead, we use repeat airborne LiDAR to measure the continuous wave scouring of talus material from the cliff-base



as a rate limiting process for episodic retreat of the cliff itself above. LiDAR measurements demonstrate that current/recent sea cliff erosion continues at background rates while rates inferred from conventional measurements of recent cliff-top retreat may erroneously suggest otherwise.

O-4036

## OSL and ESR thermochronometry of the Hida Range, northern Japanese Alps

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### Abstract

Optically stimulated luminescence (OSL) and electron spin resonance (ESR) thermochronometry are recently developed techniques that can constrain erosion histories at sub-Quaternary timescales. OSL and ESR thermochronometry determine the timing and rate at which electrons are trapped and thermally released in minerals, in response to in-situ radiation and rock cooling. Erosion histories can be inferred by translating rock cooling rates into an erosion rate using knowledge of the Earth's thermal field. In contrast to OSL which can only be applied over timescales of up to ~400 ka, ESR may be applicable over the whole Quaternary period, significantly extending the applicability of trapped-charge dating based thermochronometric methods. In this presentation, the basis of ESR and OSL thermochronometry will be outlined, before consideration of a recent application of these methods to the Hida Range, northern Japanese Alps.

Japan is one of the most tectonically active locations on Earth, situated adjacent to two triple junctions between four tectonic plates. Within this convergent zone, the Hida range is thought to have been uplifted within the last 1 to 3 Myr. OSL and ESR thermochronometry were applied to a suite of 19 bedrock samples collected from the Hida range to constrain its Quaternary evolution. Initial results show that the ESR and OSL data yield similar cooling histories, indicating rapid erosion of the Hida range over the past 100 ka. Inverting the data for erosion rates, assuming a geothermal gradient of 60 °C/km reveals a reduction in rates from ~10 mm a<sup>-1</sup> throughout MIS4, during which the most intense glaciation of the Japanese Alps occurred, to ~1-3 mm a<sup>-1</sup> over the past 20 ka. Our preliminary data indicate that erosion rates within the Hida range were higher under a cooler and wetter climate.

O-4037

## Advancing U-Th geochronology via distribution of gravimetric standards and matrix-free synthetic age solutions

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### Abstract

U-Th methods have the potential to provide the most precise and accurate age constraints for past climate, oceanographic, archaeological, geophysical change in the Quaternary. Over the past two decades, analytical precision of U-series isotope measurements has improved dramatically, largely due to the steadily increasing sensitivity of multiple-collector inductively coupled plasma mass spectrometry (MC-ICP-MS). Analytical uncertainties in U-Th dates now approach or are better than 0.1% ( $2\sigma$ ), for instance  $\pm 100$  years for a speleothem or coral that is 130 kyr old (Cheng et al., 2013). However, the accuracy of U-series dates also depends on the accuracy of tracer calibrations, reference solutions and data reduction protocols, which has not kept pace in many laboratories. This means that dates measured in different labs, while impressively precise, may not be directly comparable. Many laboratories thoroughly report detailed methodologies and full documentation of their results for U isotope or U-Th secular-equilibrium standards, but the traceability is not optimal. Confidence in derived U-Th ages for all laboratories is undermined to varying degrees by the lack of ideal reference materials and common data reductions tools.

To address issues of inter-laboratory bias and improve the accuracy and inter-comparability of U-Th dates, we instigated NERC-funded work to provide the community with two types of solutions: (1) synthetic matrix-free U-Th age solutions, mixed from high-purity mono-isotopic solutions to mimic the isotopic composition of commonly-analyzed materials (a coral from the last interglacial, with  $(^{230}\text{Th}/^{238}\text{U}) \approx 0.75$  and  $\delta^{234}\text{U} \approx 100$ ; speleothem material from the last interglacial, with  $(^{230}\text{Th}/^{238}\text{U}) \approx 1$  and  $\delta^{234}\text{U} \approx 500$ ; a young coral, with  $(^{230}\text{Th}/^{238}\text{U}) < 0.05$  and  $\delta^{234}\text{U} \approx 146$ ). These age solutions will form the basis for a major inter-laboratory comparison and serve as international reference materials for assessing long-term reproducibility. (2) Several U-Th gravimetric standards, produced using high purity material (NBL CRM 112a U metal, Ames Th crystal bar or e-beam melted Ames Th), which can be used to calibrate the mixed U-Th tracers used in the community without having to rely on materials assumed to be in secular equilibrium. Tracers calibrated against these solutions, and therefore U-Th dates measured with these tracers, will be fully metrologically traceable.

We are pleased to report that the proposed U-Th synthetic solutions and standards are now available for distribution. We report on some of the challenges thus far and lessons learned from preliminary calibration and inter-comparison efforts. We make suggestions for the next phase of comparison, eventual dissemination of results and, most importantly, we politely request community guidance and support for widespread adoption of the solutions.

O-4038

## Surface exposure dating precision: limitations and prospects

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### Abstract

Contradictory empirical studies have inferred that the Younger Dryas (YD) ice cap in Scotland was at its maximum extent late in the YD and conversely that Scotland was entirely deglaciated. Understanding how the abrupt YD temperature change influenced ice retreat rates relies on precise constraints on deglaciation rates. Currently the only technique for determining deglaciation ages directly from landforms left behind by retreating ice is surface exposure dating using accelerator mass spectrometry (AMS), but AMS suffers from *metrological limitations*. For  $^{10}\text{Be}$ , the most commonly used cosmogenic nuclide, precision of 1% has been claimed in some publications but this is usually based on individual sample measurement statistics rather than the repeatability of YD equivalent 'age' standards, which usually perform at 2-3% during AMS experiments. This introduces relative uncertainties of 200-300 years which prevents resolution of chronological inconsistencies.

AMS measurement precision can be improved with operational changes but there will always be limitations associated with sputter ion sources. Here we present a state-of-the-art new technology, invented at SUERC, which has been demonstrated to be able to measure the rare radionuclides  $^{14}\text{C}$  and  $^{26}\text{Al}$  using positive ion mass spectrometry (PIMS). PIMS represents a step change in rare isotope metrology equivalent to the change from  $^{14}\text{C}$  decay counting to  $^{14}\text{C}$ -AMS. PIMS addresses current limitations of sputter ion sources in sample to sample scatter and counting statistics by using a plasma ion source to extract a large, stable positive ion beam from the sample. A patent pending process removes interferences to the measurement from the beam by simultaneously destroying molecules and converting the beam from positive to negative charge. The treated beam is free from any interferences because the isobaric interference to both  $^{14}\text{C}$  and  $^{26}\text{Al}$  (which are  $^{14}\text{N}$  and  $^{26}\text{Mg}$ ) do not form negative ions. Other advantages to using Al-PIMS over Be-AMS include lower backgrounds (there is no meteoric contamination for  $^{26}\text{Al}$ ) and aluminium samples usually do not need to have carrier added, plus simpler and safer (no toxic BeO) sample preparation chemistry. A customised system has been built and used to demonstrate that the technique can surpass conventional AMS for  $^{14}\text{C}$  measurements. This process is now being extended to  $^{26}\text{Al}$ .

O-4039

## Accuracy of U-Th age determinations on suboptimal speleothem material

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### Abstract

U-Th dating provides precise and typically accurate timescales which now underpin much of late Quaternary geochronology. This is especially true of speleothems, which provide many important paleoenvironmental records in their own right and also increasingly allow the transfer of absolute radiometric chronology to otherwise better-understood ice and marine core records. Given this increasing importance of U-Th geochronology it is important to be able to anticipate and identify those times where it does not provide accurate results.

U-Th age determinations can be inaccurate by four means: post depositional mobility of uranium, inclusion of significant thorium at time zero, inclusion of isotopically heterogeneous thorium at time zero, or through analytical error. Despite the considerable difficulty of U-Th isotopic analyses required for dating there is very little evidence of analytical inaccuracy in the thousands of age determinations now published each year and this can be largely disregarded as a source of error. The most common source of age error is inclusion of  $^{230}\text{Th}$  at time of sample formation which can usually be accurately corrected for using  $^{232}\text{Th}$  as an index, at the expense of increased age uncertainty - there are several existing methods of estimating the necessary initial  $^{230}\text{Th}/^{232}\text{Th}$  ratio and its uncertainty.

Recent studies have highlighted the impact of post-depositional uranium mobility in speleothems, and the difficulty of detecting it in all cases. Correction techniques have been proposed (but not well accepted) for other materials including bone and coral, but its strongly heterogeneous impact in speleothem means that affected (and suspected) samples must be discarded as no correction is possible. Strongly variable initial  $^{230}\text{Th}/^{232}\text{Th}$  arises through mixing of initial Th from two or more isotopically discrete sources and is not currently (and may never be) possible to accurately correct for except by assigning sometimes prohibitively large uncertainty to the correction.

Detection of U-Th age inaccuracy if present is usually straightforward where dating density is high. This high density might take the form of closely spaced ages along a growth axis where inaccurate samples will be clearly out of sequence with their neighbours; or alternatively a single time horizon might be dated multiple times in which case most sources of inaccuracy will cause a failure of ages to replicate with respect to uncertainty. Where inaccuracy is caused by elevated but (relatively) isotopically homogeneous initial Thorium it is typically straightforward to correct for.

The effects of Uranium mobility and isotopically variable initial Th can be very similar yet must be understood in assessing the accuracy of an affected chronology. Strategies for detection and decision making regarding correction or rejection of age determinations will be presented, informed by the study of synthetic data and records from the literature.

**O-4040**

## **How far back can we date using luminescence ?**

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### **Abstract**

Luminescence dosimetry techniques are widely used for dating Quaternary deposits in a variety of geomorphological, sedimentological and archaeological contexts. Optically stimulated luminescence (OSL) from quartz has been the most commonly employed method; unfortunately the signal response to burial time saturates at around 100-150 ka (depending on the environmental dose rate), thus setting this upper age limit of the OSL technique. There is a great interest in pushing back the upper age range of the luminescence dating technique to understand sedimentary archives from the penultimate and even earlier Quaternary glacial cycles.

The last decade or so has seen several exciting new developments in this regard. New signals have been discovered in quartz which show the potential for extending the dose measurement range to greater than a kilo Gray (unit Gy = J.Kg<sup>-1</sup>). These methods include thermally-transferred OSL (TT-OSL), violet stimulated luminescence (VSL) and isothermal thermoluminescence (ITL) which suggest the potential to date as far back as 1 million years. Similarly, new methods have been developed for feldspar, the other widely used chronometer, to accurately determine dose in a kGy region using different variants of signals obtained using infrared (IR) stimulation (e.g. IR stimulated luminescence and IR photoluminescence) and IR emission (e.g. IR radiofluorescence). Although, issues remain it appears that it is possible, in a great majority of circumstances, to date deposits at least as old as middle Pleistocene using feldspar, and possibly even older deposits.

In this presentation, we will report on the performance of the most promising signals and summarise the state of the art and the potential of the luminescence dating technique with regards to dating beyond the last 100 ka.

**O-4041**

## **Results of AMS dating of flow cytometry-sorted pollen from two lakes in California's Sierra Nevada**

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### **Abstract**

High-resolution chronologies are crucial in paleoenvironmental studies. AMS dating is still the most used method for dating macrofossils in sediment cores. When terrestrial macrofossils are not available, pollen grains may represent the most valuable source to obtain a chronology. As previous studies demonstrated, pollen grains can be dated by AMS, but this process presents some difficulties in isolating pollen from other organic matter and obtaining enough carbon to produce a useful age. We present an improved method for extracting and isolating pollen through chemical digestion and flow cytometry sorting for AMS measurements. The cytometric sorting allows the nearly complete separation of pollen grains from other particles that cannot be eliminated during the pollen extraction and represent a potential source of contamination, such as microcharcoal. The results of AMS measurements of pollen concentrates from Mono Lake and Fallen Leaf Lake are presented. Both of the lakes are located on the eastern side of the Sierra Nevada and have pollen assemblages dominated by pine, but they have very different sediments: Fallen Leaf Lake contains homogeneous, organic- and pollen-rich sediment, while Mono Lake presents very heterogeneous sediments with volcanic ashes and calcareous-rich layers with variable pollen concentration. In addition to fossil samples, the results from modern specimens, collected along surface transects from the shore of Mono Lake to the Sierra Nevada, were used to test the possibility that pollen could be aged on the land surface. The pollen extraction followed a protocol modified from that used for palynological analysis, and the different sediment types required adjustments during the chemical treatment and showed different final pollen concentrations. At least 50,000 pollen grains were sorted and dated when possible, but this amount of pollen was not always available in the sediments starting from a standard sample of 1-2 cc of sediment. The smallest sample dated with reliable results contained ~16,000 grains and 0.042 mg C. The comparison of the results between two very different lakes contributes to understanding if and where pollen concentrates can be used to build a high-resolution chronology when terrestrial macrofossils are rare or completely absent in sediment cores.

**O-4042**

## **Tree ring dating using oxygen isotopes: a master chronology for central England**

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### **Abstract**

Traditional dendrochronology, based on matching patterns of ring width variability, works best when trees are growing under significant environmental (climatic) stress. In the UK, and elsewhere in the temperate mid-latitudes, trees generally experience less stress, so dating is more difficult and often fails. Oxygen isotopes in tree rings passively record changes in the isotopic ratios of summer precipitation, so they carry a strong common signal, which offers potential for cross-dating.

A master chronology covering the period 1200-2000CE was constructed using the oxygen isotope ratios of the latewood cellulose of oak samples from central England and the method evaluated by dating timbers of known age and historic timbers that could not be dated by conventional dendrochronology. The agreement between samples and the master chronology is exceptionally strong, allowing the dating of timbers with far fewer rings than is normally the case for conventional dendrochronology.

The isotope dating method has the potential to revolutionise dendrochronology, allowing the dating of short and invariant ring sequences from young, fast-grown trees which are commonplace throughout the historic building record and which were, until now, considered almost impossible to date.

**O-4043**

## **Applications of geomorphic features produced by extreme storm events: unraveling the seismic slip and creep components of fault slip**

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### **Abstract**

The southern-most San Andreas Fault in California last experienced an earthquake resulting in surface rupture in ca 1726 CE. Palaeoseismic and neotectonic studies have revealed that this section of the fault has a long-term slip rate of approximately 20 mm/yr. Creep meter, InSAR and historical data in the area suggest that this section is creeping at about 3 mm/yr. Differentiating creep and coseismic slip rates are critical in understanding palaeoseismic records and developing estimates of future slip per event. In addition, landforms such as rills and channels that are offset by creep can be used to assess mechanisms of formation of rills as their ages can be estimated by the amount of creep offset

The southern San Andreas Fault (SAF) traverses the Coachella and Imperial valleys of California. This area of California is arid and receives less than 70 mm/yr of rainfall. Major precipitation events are rare and generally relate to hurricanes or subtropical depressions that are tied to El Nino periods. Significant 1-day rainfall events in this arid region of >180 mm have been recorded. These events are capable of reactivating the landscape, developing rills and creating new channels. Two such storms, 1939 San Pedro Tropical Depression and 1858 Hurricane, have been recorded in the area. The 1939 storm, known as the Lash of St Francis, was downgraded from a category 1 storm to a depression just prior to landfall in San Pedro, CA and resulted in 180 mm of rain in 3 hours in the Coachella Valley. This was in addition to 355 mm from a series of tropical depressions earlier in the month. The 1858 Hurricane was recorded as a category 1 at landfall. No rainfall records from the Coachella Valley are available from this time period.

A Phantom 4 Pro was used to acquire high-resolution, low altitude aerial imagery of sites along the southern SAF. The < 25 m altitude resulted in sub-cm resolution imagery and was used to generate point clouds and orthophoto mosaics, which were converted into digital terrain models, hillshades and slope maps. Analysis of the imagery products resulted in the identification of two clusters of rill offset distances: 24+3 cm and 50+4 cm. Using the 3 mm/yr creep rate results in ~80 and 167 years since creation of the rills, or ca. 1939 and 1852 and almost certainly correlate to the 1939 San Pedro storm and the 1858 Hurricane.

If rill formation only occurs primarily during extreme rainfall events associated with strong El Nino conditions, then combining paleoseismic data on the timing of past earthquakes with past climate data may provide a much finer resolution to the longer-term slip history of the southern San Andreas fault.

O-4044

## Surface faulting and environmental effects accompanying the Dec. 26, 2018, Mw 4.9 Fleri earthquake, Mt. Etna volcano, Italy

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### Abstract

The December 26, 2018, Mw 4.9, Fleri earthquake, is among the largest shallow ( $H=1$  km; INGV) seismic event instrumentally recorded on Mt. Etna volcano. On Dec 26 morning we started mapping surface faulting and other coseismic ground effects along the NNW-trending, right-lateral Fiandaca Fault. Heavy damage affected the localities of Fleri (Zafferana Etnea), Mazzasette, Pennisi, Fiandaca, and Santa Maria La Stella, located along the fault trace. Very shallow focal depths are typical for the damaging tectonic earthquakes on the eastern flank of Mt. Etna volcano; in particular, the Fiandaca Fault generated similar events on 07/01/1875, 8/08/1894, 07/12/1907, 07/05/1914, 03/08/1931, 19/06/1984, 19/10/1984, 25/10/1984, 11/11/1997. Surface fault slip has been also observed along at least other 4 known capable faults (Fig.1).

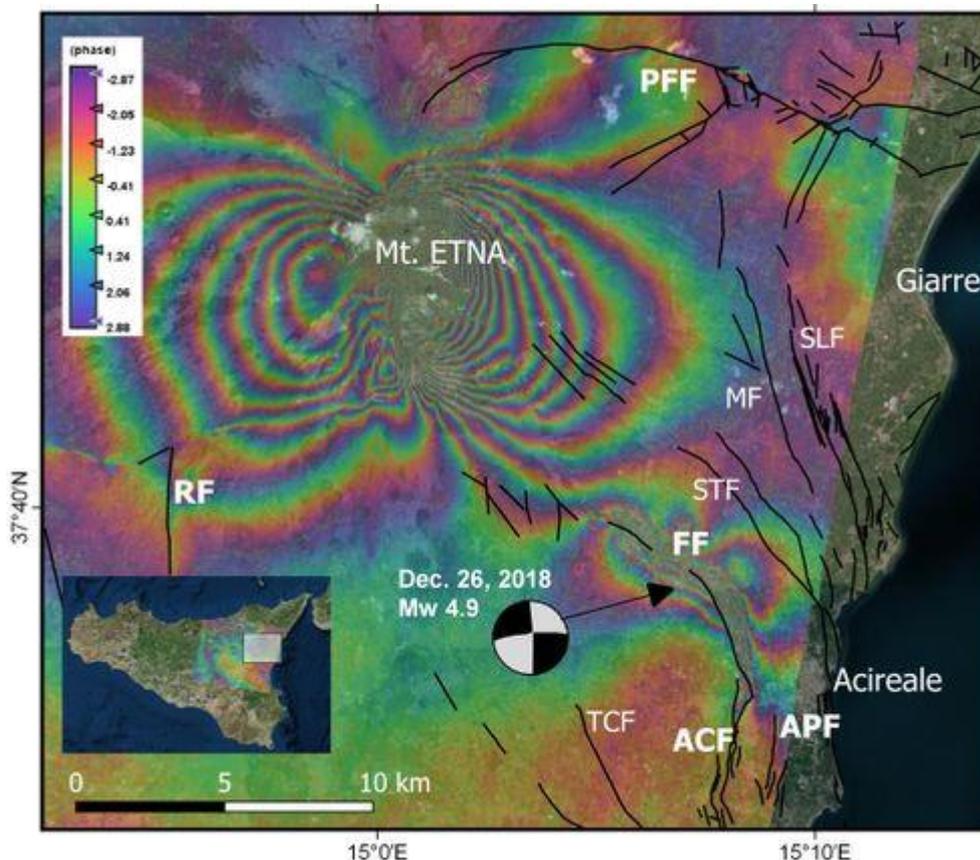


Figure 1: Surface rupture and fault creep following the Dec. 26, 2018, earthquake along the FF Fiandaca , ACF AciCatena, APF AciPlatani, RF Ragalna, PF Pernicana Faults;interferogram made with SNAP, Sentinel-1 scenes, descending, VV polarization, taken on 22 and 28/12/2018 (<http://step.esa.int/main/toolboxes/snap/>)

Along the Fiandaca Fault, we mapped continuous surface faulting throughout the entire epicentral area, for a length of about 5 km (Fig.2). We measured a belt of complex rupture segments, trending N - S, NNW - SSE, and NW – SE. In the southern section, between SantaMaria LaStella, Fiandaca, Pennisi and Mazzasette, across strike rupture width ranges between 20 and 100 m, including 3 to 8 en-echelon NNW-trending open fissures, up to 1.50 m wide and more than 3 m deep (I ESI 07 = IX). We assessed vertical displacement of 10 - 30 cm and right-lateral displacement of 2-15 cm. The northern section is affected by cracks of the same orientation but smaller opening of 3-5 cm; at SanGiovannello (Fleri), they show vertical displacement of 10-15 cm with small right-lateral components. At Monte Illice small landslides were detected too.



Figure 2: Coseismic surface rupture along the Fiandaca Fault (Domenico Bella, 26/12/2008 morning).

In the afternoon of 26/12/2018 in AciPlatani, around 14PM, we observed the inception of fault creep along the trace of the AciPlatani fault, for a length of about 700 m; creep was still in progress at the moment of writing, on 09.01.2019, with an overall normal displacement of few cm. Creep events on the AciPlatani fault are a recurring phenomenon, reported in the past for instance in 1879, 1886 and 1899.

Fault creep has been recorded also on the Fiandaca fault, especially in the southern section that affects the territory of AciCatena.



The ongoing detailed investigations will be compared with the environmental effects of the August 21, 2017, Casamicciola (Ischia Island) earthquake, providing unprecedented data for a more effective assessment of the seismic hazard in volcanic areas in Italy and abroad.

O-4045

## The Timing and Extent of the Last Surface Rupture Event on the Himalayan Frontal Thrust in Central Nepal around Butwal

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### Abstract

The 2015 Gorkha earthquake ruptured only the deeper northern part of the thrust during the Mw 7.8 earthquake, but did not rupture the surface and shallow portion of the Himalayan Frontal Thrust (HFT) in south. Since then, the evaluation of the potential of the future surface rupture event on the HFT in central Nepal in south of 2015 rupture became an important task for paleoseismology. Mishra et al. (2016), Bollinger et al. (2016), and Wesnousky et al. (2017) proposed respective 1100 CE, 1344 CE and/or 1408 CE, and 1221 CE to 1262 CE (possibly 1255 CE) for the timing of the last surface-rupture event. Each report eliminates the timing of earthquake proposed by the other authors. Therefore, it is necessary to think over the possibility of multiple events in short (less than 100 km) segments or of misleading radiocarbon dates. Also, the existence and the east termination of 1505 CE Indian central seismic gap event (Malik et al., 2017) are not certain yet. In order to solve the rupture history and rupture extents in central and western Nepal, we excavated two trenches across the HFT around the city of Butwal. One is at 12 km west of Butwal at Sorauli (27.70°N 83.36°E) and another is at 60 km ESE of Butwal at Susto (27.48°N 83.86°E). Around the Sorauli trench site there is no clear continuous scarp along the Siwalik hill front, but ~100 m wide zone of alluvial surface adjacent to the foot of the hills tilt toward south and juxtaposed to flat alluvial surface. The boundary between the tilted surface and the flat plain is continuous and looks like the active front of a flexure scarp. The trench across a small scarp on the tilted surface did not expose any fault, but a fine sand layer was tilted towards the boundary. A Bayesian model of radiocarbon dates indicates the timing of tilting is between 1405 CE and 1467 CE. This period coincides with the 1344 CE earthquake (Bollinger et al., 2016). The Susto trench in the east of Butwal was dug into the foot of ~20 m high fault/flexure scarp below an uplifted terrace surface. In this trench also, 13° south-dipping fine sand layers appeared but the fault was below the water table and not exposed. The timing of the tilt in Susuto trench as well as results from investigation in further west in the boundary area between 1344 CE and 1505 CE event will be reported. The results will be critical to evaluate the seismic risks along HFT in central and western Nepal.

O-4046

## Calibration of lacustrine paleoseismological records in the Eastern Alps with historical earthquake data: potential and challenges

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### Abstract

In intraplate settings with moderate seismicity, recurrence intervals of strong earthquakes ( $M_w > 6$ ) typically exceed the short time span of instrumental and historical data. In order to assess the seismic hazard in such regions, lake sediments can be used as earthquake archives: they can record strong seismic shaking as mass transport deposits (MTDs), turbidites or sediment deformations and can reach back several thousands of years. To provide information on paleo-earthquake size, however, the sedimentary imprints need to be thoroughly calibrated with independent information on seismic shaking strength.

In Carinthia (Eastern Alps, Austria), numerous lakes have experienced several devastating historical earthquakes with local intensities ranging from V-XI (EMS-98 scale), although located in an intraplate environment. Due to these events well-spaced in time (AD1348, AD1511, AD1690, AD1857 and AD1976), exceptional historical documentation and shakemaps based on a local intensity prediction equation, we can examine the relationship between seismic intensity and the type and size of sedimentary imprint in the lakes.

Eight lakes – differing in size, morphology, catchment lithology and sediment composition – were investigated by a dense grid of reflection seismic profiles (~460 km overall), numerous sediment cores (~100, up to 14 meters long) and multibeam bathymetry. Mapping of MTDs, their scarps and associated turbidites as well as accurate dating (radiocarbon and varve counting on sediment thin sections) showed that the AD1348 earthquake ( $M_w \sim 7$ ) led to extensive slope failures in the bigger lakes. The AD1511 ( $M_w \sim 6.9$ ) and AD1690 ( $M_w \sim 6.5$ ) events, although reportedly exhibiting intensities comparable to those of AD1348, however, are only recorded as minor MTDs and turbidites in some of the lakes. This could be due to different reasons: 1) The recurrence interval of earthquakes with high local intensities is too short to critically recharge the slopes with sediment. 2) The real intensities at the lake sites were different than what we can reconstruct from historical records. 3) The individual events differed in frequency content, shaking duration and/or directivity.

We try to overcome these problems by comparing the traces of a single event in the different lakes and by integrating our vast lake data and historical intensity data points into a probabilistic model, narrowing down possible earthquake scenarios. In the smaller lakes, even the biggest earthquakes are only recorded as thin event deposits or lack entirely, indicating lower sensitivity to seismic shaking.

Our study shows that studying one lake, let alone one sediment core, is insufficient to reconstruct a region's seismic history. Due to the exceptional setting of Carinthia, however, we can constrain the intensity pattern and localise the most likely epicentral region and fault source of past earthquakes. In an ongoing study, we use this calibration to construct long calibrated lacustrine records for the last 14 ka.

O-4047

## Resolving the paradox of geomorphic and paleoseismic rupture histories on the Teton fault, Wyoming, USA

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### Abstract

Geomorphic and paleoseismic analyses produce complementary records of fault rupture history and slip rates. The two approaches yield integrated and event-specific slip rates, respectively, while providing insight into both seismic hazards and landscape evolution. These methods are ideally suited for settings such as the dramatic normal-faulted mountain front of the Teton Range in the northeastern Basin and Range Province of western North America. Moraines, outwash terraces, and alluvial fans of varying geomorphic ages comprise much of the range-front landscape and, where cut by the 70 km long Teton fault, provide opportunities to estimate the slip rate of the fault.

Fault scarps on surfaces covered by the most recent ice advances during the late Pleistocene Pinedale glaciation (terminating ~15 ka) have an average vertical separation of ~11 m, representing an average slip rate of 0.8 m/ka. Fault scarps on surfaces and features outside those latest Pleistocene ice limits, such as fan deposits and prominent high lateral moraine crests, have vertical separation up to 35 m. These large scarps suggest that the landforms are substantially older, or that they experienced higher slip rates prior to deglaciation. Because of sparse age constraints, the slip rate estimates for these features are highly uncertain.

Likewise, until recently the entire surface faulting history of the Teton fault has been characterized by a single trench, located on the southern portion of the fault. Two Holocene events, a penultimate event at ~7.9 ka and a most recent event between 4.8 to 7.0 ka, were used to estimate a Holocene offset rate that is lower (0.3–1.1 mm/yr) than the average offset rate between deglaciation (~15 ka) and 7.9 ka (1.3–2.4 mm/yr).

To address major uncertainties such as the late Pleistocene to early Holocene slip rate and paleoseismic event history we have excavated six new paleoseismic trenches, cored range front lake sediments, and performed new cosmogenic radionuclide exposure dating on previously undated surfaces, including the higher lateral moraines. The new trenches reveal evidence of multiple Holocene rupture events. Event horizons in range-front lakes suggest more frequent seismic shaking events than are revealed through trenching, suggesting that the lakes may record strong shaking events that are not associated with surface rupture or may be triggered by distal events. Together, the geomorphic, trench, and lake sediment records provide an integrated record of fault slip spanning the past 15-25 ka and details of specific event timing and slip magnitudes.

O-4048

## Active tectonics of the Dinarides in Slovenia - new insights from palaeoseismology

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### Abstract

The highest seismicity in the Adria-Alpine collision zone occurs at the transition between the eastern Southern Alps and the Dinarides in north-eastern Italy and western Slovenia. Thrusting on E-W striking faults prevails along the Alpine front in Italy. In Slovenia, right-lateral strike-slip faulting occurs on NW-SE trending structures. Instrumental and historical earthquakes exceeded magnitude M6 here. However, strong earthquakes are relatively rare and for most events it is not clear which fault moved. No surface ruptures are known from Slovenia. Also, little is known about the recurrence intervals of strong earthquakes on individual faults and about their relative activity. In order to better understand the active tectonics of the Alpine-Dinarides collision zone, we analyse high-resolution digital elevation models that allow detecting morphological hints for recent surface-rupturing earthquakes, and we use palaeoseismological trenching studies to reveal strong past earthquakes on the main faults in Slovenia. In this study we present first results from the Predjama and Idrija Faults, the latter of which is a possible source for the destructive 1511 Idrija Earthquake. According to macroseismic sources, the 1511 earthquake reached intensity IX MCS. Magnitude estimates range between 6.3 and ~7.0. It is still debated which fault(s) ruptured in this quake. We opened a palaeoseismological trench in the central part of the Idrija Fault. We found coarse fluvial sediments and fine-grained channel fills, which show deformation features such as vertically aligned pebbles and terminated layers. A fissure filled with material from overlying layers penetrates the channel fill sediments. We interpret these structures as evidence for recent surface faulting in a strong earthquake. At the north-western part of Predjama Fault, we encountered a small uphill-facing scarp very close to the mapped fault trace. We interpret this morphology as possibly caused by a surface rupturing earthquake and trenched across this feature. Offset Palaeogene sandstones show a vertical component of motion, but the age of this deformation is not necessarily related to young tectonics. However, changes in thickness of the youngest soil horizons may indicate Late Quaternary surface faulting at this location as well. Our study shows that surface rupturing earthquakes occurred in the recent past in Slovenia, although no evidence for surface ruptures was hitherto known from historical sources. Combined with existing data, our results indicate that a number of faults are active in a wide deformation zone in Slovenia, and that each fault has the potential to rupture in large earthquakes. However, the overall deformation in the study area is rather slow and each individual fault has a low slip-rate. Therefore, recurrence intervals of large earthquakes tend to be long. Our project is part of SPP 2017 'Mountain building processes in 4D', financed by the German Science Foundation (DFG).

O-4049

## Cosmogenic $^{10}\text{Be}$ dating in a bedrock fault scarp at the Middle Kedrovaya paleoseismic rupture zone (Baikal Mountains, Russia)

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### Abstract

The 30-km-long Middle Kedrovaya (MK) paleoseismic rupture zone, on the northwestern flank of Lake Baikal, is one of most impressive late Quaternary fault scarps in the Baikal rift. It is expressed by downhill- and uphill-facing scarps and associated troughs that are developed mainly in very coarse talus deposits composed of large blocks (*kurum* in Russian). In places, clearly seismogenic ruptures are cutting bedrock and offer some opportunities to examine the faulting history.

Using cosmogenic  $^{10}\text{Be}$  exposure dating, we first measured the exposure ages of one of the MK scarps located at site with coordinates  $54.44630^\circ$  N,  $108.51524^\circ$  E and elevation 985 m. This ~12-m-high fault scarp is consisting of cataclasites in early Proterozoic granitoids of the Irel complex. We analyzed 12 from 18 collected samples, every 0.5 m, from 0.45 m above the bottom of the scarp dipping  $55^\circ$  (samples 1–6) and  $45^\circ$  (samples 7–12). However, only samples 1 ( $2.24 \pm 0.56$  ka), 2 ( $1.53 \pm 0.56$  ka), 3 ( $0.81 \pm 0.57$  ka), 5 ( $1.44 \pm 0.56$  ka), 6 ( $2.12 \pm 0.64$  ka), 8 ( $1.46 \pm 0.49$  ka) and 9 ( $1.41 \pm 0.53$  ka) gave results with relatively large errors, resulting from the large uncertainties of AMS measurements of Be isotopic ratios. Nevertheless, based on the oldest-age model, the relationship between the calculated ages and the relative sampling height along the scarp suggests that a recent rupture event with a vertical normal fault throw of at least 2.05 m (dip-slip is at least 2.5 m) occurred on the cliff ~2.18 ka ago (samples 1 and 6). If we take into account distance between bottom of sampled outcrop and first sample #SK28-1 the normal fault throw will be at least 2.419 m and dip-slip is at least 2.95 m.

A more concentrated age mode of about 1.46 ka (samples 2, 5, 8 and 9), which is in incorrect stratigraphic order in reference to the older ages, implies that a gravitational event happened on the studied fault surface. It is possible a younger earthquake without a significant displacement followed there or occurred on other faults in the northern part of Lake Baikal and adjacent area. The only age of 0.81 ka can be random due to denudation or lesser shocks from distal seismic events.

This work is partly supported by the National Natural Science Foundation of China (grant No. 41471002) and Russian Scientific Foundation (grant No. 19-17-00015).

**O-4050**

## **Using Optically Stimulated Luminescence dating to refine the history of Late Holocene alluviation and land-use in the Severn Catchment, UK**

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### **Abstract**

The development and refinement of Optically Stimulated Luminescence (OSL) dating techniques now enables high-resolution chronostratigraphic modelling of alluvial deposits lacking organic content. The Severn catchment has historically been the focus of extensive fluvial geomorphological and archaeological research, with radiocarbon dating of organics in former river channels, and chemostratigraphy in mining areas. As a result, numerous alluvial sedimentary sequences remain only partially dated or totally undated, and overbank chronologies rarely extend into the later historic period.

This paper showcases the success, and ultimately the extended potential, of OSL dating within floodplains of the Severn Catchment, and how this technique can extend our understanding of historical land-use in such landscapes. Dated sedimentary sequences are presented from sites on the Severn, Wye, Teme and Warwickshire Avon. These were sampled in locations where local place-names indicate specific water behaviours in the past, providing a crucial link to settlement and land-use in the early to later medieval period, which is largely under-represented in the archaeological record.

The results of this research demonstrate that widespread alluviation occurred in the Severn Catchment in the Late Holocene. Overbank sedimentation occurred at all the sampled sites from the Iron Age to the present day, with both climatic and land-use variations playing key roles in the extent and typology of sediments. Age-depth modelling has also enabled a better understanding of catchment responses to changing population levels, land-use and tenure from the post-Roman to post-medieval periods.

Crucially, the results also demonstrate the importance of the interaction between high-resolution dated sequences and environmental information within place-names which, in combination, inform on the dynamics of both fluvial and archaeological landscapes at a number of scales from individual sites, to wider reaches and whole catchments.

**Keywords:** Severn Catchment, Chronostratigraphy, OSL, Age-Depth Modelling, Alluviation, Historic Land-Use, Place-Names

O-4051

## A 6000-year record of mass-wasting and flooding reconstructed from sediments in the distal-glacier fed Lake Sandvinvatnet, southwest Norway.

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### Abstract

The communities around and down the valley from the lake Sandvinvatnet experience increasing threat of various natural hazards as the climate of western Norway has become warmer and wetter. Both flood- and mass movements are common as well as occasionally outburst floods from the glacier Folgefonna. The last rain/snow melting flood event (October 2014), classified as a 200 years flood, led to vast erosion and destruction of property along the river Opo through the city of Odda. In total, five houses and one bridge were destroyed. The rebuilding of the riverbanks and the infrastructure did cost close to 20 mill. EUR. In addition, a smaller rockslide blocked off a road during the winter of 2017.

The aim of our study is to explore lake sediments deposited in Lake Sandvinvatnet in order to gain a long-term understanding of hazardous events during the last 6000 years. We want to answer the following questions; what was the past frequency of various natural hazards? What was the average magnitude of these past events? Further, we explore the influence of the glacier Folgefonna on the catchment processes. Of special interest in a future warmer climate is to see if the frequency and magnitude of past floods are connected to the presence of the glacier and its size in the catchment.

Lake Sandvinvatnet is a huge sediment sink for all types of sediments produced by different earth surface processes in the catchment. Our aim is to unravel these sediments and link them to various process. We have retrieved cores from the central part of the basin at 127 meters water depth during two field seasons (2016 and 2017). The main sediment core is an 8-meter long piston core. Additionally, we have retrieved several gravity cores including one taken at the same position as the main core. By correlating the uppermost sediments and its sediment properties to recent historical events, we will fingerprint the sediments and use these to identify similar events down core. This will base upon a multi-proxy approach using X-ray fluorescence (XRF), magnetic susceptibility (MS) and computed tomography (CT). The age model is mainly constructed from carbon-14 dates and lead-210 of the most recent sediments. The current bottom sample is dated to 6203 calibrated years before present.

The piston core shows large variability in sediment properties throughout most of the core. Both thick to thin and clay- to sand-sized layers are identified in addition to a lot of organic material in several of the layers. This suggests different types of hazardous events occurring with increasing frequency during the late Holocene. By using the past as a reference, we want to gain insight into future frequency and magnitude of natural hazards in the area.

O-4052

## Geomorphologic and geochronological reconstruction of Holocene jökulhlaups along the Hvítá River and Gullfoss waterfall, Iceland

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### Abstract

Gullfoss is one of Iceland's most visited sites, a two-tiered waterfall where the Hvítá River plunges 32 meters into the 70-meter-deep Hvítárgljúfur canyon. This system is one of the most prominent lines of evidence for catastrophic glacial outburst floods that surged across southwestern Iceland in the early Holocene. As the Icelandic Ice Sheet retreated, meltwater pooled at ice margins and drained in glacial lake outburst floods (GLOFs), also known as jökulhlaups. Some of the most catastrophic floods drained from Glacial Lake Kjölur, surging south from the interior highlands to the Atlantic Ocean. These floods left behind extensive geomorphologic evidence along the modern-day course of the Hvítá, including strath terraces, cataract systems, scoured bedrock, and boulder deposits (Figure 1). The largest events reached an estimated maximum peak discharge of  $300,000 \text{ m}^3 \text{ s}^{-1}$ , ranking them among the largest known floods in Iceland and on Earth (Tómasson, 1993).

Yet, all our evidence for the Kjölur jökulhlaups comes from only one publication to date (Tómasson, 1993). My research employs new methods to better constrain flood timing, routing, magnitude, and recurrence interval at this underexplored site. This presentation has three main goals: 1) present new and synthesized geomorphologic field evidence; 2) outline a sampling strategy for geochronological analysis, namely cosmogenic nuclide exposure dating and sedimentological and tephrochronological analyses; and 3) discuss future flood reconstruction efforts such as hydraulic modeling.

Reconstructing flood timing and dynamics will situate the Kjölur floods within late Pleistocene and early Holocene deglaciation chronology in Iceland. These events may also serve as an analogue to contemporary GLOFs from ice-dammed lakes, which pose an increasing geohazard in Arctic and alpine regions worldwide due to rapid climate-driven glacial lake expansion. Moreover, reconstructing the Kjölur jökulhlaups will help answer the perennial geomorphologic question of the role of high-magnitude, low-frequency events in Earth surface change.

Citation: Tómasson, H., 1993. Jökulstífluð vötn á Kili og hamfarahlaup í Hvítá í Árnessýslu. Náttúrufræðingurinn 62, 77-98.

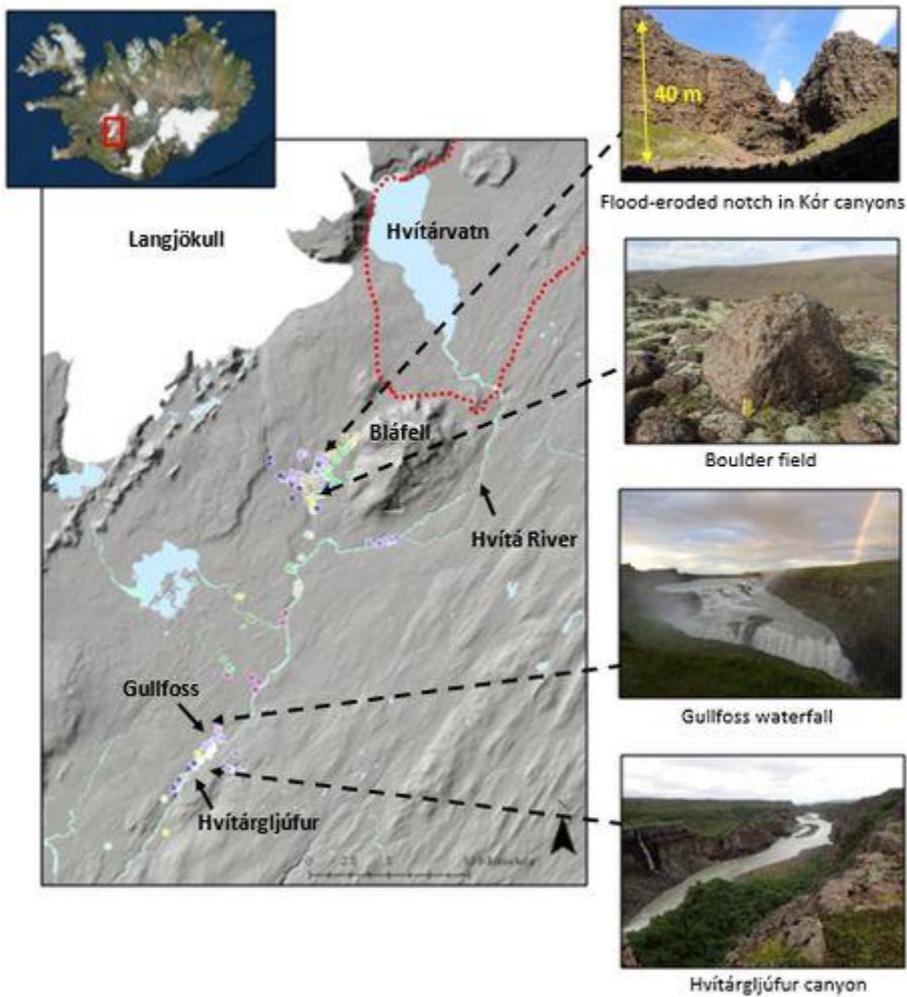


Figure 1. Study area (Arctic DEM basemap), with photos of selected Kjölur jökulhlaup geomorphologic features. Multicolored dots denote GPS points marking Kjölur jökulhlaup evidence. Red dotted line traces approximate extent of Glacial Lake Kjölur (as estimated by Tómasson, 1993).

O-4053

## Paleofloods records from Ladakh Himalaya

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### Abstract

The rivers draining the Himalaya support ~15% of the global population and the agricultural based economy of their catchment region largely depends on the hydrological consistency of these rivers systems. The normal monsoon floods in the Himalayan rivers act as conduit between mountain and the foreland bringing fine grained nutrient rich sediments to arable floodplains. However, the extreme floods resulting due to the excessive rainfall events, glacial and landslide dammed lake outbursts such the floods of June 2013 in Garhwal Himalaya and of August 2010 in Ladakh Himalaya destroy the economy and life that was built over the years. Whether such flood events are the result of natural climatic ramp or are the result of anthropogenic impact would only be understood if we have the longer records of past floods. Available historical and instrumental records are not sufficient to understand the trends and possible future intensity of such events, hence paleoflood archives to understand the variability is explored.

The upper Indus River flowing through the SW edge of Tibet in Ladakh and Indus Suture Zone is a part of the largest river catchment in the Himalaya. Geologically, the Indus valley is bounded by Ladakh batholith in the northeast and highly folded and thrust Indus Molasse in the southwest. Zaskar River, one of the major tributary of the Indus, increases the discharge and sediment flux of the Indus in multiple scale. Climatically, the Ladakh Himalaya is classified as cold desert, where the average annual precipitation is ~ 100 mm (at Leh) which at present is shared equally by westerlies (~ 50%). However, excess of contribution from the Indian Summer Monsoon (ISM) in the past often leads to extreme rainfall event and floods in the region e.g. August 2010, 2015 floods in Leh valley.

This study reconstructs the Late Pleistocene-Holocene history of extreme flood events in Ladakh using slack water deposits sequences comprised of sand-silt-clay couplet along the Indus and Zaskar river system. Chronology based on twelve <sup>14</sup>C AMS and thirty optically stimulated luminescence dating of charcoal and sand samples, respectively, suggest four major clusters of flood events occurring between ~16-4 ka that override the phases of strengthened monsoon. U-Pb chronology of Zircons used for provenance fingerprinting indicated that the flood of Indus and Zaskar rivers originated in the deglaciated regions of the catchment. This suggested the potential role of glacial lake outbursts and/or landslide lake outbursts in compounding flood magnitudes. Further, the flood sequences were noticed comprising burnt layers (hearth) and dung cake at places indicating the flood occurrences vis-à-vis human migration into the Ladakh region.

**O-4054**

## **Are the kettle-holes of Piława–Płytnica sandur (NW Poland) of the glacier flood origin?**

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### **Abstract**

Studies on the origin of the kettle-holes within Pomerania outwash plains mainly indicate their relationship with the melting of buried fragments of glacial ice during the deglaciation at the end of the Pleistocene: 1) they conserved the subglacial tunnels under fluvioglacial sediments, 2) they could have remained after the ice-core melting within the frontal moraine, 3) they could be fields of the stretched glacier tongue after the active phase of the glacier surge. The aim of the analysis was to investigate the hypothesis about the glacial flood origin of kettle-holes based on the morphometry of landforms. Selected morphometric indices were also compared to the landforms within Skeiðarársandur (S Iceland) created after the melting of ice blocks detached from the glacier front during jökulhlaup.

The research used data from the digitization of topographic maps (171 landforms) and ALS data (39 Pomeranian and 1792 Icelandic). Closed Depressions and Analytical Hillshading options (SAGA GIS 2.3.2), densed contour lines and hypsometric tints methods were used to isolate the kettle-holes. The volume, maximum and mean depth were calculated using the Surfer 12, the remaining parameters – in QGIS 2.18 and spreadsheet.

The Piława–Płytnica sandur in the roof layer (~2 m) consists of unstructured gravel-sand sediments with boulders forming two fans with a southern exposure of almost (0.1°–0.2°) flat surface varied by the remains of ‘washed out’ older frontal moraines. Kettle-holes within the distal part have an average area and an average mean depth more than twice smaller than the landforms in northern part of the study area – considered to be a marginal melting basin covered with fluvioglacial deposits. Depressions within fans show a greater degree of rounding; the compactness coefficient is 1.50 (similar to the Icelandic landforms), while those in the northern part – 2.05. The ratio of mean depth to diameter/width is on average 0.035, while in the northern part – 0.092, and so as in the case of subglacial valleys (0.090). The feature that connects the kettle-holes of Piława–Płytnica outwash plain and Skeiðarársandur (despite the size differences) is the volume model constituting a 1/5–1/4 volume of spheroid with axes corresponding to the maximum depth and the diameter. This model does not work for the northern landforms.

This morphometric analysis indicates the genetic diversity of the kettle-holes. Smaller ones within the Piława–Płytnica sandur can originate from the melting of ice blocks floated during the glacier flood. This is indicated by their morphometric similarity to the Icelandic landforms of flood origin and the unstructured deposits as well as the presence of ‘washed out’ fragments of frontal moraines. The settlement of this issue may be the dating of sediments, indicating the period of forming the depressions.

O-4055

## Imprint of recent Glacial Lake Outburst Floods (GLOFs) in Baker fjord sediments (Chile, 48 °S)

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### Abstract

Glacial Lake Outburst Floods (GLOFs) constitute a major threat in glacier-covered regions. These catastrophic events occur when a lake dammed by a glacier or moraine suddenly empties, resulting in abrupt flooding. This issue is particularly pronounced in the Baker region (47 – 48 °S) of Patagonia, where 21 GLOFs have been documented in the last decade. During such events, the Baker River, which drains most of the eastern side of the Northern Patagonian Icefield, triples in discharge and suspended sediment concentrations increase by more than one order of magnitude. The recent occurrence and the vast impact of these large-scale events on the Baker River raises the question of how these events are recorded in Baker fjord sediments. The goal of this project is therefore to understand how GLOFs are registered in Baker fjord sediments, in order to reconstruct their occurrence in the past, i.e., when river discharge was not monitored. To do so, the bathymetry of the prodelta region of Baker fjord was mapped at high resolution and a total of ten sediment cores were collected. The sediment cores were described, photographed, and scanned at 2 mm resolution on a Geotek MSCL for magnetic susceptibility, gamma density, and spectrophotometry. Additionally, XRF scanning was performed at 2 mm resolution. A core chronology was established on the most promising core using <sup>210</sup>Pb concentrations. Results show that the subaquatic delta in Baker fjord is deeply incised with well-developed sinuous channels (maximum depth of 26 m). The most prominent channel has an average width of 140 m and extends up to 8 km in Baker fjord. The morphology of the channels and the occurrence of sediment waves within the axial channels imply recent sediment transport by turbidity currents. The sediment cores, which display at least seven turbidites in a time span of 46 ± 7 years, confirm the occurrence of active turbidity currents. Although several potential triggering processes are plausible for the occurrence of dense underflows in Baker fjord and detailed monitoring of the subaquatic delta is required to pinpoint the exact triggering process(es), we believe that elevated river discharge during GLOFs is the main cause of the turbidite currents within the fjord. Although seasonal increases in river discharge due to snowmelt may trigger turbidity currents, it is more likely that the turbidites observed in the deepest sediment cores represent large-scale turbidity currents triggered by GLOFs. The lower number of turbidites in the sediment cores compared to the number of recent GLOF events however suggests that only the largest GLOFs are recorded as turbidites. This study demonstrates that GLOFs might be of key importance in shaping the fjord's morphology, and that their occurrence in the past may be reconstructed using turbidite stratigraphy.

O-4056

## Reconstructing the Holocene lateral mobility of the Rhine River and consequences on the location strategy of riverine settlements (France, Germany)

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### Abstract

The lateral mobility of the Rhine River during the Holocene and its consequence on the distribution of settlements since the Neolithic period remained poorly understood in the Upper Rhine Plain at the French-German border. This interdisciplinary study, bringing together geoscientists and archaeologists from the Universities of Strasbourg and Freiburg-im-Breisgau, focuses on the Holocene floodplain reach comprised between Strasbourg and Lauterbourg (Drusenheim/Rheinmünster and Seltz/Rastatt). Within our study area, characterized by anastomosing and meandering channels before the Rhine was regulated in the 19<sup>th</sup> c., we investigate the Rhine River mobility on a long-term perspective and its consequence on the preservation of ancient settlements.

The reconstruction of the evolution of the Holocene alluvial landscape is based on (1) a synthesis of historical and archaeological data, (2) the analysis of high-resolution LiDAR data and ancient maps (18<sup>th</sup> and 19<sup>th</sup> c.), and (3) the study of 30 new sedimentary cores drilled across the Holocene alluvial plain. The analysis of the cores brings together geomorphologists, palaeoenvironmentalists, geochronologists and archaeologists in order to (i) reconstruct lateral instability of the Rhine channels and changes of fluvial regime over time, (ii) to trace the changes in sediment origin and (iii) to produce a reliable chronological framework using different dating methods (IRSL-screening, OSL, <sup>14</sup>C) as well as archaeological and historical data. Ultimately, this reconstruction of the evolution of the alluvial plain of the Rhine is integrated into a wider palaeoclimatic context and we establish an evolutionary model of the strategy of settlement location adopted by the riverine communities since the Neolithic.

**O-4057**

## **How much did the Black Death affect regional scale vegetation composition in southern Sweden?**

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### **Abstract**

The plague pandemic known as the Black Death reached Sweden in AD 1350 and led to a large decline in the human population size. It has been shown in many local scale pollen studies from smaller sites, that this decline was followed by a decrease in land use, especially crop cultivation, and local reforestation. These changes have locally been seen to have an impact on lake catchment erosion and nutrient transport, and the land-use decline has even been suggested to have an impact on the nutrient input and oxygen levels in the Baltic Sea.

However, not all small sites show a strong land-use decline at this time, and upscaling from local studies to a wider regional scale is a challenge. In pollen diagrams from large lakes, the signals of land use change at this time are often rather subtle. In this study, the REVEALS model of the Landscape Reconstruction Algorithm is applied to new and pre-existing pollen assemblages from large lakes in southern Sweden from the medieval period, in order to quantify the regional scale vegetation changes across the period of the Black Death. By taking account of differences in pollen productivity and dispersal between species, we get a picture of a much more open landscape in most of Southern Sweden than implied by non-arboreal pollen percentages alone. However, the magnitude of this effect varies from site to site, and through time, underlining the importance of applying models to quantify land cover composition.

For smaller sites, the largest landscape changes often seem to occur in agriculturally marginal areas. Once vegetation and land use change has been quantified, the spatial patterns in the changes are analysed to see if this pattern also holds true at a larger spatial scale, and whether the responses are related to abiotic factors such as soil type and topography.

O-4058

## New land cover estimates for late-Quaternary interior Alaska: implications for early human settlement

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### Abstract

Interior Alaska, a large region of northern boreal forest and alpine tundra, has some of the oldest early human localities in North America. The Yukon-Tanana drainage was an important corridor for eastward human migration and subsequent settlement in the late Pleistocene. The oldest archaeological sites date to 14 ka BP, which also marks the onset of major climate and vegetation change. The pollen record is well studied, but key plant taxa have greatly differing pollen productivity, which has not been quantified. Thus, views vary concerning the nature of the herbaceous vegetation mosaic that persisted under cool, dry conditions until ca 14 ka and the subsequent openness of the landscape when woody taxa increased in importance as the climate became warmer and moister. Previous studies have demonstrated regional variation in relative pollen productivity for key species across Europe. Alaska's flora has had a different Quaternary history from that of much of boreal North America, and this has probably led to genetic differentiation in many taxa. We therefore developed an independent set of pollen productivity estimates (PPEs) for Alaska prior to applying the landscape reconstruction algorithm (LRA-REVEALS) to sites in the interior. Our aim was to use a quantitative approach to evaluate the vegetation cover of the landscapes experienced by the early human inhabitants of the interior. We used vegetation surveys in the alpine zone (Denali Highway) and boreal forest (middle Tanana valley), together with pollen samples, to estimate PPEs. Notably, *Betula* PPEs obtained for tundra-shrub and forest-tree taxa differed markedly. We also obtained PPEs for *Populus* (two species, undifferentiated), a generally low pollen producer that characterizes early-Holocene pollen assemblages. In testing REVEALS on large lakes and a set of small lakes, we applied mostly tundra PPEs to samples dating to the late-Pleistocene and earliest-Holocene and mostly forest PPEs to samples dating from the establishment of *Picea*-dominated evergreen boreal forest (ca 10 ka BP and later). The main findings for the early (pre-evergreen) period were that i) *Salix* was as important, or more so, than *Betula* in the shrub component of vegetation cover, ii) grasses and sedges were as abundant as shrubs, and iii) *Populus* probably had high importance, at least locally, suggesting deciduous woodland was a significant component of the vegetation mosaic. In the later period, *Betula* was less important than its pollen values might suggest, while the reverse is the case for *Picea*, *Salix*, *Poaceae*, *Populus* and *Ericales* (Figure 1). These findings suggest that concepts of the vegetation mosaic and availability of key taxa should be revised when considering resources available to early human populations.

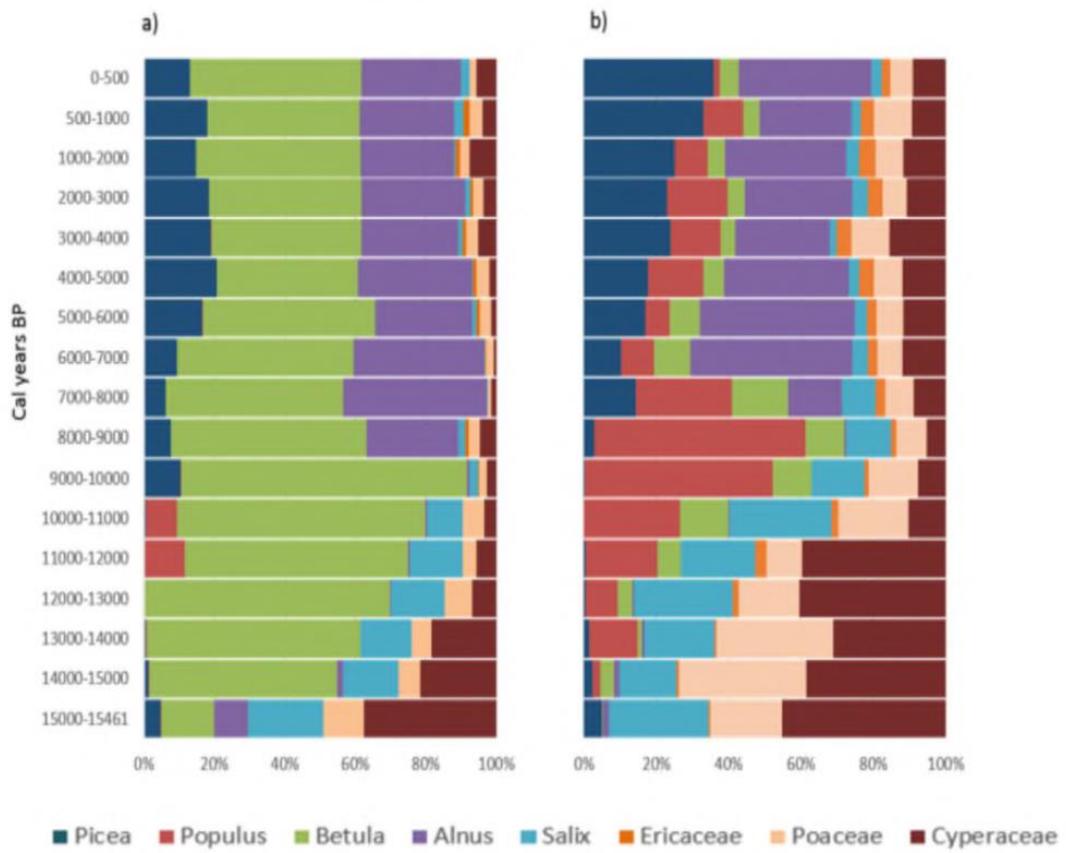


Figure 1. a) unmodified composite pollen values, interior Alaska; b) REVEALS estimates of vegetation cover using Alaska PPEs .

O-4059

## Quantitative pollen-vegetation modeling of Patagonian high Andean steppe and tree-line communities

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### Abstract

Understanding the long-term dynamics of high Andean steppe and upper tree-line communities in Patagonia is a key step in designing effective conservation and management strategies for these ecosystems in the face of expected climate changes. Pollen records covering the last 1200 years, which spans several ecologically significant climate changes in the region, are available, but applying landcover reconstruction methods to pollen records from Patagonia is still a challenge because these models are not yet parameterized for these habitats. Past work has shown that there are stable pollen-vegetation cover relationships for the main plants of interest (e.g. Burry et al., 2001; Sottile et al., 2016).

This paper reports on the calibration of pollen dispersal and deposition models for the main plant types in this region, and their implications for the reconstruction of patch-scale dynamics at the upper tree line over the last 1200 years in response to known climatic drivers. A dataset of paired modern pollen surface samples and field and remote sensing vegetation data collected at multiple distance increments using a design which incorporates the wind regime of southern South America are analysed. Multivariate analysis of the pollen assemblages from the moss polster samples showed that the pollen types *Nothofagus*, Poaceae, Asteraceae subf. Asteroideae, *Empetrum*, *Gaultheria*, Apiaceae, *Azorella*, *Mulinum* and *Nassauvia* were the most important variables for separating forest and non-forest communities, and therefore for reconstructing past forest patch dynamics. Extended R-Value analysis is then used to estimate the Relative Pollen Productivity of these pollen types, using fall speed estimates based on measurement of at least 30 locally collected grains of each pollen type. Relevant Source Areas of Pollen are then explored for both moss polsters and for potential pollen record sources using both empirical and simulation approaches in order to estimate the spatial resolution possible for land cover reconstruction at this critical ecotone.

Once the appropriate dispersal model is identified and calibrated, it can be applied both in simulation to explore the sensitivity of the pollen record to patch dynamics in this landscape and directly to the reconstruction of past land cover in this sensitive and biogeographically valuable region.

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O-4060

## A British everglades? The ten thousand year story of the formation and destruction of the Humberhead Levels wetlands.

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### Abstract

Archaeological records show that humans have long been attracted to the range of resources available in wetland ecosystems, and that a wide range of settlement and economic activities occur around the wetland-dryland interface. Wetland-dryland mosaics are highly dynamic landscapes, with the position and nature of the boundaries between different elements changing in space and time throughout the Holocene, in response to both internal dynamics (e.g. growth of raised mires) and external forcing factors (e.g. changing relative sea level). Better understanding of the natural structure and functioning of lowland wetland complexes in western Europe offers a valuable contribution to planning natural flood management against current sea level rise, to conservation of remaining wetlands across major river systems, and to the reconstruction of palaeogeographies which can help locate, interpret, and protect the archaeological record of wetland use by human societies.

Lowland wetland complexes preserve records of their evolution in complex sequences of sediments from fluvial, estuarine and terrestrial peatland ecosystems. Existing pollen data from sedimentary records can be collated and past land cover reconstructed at meso-scales using pollen dispersal and deposition models through the Multiple Scenario Approach (Bunting et al. 2018). In this presentation we will explore how MSA reconstructions can provide valuable context for analysis of archaeological data of past patterns and economics of human settlement and for exploring the ecology of past and possibly future lowland wetland landscapes.

Our case study is the Humberhead Levels (eastern England), which occupy the southern basin of a former pro-glacial lake and extend over an area of about 30x35km. Today the land cover is mostly intensive agriculture, with some protected areas centred on the remnants of heavily exploited lowland ombrotrophic mires. Historical maps and sediments underlying the fields tell a different story, showing a landscape of wetlands, marshes, water meadows, fen, wet woodland and mire, and human settlement and activity clustered on islands of higher ground. Using existing pollen records, sediment logs and other palaeoenvironmental data, the Wildscapes project is seeking to trace the dynamic history of the wetland complexes across this landscape, from their formation as rising sea level increased base levels in the Humber River around 7000 years ago, to the extensive draining and “reclaiming” works of agricultural improvement in the last centuries.

We will present reconstructions of land cover for five Holocene time windows, the late Mesolithic, mid-Neolithic, early Bronze Age, early Iron Age and Anglo-Saxon and consider the uncertainties of reconstructing palaeogeographies in these environments.

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O-4061

## Fragments of tradition: modern pollen studies and the reconstruction of landscape management

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### Abstract

Arguments about the ecology and conservation of the habitats associated with “traditional” cultural landscape use often make assumptions about the antiquity of historically documented and surviving practices. These assumptions could potentially be tested by palaeoecological methods if the pollen signal is actually capable of recording the aspects of interest. Studying the contemporary pollen rain from remnant fragments of habitats such as nature reserves offers a means of testing the detectability of properties of these ecosystems and a framework for developing a tool kit for reconstructing their history from sedimentary records.

Because pollen is widely dispersed, and pollen grains deposited together as an assemblage could have originated from plants growing in quite a wide area around the location, studies in contemporary cultural landscapes can rarely be used as direct analogues for the past. Even if the local vegetation (e.g. within a protected area) is actually a direct analogue for past land cover, the pollen signal will include background pollen sourced from within the wider landscape, which is generally highly industrialised and greatly changed since the mid-20<sup>th</sup> century. This will affect the utility of the pollen assemblages within analogue-matching analytical frameworks such as ordination analysis to match modern and past assemblages.

Land cover reconstruction methods based on pollen dispersal and deposition models such as the Landscape Reconstruction Algorithm (LRA) and Multiple Scenario Approach (MSA) are explicitly designed to address this problem, but also require that assumptions are made about how the pollen signal forms, and are used to reconstruct the main land cover types using a sub-set of the dominant components of the pollen assemblage rather than using information from the whole assemblage.

This talk will explore a range of approaches to using modern pollen-vegetation data to build up a more objective tool kit for reconstruction of past landscapes from pollen records, mostly through use of a case study of paired pollen-vegetation data collected in surviving patches of three traditional land use types in eastern Yorkshire (UK), traditionally managed hay meadow, grazed heath, and broad-leaved woodland. Detailed vegetation data were collected around each pollen sample at a range of spatial scales following the Crackles Bequest Project method (Bunting et al. 2013), allowing application of a range of methods including ERV analysis to estimate Relative Pollen Productivity, and comparison of pollen and vegetation presence (Hjelle 1997) or biodiversity.

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O-4062

## Dynamics of a forest beetle community in a Norway spruce forest in the High Tatra Mountains, Slovakia.

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### Abstract

Norway spruce (*Picea abies*) is a dominant keystone species in the montane coniferous forests in central Europe, with important ecological and commercial value. Natural disturbances such as wind throws and bark beetle outbreaks have caused major losses in these forests in the last few decades and are becoming more frequent and severe. Holeksa et al. (2016) created a dendroecological dataset from the High Tatra Mountains in Slovakia, which shows several large disturbance events occurred in this region over the last two centuries. Comparing dendroecological data with fossil beetle records from sedimentary archives can provide more specific information on the nature of these disturbances. Reconstructed long-term disturbance patterns can provide information for improved nature conservation and forest management, as they can make use of these natural factors of dynamics and resilience of the forest. From a forest hollow in the High Tatra Mountains in Slovakia, 12 cores were retrieved for a quantitative study on subfossil beetles (Coleoptera), covering the last 1000 years. Correlation and integration of the adjacent profiles was underpinned by repeatable down-core  $\mu$ XRF geochemical stratigraphy (airfall Pb and other elements). Fossil pollen and charcoal records, obtained from a parallel core, together with the fossil Coleoptera, provide a record of past disturbances that will be compared to the disturbance events recorded in the dendroecological data. The fossil record demonstrates a diverse community of beetles, including many species of bark beetles such as the European spruce bark beetle *Ips typographus* and other saproxylic taxa characteristic of dead wood habitats. Anthropogenic influences, coming from a distant village, are clearly visible in this record as well. Changes in the forest beetle community over the last 1000 years and their relation to disturbance events in the High Tatra Mountains in Slovakia are discussed.

**O-4063**

## **Quantitative vegetation reconstruction in the Neotropics: Opportunities, Problems and Progress**

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### **Abstract**

Analysis of fossil pollen in lake and peat sediments is the fundamental means by which past terrestrial vegetation is reconstructed. Developments in quantitative methods, linking plant abundance to the production and deposition of pollen in sediment archives, have allowed for vegetation reconstructions at a multitude of scales to answer questions of past climate and anthropogenic forcing of land cover change. Efforts in quantitative vegetation reconstructions, however, have been largely restricted to temperate ecosystems in Europe, Asia and North America, where there is a greater abundance of modern pollen-plant data for model calibration and detailed pollen taxonomies to link pollen morphotypes to specific groups of plant species.

Quantitative methods are particularly underdeveloped in the Neotropics, where some of the most pressing questions of past human-environment interactions and past climate-vegetation dynamics prevail. This presentation demonstrates the extensive opportunities for quantitative vegetation reconstructions in the Neotropics, and summarises the inroads that have been made, and problems encountered, in developing quantitative reconstruction methods for these ecosystems. We conclude that to achieve workable reconstruction models for the Neotropics, the problem needs to be approached from the ground up, rather than a blanket application of existing techniques, coupled with community-wide engagement to create, calibrate and test methods for this diverse and understudied region of the globe.

O-4064

## A strengthened East Asian Summer Monsoon during Pliocene warm periods: geological evidence and modelling results

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### Abstract

The Pliocene epoch (5.3–2.6 Ma) is the most recent geological interval in which atmospheric CO<sub>2</sub> levels were similar to those of the present day (~400 ppmv). This epoch is therefore considered to be the best ancient analog for predicting a future anthropogenic greenhouse world. In order to determine the response of the East Asian Summer Monsoon (EASM) rainbelt during Pliocene warm periods, a 71.9 m-thick aeolian 'red clay' sequence at Pianguan was investigated. Magnetostratigraphic data, constrained by lithostratigraphy, show that the polarity zones of the 'red clay' section correlate with those between subchrons C2An.2r and C3An.2n of the geomagnetic polarity time scale (GPTS), yielding an age range of 6.9–2.9 Ma. The 'red clay' deposits exhibit enhanced weathering intensity over two time intervals, namely 5.23–4.3 Ma and 3.7–2.9 Ma, as evidenced by their well-developed pedogenic characteristics, as well as their high free to total Fe<sub>2</sub>O<sub>3</sub> ratios and high redness (a\*) values, which in turn indicate an increased summer monsoon intensity during most of the Pliocene. The Pliocene soils at Pianguan show a pedogenic development similar to the S<sub>5</sub> soil unit (~0.5 Ma) at Luochuan in the central Plateau, which is located some 3.7° latitude south of Pianguan, but this development is much stronger than that observed at Yulin in the north, and weaker than that seen at Lantian in the south. This may imply a more northwesterly penetration (~200 km) of the monsoon rainbelt during the Pliocene warm periods compared with the Pleistocene interglacial period (~0.5 Ma ago).

Using the output of the Pliocene Model Intercomparison Project Phase 1 (PlioMIP1), we analyzed the northern edge of the EASM during the mid-Pliocene warm period (~3.3–3.0 Ma). The results show a ~150 km northwestward migration of the northern edge of the EASM during the mid-Pliocene compared to the pre-industrial period, which is consistent with that derived from the comparison of pedogenic characteristics between the Pliocene and Pleistocene soils. Our results strongly support the prediction that the EASM rainbelt shifts northward in a warmer world. In addition, it is inferred that Pliocene warmth was unlikely to have been characterized by a permanent El Niño-like state, but was possibly influenced by a La Niña-like state.

### Acknowledgements

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O-4065

## Vegetation and climate transition from late Pliocene to early Pleistocene at Nihewan Basin, north of China

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### Abstract

Nihewan Basin has been regarded as one of the Early Pleistocene standard strata in northern China, but it is lack for high-resolution environmental changes studies. In this paper, 265 samples for NHA cores (17520~13860cm, 2.92-2.33Ma) in the Nihewan Basin were used for high-resolution pollen analysis. The results showed that there are 3 transition events and the biggest transition event for vegetation and climate occurred at about 2.83Ma, when the *Pinus* pollen content was usually more than 30% and *Picea* were less than 20%, and the deciduous broad-leaved trees had the highest percentage with maximum 37%, some subtropical pollen types such as evergreen *Quercus*, *Carya*, *Melia* can be recorded, indicating that vegetation were dominated by broad-leaved forest mixed with pine and the climate was warm and humid. After 2.83 to 2.71Ma BP, the pollen content of *Picea*, *Artemisia* and Chenopodiaceae increased significantly, with the maximum reaching to 90% for *Picea* and 80% for *Artemisia* and Chenopodiaceae; on the contrary, the pollen content of *Pinus* and broad leaved trees significantly reduced to lower than 10% and 5% separately; which indicates that the regional vegetation became pruce forest or steppe and climate tended to become chilly and dry. From 2.66~2.57 Ma, it was the second transition for vegetation and climate, when the pollen assemblages were dominated by high percentages of *Picea* (more than 80%) once again, other pollen types are very rare, suggesting the vegetation become pruce forest once again and the climate become much colder. From 2.47~2.33Ma, it was the third transition for vegetation and climate, when the pollen assemblages are characterized by high percentages of *Picea* (more than 40%), *Artemisia* and Chenopodiaceae (more than 20%), however there were some deciduous broad-leaved trees can be recorded, suggesting that the regional vegetation in the study area were dominated by forest steppe or spruce forest, and though the climate was cold and dry, but the cold degree was lower than the second cold period. The climate change sequences from 2.9 to 2.3Ma in this study are comparable to the oxygen isotopes change in the deep marine in general. MIS G10, G6, G2, 104, 102, 100, 98, 96, 92, 88 and 86, which represent cold climate can be recognized.

O-4066

## **Aridification of Central Asia during the Plio-Pleistocene transition: evidence from the Charyn Canyon sequence, Kazakhstan**

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### **Abstract**

Continuous terrestrial records of palaeoclimate over long timescales extending to the Pliocene are rare, and still more so in transition zones between major climatic subsystems such as Central Asia. Charyn Canyon, located in the Ili Basin of southeast Kazakhstan, provides one such archive. Its location straddles the polar front to the north, the Asian monsoon systems to the south and the mid-latitude westerlies. The Charyn sedimentary succession is an 80-m thick exposure of alternating fluvial, alluvial, and loess deposits. Loess thickness increases upwards, suggesting a long-term trend of aridification in this part of Central Asia.

Here we provide high resolution palaeoenvironmental change over the late Cenozoic, which spans ca. 4-2 Ma based on coupled palaeomagnetic and U-Pb datings. Magnetic susceptibility data provide additional chronostratigraphic information. Stable oxygen and carbon isotopes, including clumped isotope analysis of pedogenic carbonate nodules, are used to reconstruct quantitative palaeoclimatic parameters and variability down the sequence. Our combined proxy data approach in the Charyn Canyon sequence enables us to better understand climate system dynamics in arid Central Asia during the late Cenozoic.

O-4067

## The Plio-Pleistocene transition in the continental sequences of south Western Siberia

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### Abstract

The Plio-Pleistocene deposits of south Western Siberia (south West Siberian plain and Altai Mountains) are unique archives containing substantial information on the environmental and climatic evolution of this vast territory. The Early Pliocene is characterized by a relatively stable continental sedimentation under river, lake and subaerial conditions. At that time, a sufficiently well-developed, little entrenched drainage system with northward runoff existed at absolute heights considerably higher than the low water level of the modern rivers oriented toward the high ocean level. The soils in the south of the plain were formed under a high level of ground-water according to the type of vertisols. The mammalian fauna corresponds to that of the Ruscinian of the Western Europe. The fresh-water mollusca fauna is characterized by the wide distribution of thermophilic Indo-Chinese and West Siberian endemic genera of East Asiatic origin. The climate that time was relatively stable, temperately warm. At the boundary of Early and Late Pliocene, about 3.2 Ma, the climate in the southern West Siberia became considerably colder and, probably, drier. The result was a radically restructured biota. Nearly all thermophilic species of fresh-water mollusca (10 genera) became extinct. The malacofauna acquired the Palaeartic character. The Ruscinian fauna of mammals was replaced by the Villafranchian fauna with no vole-toothed hamsters. The presence of the relict thermophilic species in malacofauna from 3.2 to 2.6 Ma suggests the climate of that time to be warmer than that of the present day. Those events coincided with uplift of the Tibet, Himalaya, Tien Shan, Altai, the increase in tectonic activity in many regions. Global cooling is marked by extinction of all thermophilic elements of fresh-water mollusca occurred at about 2.6 Ma. In Northern Asia, the only one section which is well-documented paleontologically and where the Gauss-Matuyama boundary was detected is the section on the Irtysh River near Lebjazhie village. Malacofauna obtains its present image. Middle-Villafranchian mammal fauna appeared. In that time the climate became similar to that of the present day or more cool. Early Pleistocene glaciation was spread in Altai Mountains. This follows from finds of faceted boulders buried in the Bashkaus Formation. Paleomagnetic investigations revealed in the latter a wide zone of negative polarity corresponding to the Matuyama Chron in the magnetostratigraphic scale and made it possible to correlate the formation with the Lower Pleistocene. The 2.1 Ma global warming is marked by the emergence of the thermophilic Middle Asian elements among West Siberian malacofauna. Colling at the beginning of Pleistocene about 1.8 Ma is marked by extinction of fresh-water and terrestrial malacofauna. The climate at that time is close to the present one.

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O-4068

## Paleoceanographical changes of the Plio-Pleistocene based on marine palynology at ODP Sites 882 and 887, western and eastern North Pacific

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### Abstract

The growth of glaciers in Alaska during the early Pliocene is in disagreement with the hypothesis suggesting that development of permanent continental ice in the circum-North Pacific is associated to onset of the modern halocline at 2.7 Ma (cf. Haug et al., 2005). However, the paucity of paleoceanography data documenting salinity in the eastern North Pacific prevents full understanding of the relationship between the halocline development and glaciers growth at regional scale. Numerical simulations have led to suggest that a strong contrast over the subarctic gyre during the Pliocene, with warm sea surface temperature (SST) in the east and cold SST in the west (Burls et al., 2017), might explain early ice extend in North America. Here again, the lack of paleoceanographic data is critical. In the view to fill this gap and to better constrain the scheme of the Plio-Pleistocene climate-ocean-ice transition in the northern North Pacific region, we investigated the dinocyst assemblages at Ocean Drilling Program (ODP) Sites 882 and 887, located in the west and east respectively.

Until 4.2 Ma, species associated with subpolar waters, *Pyxidinospis braboi*, *Filisphaera filifera* and *Impagidinium pallidum*, are reported in the western Pacific. The presence of these species contrasts with the occurrence of *Ataxiodinium zevenboomii*, *Impagidinium velorum* and *Impagidinium patulum* in the Gulf of Alaska, which are associated with warm and temperate sea surface conditions. Between 4.2 and 2.7 Ma, the species assemblages at both sites are characterized by the dominance of the cold tolerant taxon *Habibacysta tectata*, which alternates with *Impagidinium detroitense*, and suggests homogenous cooling of the Pacific subarctic gyre until 2.7 Ma. After 2.7 Ma, dinocysts assemblages suggest temperate conditions and seasonal warming at the surface due to enhanced stratification related to the existence of the modern halocline. Concomitant extinction of *Impagidinium detroitense*, which marks a major biostratigraphical limit, is reported simultaneously at both ODP Sites 882 and 887 supporting simultaneous onset of the modern halocline in the North Pacific at 2.7 Ma.

Dinocysts assemblages suggest the presence of warmer sea surface conditions in the Gulf of Alaska during the Pliocene and tend to support strong zonal contrast in the subarctic gyre prior to 4.2 Ma leading to early glaciers growth fostered by high evaporation and moisture supply in the east. However, our results also indicate a reduction of east-west gradient at 4.2 Ma, well before the development of the halocline at 2.7 Ma, which is recorded here for the first time in the Gulf of Alaska.

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O-4069

## Iberian margin sea surface temperatures indicate a change in glacial North Atlantic circulation during the Late Pliocene-Early Pleistocene transition

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### Abstract

The transition from the Pliocene to the Pleistocene is characterized by the intensification of the Northern Hemisphere glaciation (NHG), which is part of the long term Cenozoic global cooling trend. Records from the North Atlantic show a gradual cooling in sea surface and bottom water temperature indicating a change in the mean climate state. However, most of those studies are from sites influenced by the North Atlantic current, which brings warm water from the tropics to the high latitudes. In this work, we investigate the impact of the intensification of NHG on the Iberian Margin in order to evaluate the evolution of Southwestern European climate and its linkage to North Atlantic circulation changes in the subtropical gyre.

We present a new alkenone-based sea surface temperature (SST) record from the Iberian Margin (IODP Site U1391, 37°21.5'N; 9°24.6'W, 1085 m water depth) encompassing from ~3.4 to 2.1 Ma, combined with the Ca/Ti record obtained through x-ray fluorescence (XRF) scanning of the sediments from the same site. The temperature at the Iberian Margin during the studied interval was considerably higher than at present (18°C), with maximum values of 25 °C. SST values only decreased below present values at ~2.7 Ma, when glacial periods get intensified. From 3.4 to 2.7 Ma, the amplitude of SST variability between cold and warm intervals was small (<4 °C), with oscillations following a precessional pattern. At 2.7 Ma (MIS G6) the amplitude of SST variations shows a remarkable increase, reaching ~8 °C in the subsequent climatic cycles. Temperatures during warm intervals (interglacials) were slightly colder than prior to 2.7 Ma, whereas SSTs during cold intervals (glacials) became much colder than prior to 2.7 Ma. The periodicity of SST oscillations during the Early Pleistocene interval follows obliquity, which indicates that after 2.7 Ma the Iberian Margin climate was coupled to the obliquity-driven ice volume oscillations, whereas before 2.7 Ma it was more controlled by low-latitude mechanisms. The Ca/Ti record shows a similar pattern to the SST reconstruction supporting our SST interpretations. A comparison of our Iberian Margin reconstruction with the alkenone-based SST records from the North Atlantic (Site 982 in subpolar region and Site U1313/607 at mid-latitudes), and the Mediterranean and Tropical stacks led us to propose a change in North Atlantic circulation in the subtropical gyre during glacial periods after 2.7 Ma. This change in oceanographic conditions is probably linked to the equatorward shift of the climatic belts and the contraction of the Hadley cell circulation triggered by the glacial intensification in the Northern Hemisphere.

O-4070

## Stable isotopic composition of large mammal skeletal remains from South and Central Europe: implications for Pliocene/Early Pleistocene paleoclimate

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### Abstract

Stable isotope compositions of skeletal apatite of herbivorous mammals are outstanding archives of paleoecological, paleoenvironmental and paleoclimate conditions. Stable carbon isotopes in apatite reflect the  $^{13}\text{C}/^{12}\text{C}$  ratios of plants consumed by the herbivores, thereby providing information about the photosynthetic pathway ( $\text{C}_3$  or  $\text{C}_4$ ) and the openness of vegetation or precipitation amount. Stable oxygen isotope composition of apatite depends on that of the ingested water. The  $\delta^{18}\text{O}$  value of ingested water is usually very close to that of local precipitation, while the oxygen isotope composition of rainwater reflects regional mean annual temperature. Tooth enamel of large, obligate drinking herbivores is thought to be the best archives because enamel is the most resistant tissue to diagenetic alteration and these mammals track the average  $\delta^{18}\text{O}$  value of environmental water most closely.

This study is aimed at reconstructing temporal changes and spatial distribution of the oxygen isotope composition of precipitation ( $\delta^{18}\text{O}_{\text{ppt}}$ ) during the Pliocene and Early Pleistocene in South and Central Europe. These reconstructions are based on measured  $\delta^{18}\text{O}_{\text{PO}_4}$  values of mammal teeth. Temporal changes and spatial distribution in vegetation and/or humidity are derived from measured enamel  $\delta^{13}\text{C}$  values. To achieve these goals, multiple stable isotope measurements were performed on teeth enamel samples of large mammals, and published data from the literature were also used to extend the spatial range of reconstructions. Most of the fossils belong to *Rhinocerotidae* (about 50% of the samples), *Bovidae*, *Cervidae*, *Gomphotheridae* and *Equidae* families, while few samples are from other families.

All of the  $\delta^{13}\text{C}$  values obtained in this study indicate  $\text{C}_3$ -plant dominated ecosystems and these values follow spatial aridity gradients and /or changing openness of the vegetation. The measured  $\delta^{18}\text{O}$  values depend on many factors in each region, but these are in general higher for the Early Pliocene, and lower in Late Pliocene – Early Pleistocene samples. The spatial distribution of  $\delta^{18}\text{O}$  values resembles those of the present day, both in Early Pliocene and Late Pliocene – Early Pleistocene. (Note, however, that we could compare only three regions for the Early Pliocene.) The calculated  $\delta^{18}\text{O}_{\text{ppt}}$  values for the MN14-15 biozones are similar to the modern  $\delta^{18}\text{O}_{\text{ppt}}$  values, while they are lower compared to the MN16 and MN17 biozones.

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O-4071

## Oscillating climatic/oceanographic conditions during Heinrich Events inferred from foraminiferal data from the Porcupine Bank slope

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### Abstract

Sediment cores taken from the lower slope (>2700 m water depth) of the Porcupine Bank, eastern North Atlantic, contain abundant evidence of ice-rafted debris (IRD) which has been used as an indicator of ice sheet behaviour during the last glacial period. Located at the interface between the North Atlantic and the western Irish shelf, these cores are ideally positioned to examine the behaviour of the former British-Irish Ice Sheet (BIIS) and its relationship to wider circum-North Atlantic ice sheet change. Heinrich layers are expressed within the core sediments as distinct grey bands of high magnetic susceptibility and are readily distinguishable from the more numerous IRD layers linked to proximal sources such as the BIIS.

We identify four IRD layers linked to Heinrich Events (HE) H1, H2, H4 and H5 and use foraminiferal census data and Mg/Ca palaeothermometry to explore the changing oceanographic / climatic conditions at the Porcupine Bank across these HE. Whilst the dominance of *N. pachyderma* indicates all HE are characterised by cold conditions, a small but significant proportion of warm water species are present in the assemblage, forming distinct double peaks during H2 and H4. Sea surface temperatures (SST) derived by transfer functions and Mg/Ca<sub>*G. bulloides*</sub> palaeothermometry indicates brief warm intervals of up to 10°C and 14°C during H2 and H4 respectively.

One working hypothesis is that the appearance of warm water species and elevated SST within Heinrich layers along the Porcupine Bank is linked to intrusions of warmer water masses from the south during phases of weakened Atlantic Meridional Overturning Circulation. We conclude by briefly outline ongoing work to test this scenario.

O-4072

## Onset of Heinrich Stadial 1 driven by acceleration of northern ice sheet melt

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### Abstract

The cause of a rapid change in Atlantic Ocean circulation and northern cooling at the onset of Heinrich Stadial 1 18.5 ka is unclear. Previous studies have simulated the event using ice sheet and/or iceberg meltwater forcing, but these idealised freshwater fluxes have been unrealistically large. Here, we use a different approach, driving a high-resolution drainage network model with a recent time-resolved global palaeo ice sheet reconstruction to generate a realistic meltwater forcing. We input this flux to the HadCM3 climate model without adjusting the timing or amplitude and find that an acceleration in northern ice sheet melting (up to 7.5 m/kyr global mean sea level rise equivalent) triggers a 20% reduction in the Atlantic Meridional Overturning Circulation (AMOC).

The result is widespread Northern Hemisphere surface cooling and enhanced seasonality, with regional surface warming and subsurface Atlantic warming. There is also weak southern Hemisphere warming. The simulated pattern of ocean circulation and climate change matches an array of palaeoclimate and ocean circulation reconstructions for the onset of Heinrich Stadial 1, both in terms of rates and magnitude of change. This is achieved with a meltwater flux that matches constraints on sea level changes and ice sheet evolution around 19-18 ka, and suggests that a much more modest AMOC reduction could drive the climate event than previously thought. Furthermore, the results provide the basis for a chain of events to link the recorded climate and ocean circulation changes with ice sheet evolution (the main trigger) and enhanced iceberg calving (a possible feedback).

Since the rates of melting used here are similar to those projected for Greenland by 2200, constraining the melt rates and magnitude of climate change during Heinrich Stadial 1 would provide an important test of climate model sensitivity to future ice sheet melt.

O-4073

## The Nordic Seas - North Atlantic regional seesaw during the last glacial millennial climate events: new evidence from biomarkers.

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### Abstract

Dansgaard–Oeschger and Heinrich events constitute ones of the most enigmatic features of the last glacial period. Many studies have focused on their characteristic millennial climate variability, testing atmosphere-cryosphere-ocean couplings, but major uncertainties and discrepancies still remain. A new scenario, mainly supported by dinocyst-derived paleoreconstructions and freshwater hosing experiments, has recently emerged. Reconciling most of the up to now hypothesized theories, it suggests the occurrence of a regional paradoxical seesaw pattern: cold Greenland and North Atlantic phases coincide with warmer sea-surface conditions and shorter seasonal sea-ice cover durations in the Norwegian Sea, in relation to enhanced subsurface advection of warm Atlantic waters re-emerging in the Norwegian Sea. Here we provide new paleoreconstructions of sea-ice dynamics in the Southern Norwegian Sea (core MD95-2009), over the 35-27 ka BP interval encompassing four interstadials-stadials (including HS3) cycles, based for the first time on the combination of biomarker IP<sub>25</sub> concentration and dinocyst-derived sea-ice cover duration. The striking correspondence, over the millennial climate shifts, between these reconstructions derived from two independent proxies, further provides robust evidence for the occurrence of this atypical hydrographical pattern. Reversely, the strong variability of the three PIP<sub>25</sub> signals (calculated by combining IP<sub>25</sub> concentration with either triene, brassicasterol, or dinosterol concentration), between each other as well as relatively to our two other independent indicators of sea-ice dynamics, highlights the need to better constrain this semi-quantitative proxy of seasonal sea-ice.

O-4074

## The dominance of extreme continentality during European stadials – a climate modelling study and conflicting proxy evidence

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### Abstract

An open and mostly sea-ice free North Atlantic Ocean acts as a major heat source for the atmosphere during winter. During stadials, winter sea-ice extended as far south as 45-50° N. The loss of the oceanic heat source led to severe winter cooling. However, it remains unclear whether and (if so) how these cold ocean states during stadials should lead to cold European summers as suggested by most but not all proxy studies.

Here we present new results from high-resolution (~100 km) global climate simulations of the late deglaciation conducted with the Community Earth System Model (CESM1) for different (inter-)stadials within the period ~15 ka BP to 9 ka BP. We study how different cold/warm ocean states caused by Atlantic Meridional Overturning Circulation (AMOC) instabilities influence the European summer climate under different orbital/solar and greenhouse gas forcing.

Our simulations show that atmospheric/orographic blocking of westerly flow over the Fennoscandian Ice Sheet (FIS) is a dominant factor during the summer season during all periods of the deglaciation. With a diameter of several thousand km and elevations of more than 2-3 km, FIS acts as a fluid dynamical barrier which enforces a diversion of westerly flow and anticyclonic rotation of the wind field over FIS due to Coriolis forcing. Sensitivity simulations suggest that the blocking by FIS is enhanced by cold ocean conditions through an extended high-pressure build-up while increasing solar insolation leads to a weakening of the blocking.

As a result of blocked westerly winds by FIS, stadial summers show little or no cooling relative to the preceding interstadial across Europe with exception of Ireland and coastal areas of Western Europe which lay outside the blocked wind field. However, with a stronger winter Jetstream, westerly flow recovers early in September leading to strong cooling with the beginning of autumn. The dominance of westerly flow until May results in longer lasting snow cover and strong cooling during May. Stadial climates are hence dominated by a shift to extreme continentality with very short but warm summers and severe and long-lasting winters. In addition, strong ocean cooling and/or large sea-ice extend lead to significant reductions in evaporation over the North Atlantic resulting in a strong decrease in precipitation during stadials as supported by biomarker palaeohydrological proxy data.

Taking the extreme continentality during stadials into account, we reconstructed chironomid-based mean July air temperatures for southern Sweden with different regional European and Russian training sets. We find that July



temperatures inferred from the most continental of the Russian training sets yield considerably warmer stadial summers with values close to the thermal limits of climate indicator plant species (plant macrofossils) which show little or no stadial summer cooling for most sites.

O-4075

## Evolution of the Atlantic water inflow in the western Svalbard margin through the study of benthic foraminifera since MIS5/4 transition

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### Abstract

The western Svalbard margin represents a key area to reconstruct the inflow of Atlantic water into the Arctic Ocean. The piston core HH15-1525PC was retrieved at Vestnesa Ridge, northwestern Svalbard at a water depth of 1273 m. The core covers the time interval from the Marine Isotopic Stage (MIS) 5/4 transition to the late Holocene. The species composition of benthic foraminiferal faunas and the geochemical signature (Mg/Ca) of selected species have been studied to reconstruct past variations in bottom water temperature. The benthic foraminiferal assemblage composition show clear variations in relation to millennial-scale climate oscillations such as Heinrich stadials, when species with an affinity to warmer Atlantic waters dominate, and Dansgaard-Oeschger interstadials, when cold-water species become more abundant. Quantitative temperature estimations have been performed via Mg/Ca analyses in parallel to the faunal studies to confirm the observed trends on foraminiferal assemblage evolution. Moreover, in selected intervals different Mg/Ca analytical techniques and cleaning methods have been implemented to obtain more accurate temperature estimates. This is the first continuous sedimentary record in Vestnesa Ridge covering the last 80 ka, making these results valuable not only for the reconstruction of changes in Atlantic water inflow in relation to past climate change, but also to investigate the ongoing mechanisms on the seabed during abrupt climate oscillations.

**O-4076**

## **Heinrich events in the North Pacific Ocean**

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### **Abstract**

Previous research has suggested that the subarctic North Pacific Ocean and North Atlantic Ocean were closely coupled during the last glacial (Kiefer et al., 2001; Praetorius and Mix, 2014). However, less is known about the extent to which Heinrich events are associated with corresponding changes in the North Pacific region. Whilst cores from the coastal north-east Pacific Ocean reveals increases in glacial discharge during Heinrich events (Cosma and Hendy, 2008; Hendy and Cosma, 2008), it remains unclear to what extent this water was transported to and impacted the open waters of the North Pacific Ocean and surrounding gyres.

Recent work, using diatom  $\delta^{18}\text{O}$  analyses ( $\delta^{18}\text{O}_{\text{diatom}}$ ), has documented declines in  $\delta^{18}\text{O}_{\text{diatom}}$  within the open waters of the north-east Pacific Ocean over the last 50 ka that are broadly synchronous with Heinrichs events in the North Atlantic Ocean (Maier et al., 2018). Here, this work is extended to show that that these large decreases in  $\delta^{18}\text{O}_{\text{diatom}}$  occurred throughout the last glacial, providing further evidence that Heinrich events were concordant with the export of significant volumes of glacial discharge from the Cordilleran Ice Sheet (CIS) into the open waters of North Pacific Ocean.

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O-4077

## Sea-ice derived from transfer functions based on planktonic foraminifera: are such reconstructions meaningful? A test over the last 50 ka

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### Abstract

Planktonic foraminifera (PF) constitute key material for paleoceanographers for who they are, since nearly one century, basic tools for stratigraphical and hydrographical reconstructions. Recently, paralleling an effort of diversification of the PF tool, its modern calibration and accuracy were reconsidered and challenged. Apart from geochemical considerations on their tests, major questions were raised regarding values of fossil assemblages to decipher basin-wide hydrological past changes since complex patterns of habitats are known for PF populations (depending on seasonality, water depth...). Working on the basis of high latitude assemblages are, for instance, often hampered by their monospecific diversity.

In this context, approaches relying on the compilation of modern eco-biogeographical databases, derived from the analysis of recently fossilized populations in the topmost oceanic sediment layers, provide comprehensive sets which have considerably improved our bioclimatic knowledges on PF. These modern sedimentary spectra, analysed for their contents/ relative abundances in PF, offer the advantage of integrating regional taphonomic processes, and can furthermore be statistically tested and exploited to provide proxies of oceanic conditions, as done for instance with transfer functions *sensu lato*.

Here we test the robustness of the Modern Analog Technique to reconstruct past sea-ice cover with PF, focusing on the Northern North Atlantic Ocean, thanks to a training set of  $n=1007$  modern analogs for which new extractions on oceanic parameters from the NOAA atlas have been obtained. Through a few key archives covering the last 50 thousand years, we will document the coherency of the results obtained on sea-ice evolution at millennial scales in comparison to other tools providing past sea-ice cover reconstructions. The conducted test is especially fruitful and rich of learnings for Heinrich events, underlining clearly the robustness of PF assemblages to provide accurate paleohydrographical contexts, in spite of strong limitation due to the dominance of the polar species *Neogloboquadrina pachyderma* during those events.

O-4078

## The isotopic composition of land snails from tropical Mesoamerica as a discrete indicator of land use

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### Abstract

Land snail shells are a common component of faunal assemblages found in archaeological sites. Whether representing dietary refuse or bycatch of depositional circumstances carbonate shells can provide important environmental information. Although the isotopic composition ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ) of a single land snail shell represents only a short snapshot, it is an established indicator of conditions in which the snail lived, e.g.: precipitation and temperature regime, and vegetation type ( $\text{C}_3/\text{C}_4$  plants).

Here we present sequential isotope analyses on modern and well-dated ancient shells from a Pleistocene/Holocene archaeological site in tropical Mesoamerica (Belize). The goal of this work is twofold: first we test which species of modern gastropods is most suitable for recording precipitation and vegetation/land cover changes. Next, isotope analyses on ancient shells aim at providing environmental context for the history of human migration and occupation in southern Belize over the last ca. 12 ka.

Comparing and contrasting the  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  composition of modern species from different habitats (litter, tree canopies, lower plants, limestone bedrock) with their ecological preferences revealed that the litter-feeding *Neocyclotus* (abundant in archaeological profile) responds with high fidelity to changes in the local environment. The range of  $\delta^{18}\text{O}$  values from ancient *Neocyclotus* is relatively stable throughout the last 12 ka, implying little variability in local moisture. In contrast, the  $\delta^{13}\text{C}$  record points to a substantial shift in snail diet (from  $\text{C}_3$  to  $\text{C}_4$  plants) ca. 800 years ago. Not accompanied by moisture changes, this shift, corresponding to the Late Maya proliferation period, suggests the spread of agricultural practices (e.g.: maize farming).

Further, comparison of our results with published continuous time series from the wider region (e.g. speleothems, marine and lacustrine sediments) suggest that the  $\delta^{18}\text{O}$  of *Neocyclotus* shells is a valid indicator of seasonal precipitation changes.

O-4080

## Mid-Holocene Pollen records of vegetation and climate change in Chenyaohu Lake, the plain of the lower reaches of Yangtze River

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### Abstract

The formation and evolution of Peatland is the research focus of Global changes. It also the key carrier to the study of paleoclimate and the carbon cycle. This study will focus on the peatland in the plain of the lower reaches of Yangtze River since the middle Holocene and we hope to explore the formation and development of the peatland and their environmental controlling actors. Palynological analyses of a peat profile in the Chenyao Lake documented the vegetation history and climate change perfectly during the time of peat evolution. Since 6600 cal. aBP the evergreen and deciduous mixed broad-leaved forest dominated by *Quercus* developed in this area and the climate had turned into the warm and humid period. The peat began to develop since 5700 cal. aBP when the sediment environment changed to swamp. After 4850 cal. aBP the broad-leaved forest decreased rapidly, instead the land herbs, mainly the Poaceae, increased. In the meantime peat also disappeared. Based on the pollen vegetation was characterized by the human activities, we consider that human activities should be cause the end of peat evolution in this area meanwhile the nature environment did not changed. Our study provide a new important data and information for the researches on the relation between climate change and peatland formation and development theories in the lower reaches of the Yangtze River.

**O-4081**

## **Magnetism signals in a southern China stalagmite and paleorainfall reconstruction during MIS5**

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### **Abstract**

Precipitation variations were suggested to exert great impact on early human migration and occupation. Southern China is a key region of early modern human evolution in China, however, there is a shortage of the precipitation data in the hominin fossil sites of southern China. So far, broad-area precipitation variations in monsoonal China have been reconstructed from speleothem stable oxygen isotope ( $\delta^{18}\text{O}$ ) (Cheng et al., 2009, 2016), and supported by most modeling researches (Li et al., 2013). However, the challenge on the interpretation of speleothem  $\delta^{18}\text{O}$  lead to them being an ongoing debate. Thus, a reliable index for high-resolution precipitation reconstruction is required in southern China.

In this study, we conduct the high-resolution environmental magnetism measurement in stalagmites from Tongnei Cave and Xinli Cave located near the hominin occupied area in southern China. Strong magnetic signals were deduced from hysteresis loops and magnetic parameters  $M_s$  and  $H_c$ .  $M_s$  was used to trace the long-term and abrupt rainfall variations in southern China during MIS 5. The  $M_s$  record demonstrates that the precipitation changed greatly during MIS 5/4 transition, with gradually increased precipitation in the period prior to 80.5 ka BP and after that a drop to precipitation anomaly. Although we cannot deduce the causal link between the sudden shift of precipitation and hominin evolution in southern China, we can, at least, infer that regional precipitation varied greatly with high frequent extremes during MIS5/4 transition in hominin occupational area in southern China.

**O-4082**

## **Investigating human-environmental interrelationships and resilience in the Zagros region during the Early Holocene period – a multi-proxy approach**

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### **Abstract**

The important wide-scale transition from mobile hunter-gatherer to sedentary farmers in the Fertile Crescent during the Neolithic period marked the beginning of a new lifestyle, including plant and animal domestication.

Published palaeoenvironmental records for this region show a similar vegetation trend for the Late-glacial and Holocene period with oak woodland expansion experiencing a delay of about 3000 years in comparison to the Mediterranean region, despite improvements in climate occurring roughly at the same time in both regions. To explain this delay and the extent to which anthropogenic activity and climate change impacted on vegetation cover, it is vital to investigate human-environmental relationships which forms the core of this research.

Available palaeoenvironmental records for the Zagros region are sparse and some records available either have low-sampling resolution or do not cover the Neolithic period, making it difficult to compare palaeoenvironmental records with the archaeological data, and distinguish between anthropogenic and climatic factors that might have impacted on vegetation cover over time.

The aim of this three-year long research is to reconstruct the palaeoenvironmental history between ca.12,000-9000 BP, to identify changes in vegetation cover and correlate them with human activity and climate change which will help placing climatic and vegetational changes as well as human response in the Zagros region within the wider region and context during the Early Neolithic while appreciating local differences across Southwest Asia.

To produce a high-resolution palaeoenvironmental record for Lake Ganau, located in the Raniya plain in Iraq, and Hashilan wetland, which is located in the Kermanshah province of Iran, the lake cores have been subject to different analyses including pollen, non-pollen palynomorph and geochemical analyses (XRF and loss-on ignition).

This research will demonstrate how human activity and climate impacted on vegetation cover, will shed light on human-environmental relationships in the Zagros region, highlight the significance of multi-proxy records, explain the oak woodland delay in this region, and to what extent early human societies were resilient to changes in the environment and climate.

The aim of this session will be to present preliminary results gained from the Lake Ganau and Hashilan wetland cores and their interpretation which will form the framework for this much needed multi-proxy research for this region.

O-4083

## Relation of human activity and the environment in the young-glacial landscape: the Paliwodzizna site (central Poland)

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### Abstract

Territories within the extent of the last glaciation (young-glacial areas) are among the youngest and most dynamic landscapes on Earth. During the last approximately 20 ka they have been subject to very dynamic transformations. The same time span saw the appearance of humans, and their increasing activity. Interdisciplinary studies (palaeogeographical, palaeoecological, palaeopedological and archaeological) conducted at the Paliwodzizna site (the Dobrzyń Lakeland, north-central Poland) are focused on reconstructing the interplay between landscape evolution and human existence in this geographical zone.

The evolution of the young-glacial landscape started at the end of the Weichselian Glaciation with intense geomorphological processes related to the ice-sheet recession and the formation of till plains, outwash plains, and tunnel- and river valleys. During the Late Glacial period all of these features were transformed according to climate improvement, the degradation of permafrost and dead-ice blocks, the formation of the hydrological network (river and lake systems) and the development of tundra–forest vegetation. This period was also the time of the first appearance of Late-Palaeolithic humans (the Swider Culture, “reindeer hunters”) in this area. Their settlement at the Paliwodzizna site was located in the north of the Grodno Lake tunnel valley, in the contact zone of the till plain and the Drwęca River ice-marginal valley. The period of the Eo- to Mesoholocene was dominated by biological activity in conditions of forest vegetation limiting the dynamics of relief transformation. Preferential conditions for biomass production also resulted in the lake shore zone being transformed into a eutrophic mire. Mesolithic humans occupied the same site as Palaeolithic ones, but they exploited different natural resources (e.g. wood, forest animals, fish). During the Neoholocene, humans’ agricultural activity became an important – and, with time, the main – force driving landscape transformations. At the Paliwodzizna site, deforestation since the Bronze Age (the Lusatian Culture) through the Middle Ages and up to modern times has been recorded in colluvial sediments accumulated in local surface depressions and in the edge zone of the mire. However, phases of settlement were divided by spontaneous forest succession, which is confirmed by the development of the soil cover (Brunic Arenosols, Gleysols, and Histosols).

Recurrent settlement recorded at the Paliwodzizna site attests to the fact that the diverse relief, lithological, hydrological, pedological and ecological conditions offered by the young-glacial landscape were attractive to humans in various epochs, even if their activities were completely differently directed and changed in relation to climate fluctuations and landscape evolution. Places located in contact zones between various landscape units were especially preferred for settlement.

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O-4084

## Early human impact on biogeochemical cycling of Moossee, Switzerland: A Holocene high-resolution record of paleoproductivity and meromixis in lake sediments

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### Abstract

Global Change has seen unprecedented environmental change putting freshwater ecosystems at risk. Anthropogenically altered biogeochemical cycles have adverse ecosystem impacts such as eutrophication, hypoxic/anoxic conditions and altered lake mixing regimes. Even though recent anoxia has been well studied, long-term records are scarce because of analytical difficulties and costs. Hence, questions about the occurrence of meromixis in the past, the processes and triggering mechanisms remain open. Here we present a quantitative ultra-high (sub-annual) resolution record of sedimentary pigments preserved in biogenic varves. Moossee is located on the Swiss Plateau, a lowland region with favorable conditions for early (Neolithic and onwards) human settlements and agriculture [1]. We show how and when meromixis/hypoxia has developed throughout the Holocene and what is the role of anthropogenic impacts (deforestation, erosion, nutrient cycling) and climate. We use hyperspectral imaging proxies (HSI), calibrated quantitative total chlorophyll for productivity and Bphe *a* for meromixis [2]. The core was dated using radiocarbon ages, annual lamination counts and wiggle matching approaches [3]. XRF scans were made at 1 mm resolution. Pollen samples were analyzed at high 10-year resolution for selected sections and lower resolution for the entire core.

Moossee contains a continuously varved paleoproductivity and meromixis record for the past 15,000 years. HSI data show a first increase in lake productivity at around 14,300 BP (Bölling warming), with a drop in Ti suggesting stabilization of the landscape. Productivity increases further after the onset of the Holocene, which is also reflected in Br counts. Meromixis events were observed from 7500 to 2500 BP, starting after the establishment of beech forest in the mid-Holocene (thermal optimum), interrupted by 3 periods of local anthropogenic deforestation (AP < 80%). During these deforestation phases, landscape clearance was followed by increased erosion and thus increased lake productivity. Under such conditions, with AP lower than 80% the lake was mixing annually. Strikingly, with gradual afforestation Bphe *a* values increase sharply, suggesting that the lake switched from holomixis to meromixis. Br and P increase as well indicating higher productivity and limited mixing. Complete mixing is attributed to high wind fetch during periods of open landscapes with reduced forest covers facilitating full mixing. We conclude that, with gradual reforestation (AP > 80%), wind fetch declined, and the lake switched from holomixis to meromixis. This cycle occurred three times during the Neolithic and/Bronze Age, lasting for 200 to 400 years each time. This unambiguously documents how millennial-old prehistoric human impact had already modified the biogeochemical cycle in the lake.

<sup>1</sup> F. Rey, E. Gobet, E. Schwörer, C. Wey, A. Hafner, W. Tinner 2019, *J Ecol*, doi:[10.1111/1365-2745.13121](https://doi.org/10.1111/1365-2745.13121)

<sup>2</sup> C. Butz, M. Grosjean, A. Poraj-Górska, D. Enters, W. Tylmann, *Glob. Planet. Change* 2016, 144, 109

<sup>3</sup> F. Rey and 6 co-authors, *Radiocarbon* 2018, 1-21

O-4085

## Subpolar North Atlantic circulation changes during the Younger Dryas and impacts on the cryosphere and atmosphere circulation in north-western Europe

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### Abstract

The Younger Dryas is a canonical example of abrupt climate change during the Last Glacial-Interglacial Transition (16-8 ka BP), involving cooling of the northern hemisphere that is thought to have been caused by weakening of the Atlantic Meridional Overturning Circulation (AMOC).

Recent studies have suggested that there may have been different phases to the Younger Dryas cold event, each having different impacts on the climate of the North Atlantic and European seaboard. For example, some studies suggest that a late Younger Dryas AMOC recovery caused retreat of sea-ice and a northward shift in the mid-latitude westerlies which altered the climate of Europe, from Iberia to Scandinavia. Further inland, there is also evidence for intra-stadial changes in hydroclimate at several sites. Other terrestrial lake and glacier records from these mid-latitudes imply that there was a late-stadial ice maxima, most notably in Scotland but with some evidence of two phases of Younger Dryas ice advance in Scandinavia. However, there are few high-resolution marine records of North Atlantic circulation change during the Younger Dryas, which are needed to test how possible changes in AMOC may have driven climatic changes in different regions of the North Atlantic seaboard.

Here, we compile and present new sea surface temperature reconstructions and records of ice-rafted detritus from the subpolar North Atlantic, with particular emphasis on a site south of Iceland (RAPiD-10-1P) and two sites of temperature and sea-ice change in the north-western Atlantic (KNR-158-4-09GC and RAPiD-40-18P). These new high-resolution marine records are directly linked through the identification of the Vedde Ash tephra isochron in combination with a radiocarbon-based Bayesian chronology but show subtly different records of oceanic change. Depending upon location, we reveal two or three distinct stages of the Younger Dryas in the marine records, which appear related to changes in the AMOC and manifest as large changes in surface conditions.

These oceanic circulation changes appear to be associated with several events recorded in the terrestrial systems within the stadial. Using these records, we explore the possible mechanisms responsible for the changes in the subpolar North Atlantic (50-70°N) that occurred during the Younger Dryas and which led to more complex behaviour than just a single cooling and AMOC weakening, followed by a gradual amelioration of sea surface temperatures into the Holocene. Moreover, with our new marine reconstructions we re-evaluate hypotheses related to the coupling of North Atlantic climate with shifts in atmospheric circulation - namely the mid-latitude westerlies - over Europe and further afield.

O-4086

## Climatic and environmental change during the Younger Dryas cold period in the Lake Gościąg sediment record

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### Abstract

The last deglaciation in the northern hemisphere featured several short climatic oscillations with the Younger Dryas (YD) as the most pronounced cold setback. Due to its abrupt and distinct onset and termination, this period provides valuable insights into climate and landscape evolution at periods of extreme change. High-resolution climate archives like annually laminated (varved) sediments are crucial to decode the rate and response of environmental variations to such rapid climate changes.

Lake Gościąg (central Poland) exhibits an iconic varved lake sediment record since it is one of the longest and best-preserved records in Europe. For re-investigation of this archive, 10 new sediment cores have been obtained along a ~120 m long N-S transect through the deepest part of the lake basin. Here, we focus on the YD/Holocene transition using a combination of high-resolution microfacies analyses, XRF element core scanning,  $\mu$ -XRF mapping, stable oxygen and carbon isotope and pollen analyses.

The transition from glacial sands to fine-grained lacustrine sediments occurs at varying core depths between ~14 m and ~18 m due to undulating basin morphology. After lacustrine sedimentation commenced in the late Allerød, a slump from the southern shore disturbed the sediments during the early YD. The slump thickness decreases from ca 200 cm in the southern cores to 4 cm in the northern.

Here, we present a first continuous microfacies investigation of the YD in Lake Gościąg. The YD varves consist predominantly of diatom frustules, calcite and re-suspended material, whereas the Holocene varves feature primarily calcite and organic matter. In general, the YD shows higher interannual variability in varve deposition than the Holocene.  $\mu$ -XRF mapping supports these results. Further, we present XRF element records of Ca/Ti (relative calcite precipitation), Ti (detrital influx), Mn/Fe (oxygenation) and Si/Ti (diatom bioproductivity), as well as bulk stable oxygen ( $\delta^{18}\text{O}_{\text{carb}}$ ) and carbon ( $\delta^{13}\text{C}_{\text{carb}}$  and  $\delta^{13}\text{C}_{\text{org}}$ ) isotopes.

At the by pollen defined biostratigraphic YD/Holocene transition, the proxies show differences in the timing of their response and in their amplitudes. First changes occur in Ti ca 70 years before the biostratigraphic boundary, while the varve microfacies changed ca 50 years after the Holocene onset as the last proxy. Besides, the time interval during which each proxy shifts strongly varies from 1 varve year in the varve microfacies to 160 varve years in the Ti record. Here, we discuss causes and the differences in proxy responses and what they imply in regard to the dynamics of environmental change during a major climate warming.



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O-4087

## Influence of Atmospheric Circulation Changes on Spatiotemporal Patterns of European Hydroclimate During the Younger Dryas

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### Abstract

The Younger Dryas (YD) cold period at the end of the Last Glacial, likely initiated by a slowdown of the Atlantic Meridional Overturning Circulation driven by freshwater input in the North Atlantic, provides a natural laboratory to study the difference in regional abrupt responses to hemispheric climate change on continental Europe.

To minimize the effect of differences in proxy response and dating uncertainties we applied the same proxy (the hydrogen isotopic composition ( $\delta D$ ) of lipid biomarkers as a proxy for precipitation  $\delta D$  and aridity) on four lacustrine sediment profiles spanning a 900km transect from western to eastern Europe (Meerfelder Maar, Hämelsee, Rehweise, Trzechowskie). All lakes contain annually laminated sediments and share tephra layers, permitting a direct comparison on decadal timescales.

All sites were characterized by lower biomarker  $\delta D$  values during the YD compared to the Allerød and Holocene, reflecting the cooling northern hemisphere and changes in westerly storm tracks over Europe. In western Europe changes began simultaneously with the decrease of  $\delta^{18}O$  values in the Greenland ice cores, i.e. the onset of Greenland Stadial 1 at around 12.846 yrs BP, whereas in eastern Europe change is diminished or absent. A second, stronger isotopic decrease was observed in all four sites and occurred simultaneously with the onset of vegetation changes (i.e. the classically defined YD) at around 12.680 yrs BP in western Europe, but a few decades earlier in eastern Europe. The magnitude of isotopic change is halved and decadal variability is less pronounced towards the east. The pronounced multi-decadal isotopic variability during the second half of the YD fades out towards eastern Europe. This suggests less severe change and more stable conditions in eastern Europe. These observations cannot be explained by a southward displacement of the westerly flow due to expanded winter sea ice cover in the Northern Atlantic alone, but require a mechanism stabilizing climate and counteracting westerly airflow in eastern Europe.



Recent high-resolution climate model data suggest strong seasonal and regional differences during the YD caused by the modulation of westerly atmospheric flow by the Scandinavian Ice Sheet (SIS). We therefore suggest that a persistent high-pressure system over the SIS and the associated reorganization of atmospheric circulation over Europe created an atmospheric blocking resulting in more resilient continental climate conditions in eastern Europe in particular during the first phase of the YD. Increasing solar/orbital forcing during the second phase of the YD led to increasingly instable blocking, expressed as a higher variability in our  $\delta D$  records.

Overall, our results highlight differences in the response of hydroclimate across relatively small spatial scales and emphasize the importance of atmospheric circulation changes in transmitting the effect of a hemispheric scale climate forcing abruptly to the local scale of continental Europe.

O-4088

## Investigating the spatial heterogeneity of abrupt cooling events during the Lateglacial Interstadial in Britain and Ireland using chironomids and oxygen-isotopes.

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### Abstract

The Lateglacial Interstadial (c. 14.7-12.9kyr ago), a relatively warm period at the end of the last glaciation, provides an excellent opportunity to study past abrupt cooling events (ACEs), as it was punctuated by several centennial-scale cooling events. Such events, on the basis of their magnitude and driving factors, offer the best analogues for future ACEs triggered by anthropogenic warming. These ACEs, commonly known as GI-1d and GI-1b, are clearly expressed in the Greenland ice cores but have variable expression across Europe and the North Atlantic region. In some areas, GI-1d represents the major climatic event, in other areas GI-1b is the stronger cooling interval. This spatial diversity in ACE expression is likely to reflect the forcing factors that drive them, however, these are currently poorly understood. Only a systematic application of high-resolution proxies applied to sites over varying latitudinal and longitudinal gradients can seek to address this. Although numerous studies of the Lateglacial Interstadial exist, they are frequently generated on a site-by-site basis using various proxies at varying scales of resolution, making inter-comparison problematic. To address these research questions requires consistent application of high-resolution proxies at sites chosen for their geographical importance.

In this study, we have applied Chironomid and Oxygen-isotope analysis at a high-resolution to a number of Lateglacial Interstadial records from spatially diverse locations across the British Isles. When combined with previous studies this generates a palaeoclimatic database that allows the expression of ACEs during this time interval to be studied along both latitudinal and longitudinal gradients. Even across a relatively restricted area such as the British Isles, clear spatial patterns can be observed in ACE strength. GI-1d is at greatest intensity in the North and East of the region whilst GI-1b is most strongly expressed in the South and West. The results highlight the pivotal location of the British Isles in relation to factors driving ACEs and the conclusions allow the driving factors of these events to be discussed in greater detail.

O-4089

## Using chironomids to assess Lateglacial climate evolution in at Burgäschisee, Switzerland

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### Abstract

There are few chironomid-based temperature reconstructions in Central Europe extending back into the Early Lateglacial before 14,700 cal BP, and for northern Switzerland none are reliably dated. This presents a significant knowledge gap, exemplified by new pollen evidence displaying Early Lateglacial warming in the Swiss Plateau lowlands as early as 16,000 cal BP (Rey et al., 2017). Currently, the only independent temperature reconstructions available for comparison are from South of the Alps (Samartin et al. 2012). As such, the production of a well temporally constrained chironomid assemblage record for Switzerland is paramount, as it can provide new information about Early Lateglacial environment and climate evolution on the Swiss Plateau, and can be used as an independent dataset with which to corroborate the new observations of Early Lateglacial warming from pollen and macrofossil data.

Lake sediments from Burgäschisee, a small, well studied lake on the Swiss Plateau, have been sampled for chironomids. Previous work from Burgäschisee has produced a pollen record displaying a transition from tundra to shrub tundra vegetation in the Early Late glacial at 16,000 cal BP (Rey et al., 2017), prior to the onset of the Bölling warming (ca. 14,700 cal BP). Here, we present the first well dated chironomid assemblage record for the Swiss Plateau Early Lateglacial, in parallel and on a centennial scale, exploring lake and climate development throughout the period 14,000 - 18,000 cal BP. Initial results indicate that chironomid assemblages were dominated by the cold stenothermic taxa *Sergentia coracina*-type throughout the period preceding Bölling warming. Despite the persistent dominance of *S. coracina*-type, there are observed changes in the sub dominant taxa during the pre Bölling period, with cold stenotherms such as *Micropsectra radialis*-type and *Paratanytarsus austriacus*-type becoming less abundant while types indicative of relatively warmer conditions, such as *Dicrotendipes nervosus*-type, begin to occur. These changes are concurrent with the vegetational shift from tundra to shrub-tundra at 16,000 cal BP in the Burgäschisee record and are coeval with chironomid-inferred warming and pollen-inferred afforestation in the Ticino lowlands south of the Swiss Alps (Samartin et al., 2012), indicating that circum-alpine climatic warming after the end of Heinrich Event 1 was substantial enough to release major vegetation reorganizations.

### References

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O-4090

## Multi-decadal spring season warming precedes sudden summer temperature rise in pre-anthropogenic climate change

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### Abstract

Waning annual seasonality is documented in an up to one-month advance in spring onset since the 1980's in northern latitudes, perturbing ecosystem functioning and socio-economic performance. Summer temperatures, in contrast, have been rising only recently, indicating an offset in seasonal warming. The limited time span of observational data makes this asynchronous pattern difficult to quantify, hindering projections of intra-annual dynamics. We explore temporal phase relations of seasonal warming over the Late Pleniglacial/Bølling and the Younger Dryas/Holocene climate transitions that preceded present anthropogenic warming. We determine past spring onset and thermal properties from dwarf birch paleo-phenology. Reconstructed spring warming led maximum summer warming by about a century during both transitions. Long-term reconstruction of intra-annual temperature regimes provides the perspective required for seasonal response analysis. Our results document that multi-decadal spring season warming precedes sudden summer temperature rise also during natural climate change. The rapidity of present seasonality changes, however, is unprecedented.

O-4091

## Investigating the environmental response to the Preboreal Oscillation through integrating multi-proxy records across Europe

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### Abstract

Evidence from high-resolution, multi-proxy records over the Late Glacial to Early Holocene transition (~16-8kya) shows abrupt climatic events of centennial to decadal timescales punctuating this period. The abrupt climatic cooling perturbation termed the Preboreal Oscillation (PBO, ~11.3-11.15kya) has been widely detected across Europe, particularly through vegetation response to this abrupt cooling (Björck et al., 1997). However, there are environmental variations apparent in the timing, spatial extent and magnitude of response to the PBO in sites from across Europe.

To provide insight into these spatial and temporal environmental variations in response to the proposed PBO, the INTIMATE database has been used (<https://c14.arch.ox.ac.uk/intimate/db.php>). This chronological tool has allowed vegetation records from dated, terrestrial archives across Europe to be integrated, providing understanding of the temporal and spatial variation of the climate oscillations around this period. Each (<sup>14</sup>C) dated record has been handled on their own individual timescale and tied together through the use of known chronological relationships from tephra horizons (in particular the Hasseldalen and Askja-S tephra). In addition, the quantification of chronological uncertainties has allowed regional comparisons to be made, providing insight into the heterogeneity of the past climate. Using data directly from the INTIMATE database, together with statistical tools developed in R, has allowed the timing and environmental response of the PBO to be quantified.

Through selected case studies of multi-proxy sites spanning from western to eastern Europe, we provide insight into the possibility of spatial and temporal variations of the environmental responses to the climatic perturbation of the PBO. By using the INTIMATE database in conjunction with the proposed stratigraphic position of the Hasseldalen and Askja-S tephra bracketing the PBO (Wohlfarth et al., 2006), questions such as time transgression and regional-specific expression of this abrupt climatic oscillation can be investigated.

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O-4092

## Groundwater $\delta^{18}\text{O}$ record of paleorecharge and climate for the last 35ka in south-west Western Australia

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### Abstract

The isotopic composition of groundwater can be a useful indicator of rainfall isotope compositions and help to determine the drivers and impacts of rainfall and climate change. Additionally, as most large groundwater basins can contain 'old' groundwater where extraction exceeds groundwater recharge, knowledge of the past conditions and timing under which groundwater was recharged is needed to sustainably manage groundwater resources. Applying isotopic tools to groundwater contained in regional aquifer systems can provide low-resolution information on recharge intensity, recharge source and past climatic conditions for the region. Furthermore, an understanding of how groundwater recharge and climate have been connected in the past can be used to inform climate adaptation strategies for sustaining groundwater resources during climate change.

Groundwater from south-west Western Australia located at the northernmost extent of the westerly wind belt can help constrain the drivers and impacts of rainfall and climate change in this region. Large regional groundwater systems contained within the Perth Basin in south-west Western Australia were used in this study to provide information on groundwater recharge and climate over the past 35,000 years. This dataset containing groundwater ages ( $^{14}\text{C}_{\text{DIC}}$ ) and stable isotopes of water ( $\delta^{18}\text{O}$  and  $\delta^2\text{H}$ ) from two regional groundwater systems within the Perth Basin provides a unique opportunity to produce a low-resolution palaeo-archive of groundwater recharge, and hence interpret rainfall and climate change, for south-west Western Australia. The trends in stable isotopes of water over time in the regional groundwater data are consistent with the groundwater flow line data supporting our hypothesis that groundwater stable isotopes are a proxy for palaeo-recharge. The Southern Perth Basin groundwater isotope record is interpreted to be a low resolution archive of recharge driven by changes in the relative intensity of past rainfall, moisture source from changes in the position of the westerlies and recharge thresholds. This long-term stable isotopic recharge record provides a greater understanding of groundwater palaeo-recharge, and the connection between recharge and climate in the past.

O-4093

## Millennial-scale variability in subtropical precipitation observed in speleothems from central eastern Queensland, Australia

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### Abstract

Australia is the driest inhabited continent with the most spatially and temporarily variable precipitation, it is therefore vital to understand what drives precipitation regimes during periods of global climatic change. The subtropics are a particularly important area for understanding interactions between climate systems. Several studies indicate that high latitude forcing may influence precipitation in the Australian subtropics, however there are significant gaps in our understanding of the nature of this forcing owing largely to the lack of reliable, high-resolution and well-dated records of hydrological variability that span the last glacial cycle. This is because the majority of studies that have been the focus of such investigations rely upon <sup>14</sup>C dating of lake and swamp and marine cores that are less precise than desirable during MIS3. There is also a conspicuous lack of continuous records in the northern subtropics meaning that our spatial reconstructions are limited. Here we present two overlapping stable isotope and trace element records derived from well-dated speleothems from Mt Etna, central eastern Queensland, Australia. U/ Th dating indicate that they collectively span between 46ka and the late Holocene. Mg/ Ca patterns are reproduced across both speleothems. Correlation of carbon stable isotopes and Mg/ Ca support the interpretation that these two proxies are driven by variations in rainfall at this site. These records appear to indicate millennial scale changes in relative precipitation that are coeval with the Northern Hemisphere Heinrich events. The relative rapidity of the changes in Mg/ Ca may support a response to forcing from the Northern Hemisphere rather than Southern Hemisphere in the northern subtropics, probably a change in the mean position of the ITCZ. During the LGM growth rates in both speleothems appear to decline dramatically and little calcite is precipitated which likely indicates a period of relatively low precipitation.

O-4094

## A Holocene isotope hydroclimate record from Blue Lake, North Stradbroke Island, Queensland, subtropical Australia

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### Abstract

Blue Lake on North Stradbroke Island, Queensland, is a groundwater window lake of major ecological and cultural significance. North Stradbroke Island is the second largest sand island in the world. Blue Lake is unique to the island as it is the only groundwater window lake on the island, and one of the few in Eastern Australia. The lake's strong connection to the regional groundwater table and short residence time (<50 days) underpin a stable aquatic ecology which makes Blue Lake sediments an ideal tracer of subtle changes in the climate and regional environment.

Here we report a new ~7,500 year high resolution C/N and carbon isotope record from Blue Lake, which shows an abrupt shift at ~4 ka from terrestrially-dominated sources of organic matter to predominantly in-lake sources. This shift reflects a decline in rainfall on the island, as documented in a quantitative rainfall reconstruction from nearby Swallow Lagoon. This carbon isotope record is the starting point for further contemporary and palaeoclimatic research at the site.

Ongoing monitoring aims to quantify the relationship between climate, hydrology, and the isotopic composition of Blue Lake sediments. The modern process study is focused on oxygen isotope variation and will quantify the isotope hydrology of the system: from initial precipitation to uptake by plants in the lake. Using this as a foundation, we will create a high resolution palaeo-rainfall record from Blue Lake that will build on previous studies of pollen, macrophytes, and diatoms from North Stradbroke Island and eastern Australia more broadly, which suggest a mid-Holocene shift in rainfall. Quantitatively defining such a shift will enable a more thorough investigation into the impacts of climate drivers such as El Niño Southern Oscillation in eastern Australia.

O-4095

## Regional patterns of hydroclimate variability in southeastern Australia over the past 1200 years

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### Abstract

The Australian continent experiences extreme climatic conditions, and is at risk of these extremes intensifying in the coming decades with profound socioeconomic and environmental consequences. Therefore, it is of vital importance to understand the drivers and range of hydroclimate variability through time. The past 2,000 years is advocated as an appropriate period for establishing a baseline of recent natural climate variability. Recent work has compiled the non-annually resolved palaeoclimate records across Australasia. Eight records across southeast Australia have been identified as possessing satisfactory sampling and geochronological resolution for reconstructing multi-decadal to centennial-scale hydroclimate variability during the Common Era. This work employs a two-tiered regional Monte Carlo Empirical Orthogonal Functions (MCEOF) approach to examine the inter- and intra-site coherency of climate signals within southeast Australia. Two identified regional modes of climate variability demonstrate an increase in effective moisture between 900CE-1750CE. Agreement between regional MCEOF 1 and Australian temperature reconstructions suggests suppressed evaporation was a significant influence on regional effective moisture during this time. Regional MCEOF 2 exhibits shorter, centennial-scale oscillations that show some agreement with existing rainfall reconstructions. We interpret MCEOF2 to represent regional-scale rainfall patterns driven by rainfall seasonality and the influence of the Southern Annular Mode over southern Australian rainfall. The findings of this study suggest that although there are few records that are ideal for examining climate during the Common Era, a small subset of quality-controlled records is effective for examining hydroclimate variability in southeast Australia.

O-4096

## Long record of environmental change from the Bassian land bridge between mainland Australia and Tasmania spanning the last glacial period.

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### Abstract

Here we present preliminary pollen, charcoal, geochemical and sediment analyses from a record spanning at least MIS4-MIS1 from Remy Boy Lagoon, located near the coast of Ingham Island (Clarke Island) in the Furneaux Island Group, Bass Strait (40°32'32.21"S, 148°13'4.22"E). The site is located in an important region for the movement of people from mainland Australia to Tasmania via the Bass Strait land bridge which was exposed when sea levels were lower; a time when the site would also have been an inland lake ~ 70 km from the past coastline. This new record of environmental change is one of only a few long records from Tasmania and we compare our findings with other terrestrial records from southeast Australia as well as nearby marine records.

The pollen record indicates the changing dynamics of *Eucalyptus*, *Callitris* and *Allocasuarina* dominated vegetation, with expansion of herbaceous vegetation around the Last Glacial Maximum, the coolest, driest period of the record. Peak levels of macrocharcoal occur around 40 kyr BP with a phase of increased rainforest pollen prior to the LGM possibly indicating the expansion of rainforest in the wider region under a warmer/wetter glacial climate. Changes in macrophytic wetland taxa provide insight into local changes in hydroclimate.

O-4097

## Mid- to late Pleistocene diatom record from Darwin Crater, Tasmania, Australia

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### Abstract

Continuous continental records are critical to understanding how terrestrial environments responded to the large-scale shifts between glacial and interglacial climate states, providing valuable insights into the interactions between the atmosphere, oceans, cryosphere and biosphere, and the long-term context from which to interpret current and future trends. 160m of overlapping sediment cores were collected from Darwin Crater in Tasmania, Australia. This continuous ~800 ka Pleistocene record provides new insights into glacial-interglacial climatic variability in the Southern Hemisphere. Darwin crater is a palaeolake formed by the collision of a meteorite at  $816 \pm 7$  ka ( $^{40}\text{Ar}/^{39}\text{Ar}$  dating of Darwin glass) and infilled with lake sediments throughout several glacial/interglacial climate cycles. The sediment sequence provides a continuous Pleistocene record with multi-proxy signatures of alternating cold and warm climates based on spectrophotometry, grain size, natural gamma ray, palaeo- and rock-magnetism, loss-on-ignition, and pollen analysis. Olive coarse grain sediments with high siliciclastic material and cool climate pollen taxa suggest deposits during glacial periods, while, brown-black fine grained sediments with low siliciclastic material and warm climate pollen taxa indicate interglacial deposits. Here we further investigate these climatic signatures with the use of diatoms in the lake sediment deposits. Diatoms are highly sensitive to environmental change and have shown good preservation throughout the Darwin crater core with minimal dissolution. Preliminary results suggests an aquatic ecosystem response to these glacial-interglacial climates and provide further insight into the palaeoclimate context for the Southern Hemisphere. These results contribute to an ongoing project with future investigation into the chronology and palaeoclimate history of Darwin Crater over multiple glacial-interglacial transitions in the Southern Hemisphere.

O-4098

## Beyond the bipolar seesaw: Unravelling the processes of interhemispheric climate coupling

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### Abstract

The thermal bipolar ocean seesaw hypothesis was advanced by Stocker and Johnsen [2003] as the 'simplest possible thermodynamic model' to explain the time relationship between Dansgaard-Oeschger (DO) and Antarctic Isotope Maxima (AIM) events. Our intention with this presentation is to take up the challenge of moving from a conceptual toward a process-based understanding of interhemispheric coupling and the forcing of AIM events.

Following our recent critical review of the thermal seesaw [Pedro et al., 2018], we here further test the mechanisms of DO-AIM coupling using a general circulation model (GCM) that exhibits unforced DO oscillations. We present four main results:

1. Changes in Atlantic heat transport during the DO oscillations are largely compensated by opposing changes in heat transport by the global atmosphere and Pacific Ocean. This 'Bjerknes compensation' acts as a negative feedback, which is likely integral to the oscillation
2. Contrary to the prevailing view, the Southern Ocean is not a major heat reservoir during DO-AIM coupling. This is because the Antarctic Circumpolar Current strongly inhibits meridional ocean heat transport.
3. Energy budget analysis indicates that Antarctic warming during AIM events results from increasing poleward sensible heat and moisture transport following surface warming and sea ice retreat in the Southern Ocean.
4. The Antarctic sea ice retreat is itself driven by eddy-heat fluxes across the ACC, amplified by sea-ice-albedo feedbacks. We examine the sensitivity of this eddy-heat transport to seafloor topography and model resolution.

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O-4099

## Variability of timing and behavioral context of pottery adoption in the Japanese Archipelago.

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### Abstract

In East Asia, transition from Palaeolithic to Neolithic is characterized not by the adoption of village life incorporating farming economies, but by the behavioral change of hunter-gatherer communities from a mobile to a sedentary lifestyle.

In the Japanese archipelago, past researches advocated that hunter-gatherer lifestyle changed with climatic amelioration from the beginning of Holocene which brought warm and wet climatic conditions and stable land/marine food resources. Pottery was also invented during this period to exploit and process these newly available resources efficiently.

However, the discovery of 'ice-age pottery' in the Odai-yamamoto site in northern Japan pushed back the appearance of the earliest pottery in Japan to between 16,500 and 15 000 cal BP at the end of the Last Glacial period, critically challenging the past hypothesis. Now it is known that a small amount of 'ice age pottery' was used by mobile hunter-gatherers in various regions of the Japanese Archipelago just before the Late Glacial warm period.

On the other hand, settlements of sedentary hunter-gatherers comprising several pit-houses with the constant use of pottery suddenly appeared mostly around the Pacific coastal region of the southwestern Japan, just after the climatic warming in the early Late Glacial. This suggests that climatic amelioration did not induce the 'beginning', but prompted the 'development' of sedentary lifestyle with the use of pottery.

Since recent accumulation of archaeological data regarding emergence of pottery suggests that the timing and behavioral context of early pottery adoption in the Japanese Archipelago are variable from region to region and according to climate change, we need to assign chronological position of each archaeological site carefully on the basis of reliable radiometric dates and describe regional variation of correlation between human behavioral change, pottery adoption, and environmental change.

This presentation examines regional difference of the timing and behavioral context of pottery adoption by synchronically comparing two regions on the basis of AMS radiocarbon dating in the southwestern Japan, where plenty of archaeological data has been accumulated.

**O-4100**

## **Stone tool caches and early ceramic producers in the terminal Pleistocene of Japan**

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### **Abstract**

While spatially definitive features such as dwellings and burials are rarely found from the Pleistocene archaeological sites, stone tool caches defined as small clusters of stone tools that are spatially differentiated from lithic scatters are not particularly unique. Stone tool caches mostly consisting of combinations of bifaces, points, blades, and stone axes are also visible in the terminal Pleistocene (ca. 15,000 – 11,500 cal. BP) archaeological record in the Japanese Archipelago where moist climate and acidic sediments almost entirely prevented to preserve organic record. Despite the presence of stone tool caches in the Japanese archaeological record during the terminal Pleistocene, archaeologists have not adequately evaluated their significance and seldom provided explanations well beyond site-specific analysis. In the present paper, we discuss the variability in patterns of stone tool caches (e.g., discovered context, stone-tool components, spatial patterns, probable chronozones that caches are affiliated with) and their behavioral significance based on a comparative analysis of representative stone tool caches during the terminal Pleistocene in the Japanese Archipelago. Examples of stone tool caches are mostly from the Incipient Jomon assemblages with and without pottery, but their meanings likely vary between spectrum of being functional and symbolic. We will also discuss some pertinent issues regarding human behavioral and organizational responses to ecological diversity among regions of the Japanese Archipelago, such as changes in foraging patterns, and emergence of pottery use. It is also expected that the present study of stone tool caches in the terminal Pleistocene in Japan will illuminate behavioral and organizational variability in prehistoric hunter-gatherers beyond the regional scale.

**O-4101**

## **The paradox of pottery in the Kuril Islands**

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### **Abstract**

The Kuril Islands of Northeast Asia present one of the most difficult natural environments for the production of pottery. The coastal sub-arctic climate of the region has winter seasons that are long and cold, summer seasons that are wet and short, and limited availability of high-quality clay resources. Despite these challenging conditions, archaeological research shows initial pottery production began around 8,000 years ago but widespread use of pottery in the archipelago does not occur until over 4,000 years later. This paper will explore this apparent paradox by reviewing the evidence for pottery manufacture and use in the southern, central and northern regions of the island chain. The comparative approach taken here aims to offer insights into the role that various environmental and cultural factors have on the production of ceramics and the use of pottery vessels. Specific focus will be placed on variability in the decoration and morphological features of pottery that emerged during the Late Jomon and later periods. Preliminary evidence from ceramic analysis and organic residue analysis suggest that despite using the same raw materials, substantial differences exist in how pottery was used between various ecological zones. Finally, the pottery of the Kuril Islands will be contextualized within the broader sphere of Northeast Asian pottery traditions including Japan, the Russian Far East and Siberia. Through this comparison it will be suggested that Kuril pottery highlights many of the same features that are associated with the pottery technology of neighboring maritime foragers. These insights aim to contribute to the growing knowledge base about the emergence and long-term persistence of pottery technology within maritime hunter-gatherer communities.

O-4102

## Ceramic production and distribution before the Younger Dryas: Petrographic provenance research from Tanegashima Island of Japan

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### Abstract

The earliest ceramic vessel technologies in the world, dated to the Late Pleistocene, have been reported from East and Northeast Asia. However, the timings of adoption are debated. For example, in South China, pottery-making may have been adopted by foragers as early as the Last Glacial Maximum, or by people who consumed rice in an early form of domestication as late as the Early Holocene. In the Transbaikal, the debate lies between the Bølling/Allerød period, determined from the evidence of radiocarbon chronology, and the Early to Mid-Holocene transitions assessed from stratigraphy. Additionally, although the earliest pottery dates from the Japanese Archipelago have not commonly been debated, the Oldest Dryas and Bølling/Allerød chronological contexts require further assessment at various sites.

Nevertheless, some regions are currently more suitable than others for reconstructing human behaviors associated with pottery in the Late Pleistocene. For example, southern Kyushu of Japan is a rare place where firm dates for the Late Pleistocene origins of pottery can be determined. There, the Incipient Jomon pottery is encountered below the Satsuma Tephra, dated to 12,800 Cal BP, which coincides with the period of the Younger Dryas. In this project, we studied the Incipient Jomon pottery from southern Kyushu. We selected the Sankakuyama I site on Tanegashima Island, 40km south of the tip of the mainland Kagoshima Prefecture, and about 18km east of Yakushima Island. The Incipient Jomon pottery at Sankakuyama I is dated between ca. 14,000/13,500 to 12,800 Cal BP. Ceramics were used by foragers that also constructed pit-houses and used groundstones. We conducted petrographic analyses of ceramic thin sections. Our results support our previous results, based on a visual observation, that there are local and non-local ceramics. The ceramics include felsic intrusive materials not found as bedrock materials on Tanegashima Island today. Based on recent literature on the timing of sea level rise conducted in Kagoshima Bay which suggests that seawater entered there by 14,300 Cal BP, there is a possibility that, by around the same period, Tanegashima was disconnected from the mainland and Yakushima Island. Both Yakushima and the mainland southern Kyushu have intrusive plutonic rocks. This suggests long-distance transportation of pottery or its raw material, either by sea or land, before the Younger Dryas. Because of the firm chronology in this region, the study serves to provide among the earliest evidence for pottery production and circulation in the world.

O-4103

## Final Pleistocene-Early Holocene Population Dynamics and the Emergence of Pottery on the Korean Peninsula

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### Abstract

While located in the heartland of northeast Asia which witnessed the emergence of pottery in the final Pleistocene, the Korean Peninsula lacked comparable archaeological evidence until circa 6000 cal BCE when pottery first appeared on the peninsula much later than neighboring areas. Using radiocarbon dates as a population proxy and focusing on mobile hunter-gatherers' response to environmental changes, we attempt to provide a hypothesis for this issue.

Critical evaluation of available radiocarbon dates for the final Pleistocene and early Holocene of the Korean Peninsula suggests (1) a consistent increase in the number of sites during the Last Glacial Maximum (LGM), (2) a notable drop after the LGM and (3) an almost complete gap during the post-Pleistocene. The lack of early pottery in Korea is likely to have been associated with the paucity of the archaeological record during the post-LGM and post-Pleistocene. We hypothesize that under the harsh environmental conditions during LGM, the Korean Peninsula might have been the population refugium. But as temperature rose toward the end of the Pleistocene (between 15,000 to 9500 cal BCE), many mobile groups would have moved to the north leaving not much evidence for occupation of the peninsula, followed by a lack of occupation during the post-Pleistocene. This population change suggests that while small number of mobile groups dispersed during the final Pleistocene around the cold and dry phase of Younger Dryas, the Peninsula might have been only a seasonally visited place or even deserted during the global warming.

The lack of the archaeological evidence during the post-Pleistocene of the Korean Peninsula is followed by the appearance of pottery and boom of occupations especially along the eastern and southern coasts around 6,000 BCE. We suggest that the appearance of pottery and occupation boom are related with the so-called 8.2 k event known for recognizable drop of temperature that lasted several hundred years. To understand this relationship, we also look into population dynamics of the neighboring areas that early pottery producers had occupied between post-Pleistocene and the 8.2k event. As seen in the population fluctuation on the Korean Peninsula depending on climatic changes during the final Pleistocene and post-Pleistocene, the sudden drop of temperature associated with the 8.2k event would have led to population dispersal or reorganization on a regional scale, eventually resulting in the occupation of coasts of southern part of the peninsula by pottery producing hunter-gatherers. Although where the first pottery producers of Korea were originated from needs a further scrutiny, we suggest that the lack of pottery during the final Pleistocene and post-Pleistocene in Korea and the late appearance of pottery coincident with the 8.2k event be understood in relation with climatic fluctuations and regional-scale responses of hunter-gatherers of northeast Asia.

**O-4104**

## **The earliest pottery surrounding Mt. Nanling Region, South China**

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### **Abstract**

During last several decades, more early pottery remains have been found in South China, especially surrounding the Mt Nanling area. The new researches indicated that the owners of earliest pottery had occupied this region since 20000BP, as the cases in Xianrendong, Jiangxi Province, Yuchanyan, Hunan Province and Huangmenyan, Guangdong Province. They lived in caves or rock shelter within the huge karst area by the terminal Pleistocene. Together with the pottery, thousands of stone artifacts (mainly pebble tools) were found during the excavations. A large number of antler, bone tools, as well as shell knives, were also found. In addition, fireplaces and occupation surfaces were uncovered in different cultural horizons of many caves. The diversity of the finds indicates that during the terminal Pleistocene, the cave or rock shelter had been used by hunter-gatherers for a variety of activities, including base camps, stone workshops, animal butchery and etc. This paper will briefly introduce the earliest pottery and terminal Pleistocene settlement surrounding Mt. Nanling area in South China, and discuss the complex history of modern human dispersal in this region.

O-4106

## Coastal barriers and transgressive dune fields fronting perched lakes: The Northwest Iberia case study

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### Abstract

Rocky and indented coasts host a large number of sedimentary features that typically develop associated with the irregular nature of these coasts, such as small perched lakes and bay-mouth or mid-bay barriers. Besides, the position of these basins relative to mean sea level and the occurrence of infilling transgressive aeolian deposits favor the preservation of valuable sedimentary archives that may contribute to reconstructing the coast evolution over the past, as well as to shed some light over changing regional wind field or storminess regimes.

Here, two examples of coastal barriers and transgressive dune fields fronting perched lakes (Traba and Doniños, Galicia, NW Iberia), are investigated to decipher the main processes controlling their evolution. For that, Ground Penetrating Radar and borehole transects were collected to characterize the sedimentary architecture of both systems. Selected samples were dated using both accelerated mass spectrometry radiocarbon and optically stimulated luminescence dating techniques.

Five dominant radar facies (Rf) and four radar surfaces (Rs) were identified within the radargrams. The identified Rf fall into two groups: (i) inclined reflections and (ii) horizontal to subhorizontal reflections. These Rf are interpreted as transgressive dunes (Rf-1), foredunes (Rf-2), channel infilling (Rf-3), scour and fill structures (Rf-4) and aeolian dune deposits with vertical aggradation or lateral accretion (Rf-5). The identified Rs are grouped into two main types: (i) erosive surfaces and (ii) boundary surfaces. Rs are interpreted as dune scarps (Rs-1), incised channels (Rs-2), water-table (Rs-3) and centimeter-thick layers of organic-rich sediments (Rs-4).

A preliminary conceptual model is suggested to explain their onset and evolution, integrating all available information from both sites. The onset of the system is marked by the anchoring of the barriers ca. 4000 BC and the subsequent formation of a dune field through the inland migration of transgressive dunes starting ca. 3000 BC. This inland migration was not a continuous process, as documented by the presence of interbedding organic-rich layers. They may indicate the temporary cessation of aeolian activity but might have also been related to the fragmentation of a former coastal barrier through the formation of erosive features within the foredunes as blowouts driven by the impact of frequent and intense storms. The latter could also be responsible for the eventual overwash and inundation of barriers as suggested by the sedimentary record. Ancient human intervention opening the barriers can however not be completely disregarded.

The timing of the formation of the different transgressive dune pulses and overwash deposits will be further investigated in order to construct a more constrained storminess chronology within the explored region.



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O-4107

## Late Mesolithic occupation in a Holocene changing landscape: a multi-proxy analysis of sediments from the Sado alluvial plain, SW Portugal

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### Abstract

Roughly between 8400 and 7000 cal BP the major Portuguese estuaries like the Tagus and the Sado were intensively occupied by Late Mesolithic communities, leading to the formation of sites known as shell middens. These sites resulted from successive accumulation of shells consumed during the Mesolithic stays as well as other remains related to the exploitation of the environment. Palaeodiet studies ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) performed in individuals buried in some of these shell midden sites confirm that marine resources were a food-component of their diet.

During the Mesolithic occupation of these palaeoestuaries coastal landscapes suffered major changes mostly due to sea level rise. An estimated mean rate of ca.  $8.1 \pm 0.7 \text{ mm yr}^{-1}$  until 7500 cal BP – decreasing to a rate of ca.  $3.4 \pm 1.0 \text{ mm yr}^{-1}$  between 7500 and 6900 cal BP – is known, promoting the flooding of the valleys formed during the lower than present sea-level stages and the formation of marginal tidal environments.

The multi-proxy study (texture, organic chemistry, magnetic susceptibility, organic matter and  $\text{CaCO}_3$  contents, diatoms and  $^{14}\text{C}$  dating) of six sediment cores recovered from the Sado alluvial plain, close to Mesolithic shell middens (fig.1), aims to characterize the extension of the marine influence in the Sado valley and the landscape evolution during the Holocene. Preliminary data point to the presence of estuarine conditions between Arapouco and São Bento sites (fig.1) since the beginning of the Mesolithic occupation and until ca. 3300 cal BP, favourable to the collection of marine species in the vicinity of their settlements. Further upstream fluvial conditions prevailed at least since ca. 4400 cal BP, reflecting the contraction of the estuarine area after sea level rise deceleration.

It is important to highlight that during the ca. 1500 years of Mesolithic occupation in the Sado area sea level rose ca. 12m driving constant changes in the exploited environments and reflecting the resilience of these hunter-gather communities upon estuarine environments.

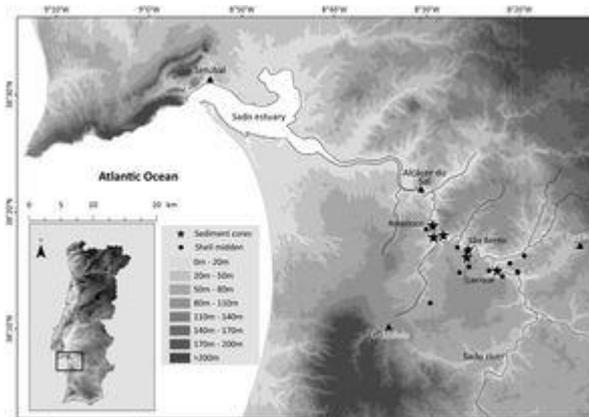


Figure 1 - Location of the Late Mesolithic shell middens (black circles) and of the studied sediment cores (black stars), Sado, Portugal.

#### Acknowledgements

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O-4108

## Reconstructing the Holocene evolution of the Lower Danube floodplain

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### Abstract

The sedimentary deposits of the large rivers are some of the most interesting Quaternary records because they provide valuable information not only about river and floodplain dynamics but also about the complex response to autogenic (solid and liquid discharge, thalweg slope, floodplain width, etc.) and allogenic factors (climate change, sea level rise, anthropic activity). In this study we present the measurements performed on 10 cores sampled along ca. 100 km within the Danube floodplain, immediately upstream of Danube delta. The multi-proxy analysis includes geochronology based on absolute ages (AMS), sedimentological (grain-size, loss on ignition, magnetic susceptibility), geochemical and paleo-ecological (pollen, seeds, ostracods, forams, dinoflagellates) methods which were mainly focused on the changes observed in the sedimentary records. The results allowed for the identification of the main evolutionary phases from the estuarine conditions which followed the sudden Black Sea level rise induced by the invasion of the Mediterranean Sea till river floodplain development via Danube delta front advance. Thus, most of the floodplain stratigraphies show similar patterns with turning points induced by the dramatic change from a configuration to another: continental floodplain - estuarine bay – delta front advance – shoreline – river floodplain – lake and marsh inception. Different proxies, but especially the sedimentation rates derived from the age-depth models show marked differences correlated with local water history (dependent on sea level and tectonics) and later (since Neolithic) with the human history especially via land-use change (deforestation, crops). The latest have been also documented by means of paleo-ecology which allowed to assess the agriculture activities based on pollen and cereals seeds.



RăspundeRedirecționează

**O-4109**

## **Crypto tephra in the sediments of Paleolake Gorgana, Romania – a trigger for paleoecological changes of the lake environment**

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### **Abstract**

Research in the Lower Danube valley in southern Romania, a large paleolake, Lake Gorgana, was discovered. The sediments of this lake represent an excellent geo-archive for the reconstruction of the paleoenvironment. Connected to the catchment area of the Danube and equipped with a water surface of over 2400 km<sup>2</sup>, this geoarchive reflects major changes of the paleoecological conditions.

A prominent dark section in the sedimentary record of Lake Gorgana that was deposited between the 7<sup>th</sup> and 4<sup>th</sup> millennium BC in the Atlantic period, was the special focus of the research. Using a multi-proxy approach based on the analyses of several corings using XRF, XRD and  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  isotopes the complex evolution, including input of crypto tephra, of this dark section was revealed. The input of volcanic material into the former lake triggered some serious ecological changes in the lake, for example immense acidification followed by eutrophication of the lake. Considering the dimension of this effect it must be assumed that the volcanic event affected the whole catchment area of the lake.

Dark deposits of similar shape are described in several studies of other authors for European and Mediterranean geoarchives for the Atlantic period. These dark deposits are mostly characterized by high proportions of organic material, indications of anaerobic conditions and poorly preserved or corroded pollen. However, these deposits are interpreted in different ways by the corresponding authors.

In this paper, we will present evidence that the development of the dark layer in the sediments of Lake Gorgana was initially triggered by a volcanic event that might have been of global influence on ecosystems.

O-4110

## Late Quaternary relative sea-level changes and evolution of the Lacepede Shelf, southern Australia

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### Abstract

The River Murray, part of the Murray-Darling Basin, the largest river system in Australia to reach the sea (1,060,000 km<sup>2</sup>), debouches onto the Lacepede Shelf, in SE South Australia. The Lacepede is a wide (180 km), shallow ( $\leq 150$  m), tectonically stable shelf, part of the largest modern temperate cool-water carbonate depositional province in the world. During the Quaternary, the dominant geomorphological changes resulted from transgressive/regressive events with minimal isostatic effects in this far-field environment. At times of lower sea-level in the Middle and Late Pleistocene, the former Murray extended farther south on the exposed shelf. Therefore, its sedimentary record allows reconstruction the history of the palaeo-river, which encompasses changes in sea-level and shoreline extents during the last glacial cycle. Multiproxy analyses including taxonomy, taphonomy, dating (<sup>14</sup>C-AMS and AAR) of foraminifers and bivalve shells, sedimentological and mineralogical data were performed on five cores located along the palaeo-channels of the ancient river system. The results indicate a sea-level position at  $\sim 3$  m APSL at the beginning of the Last Interglacial (125 kyr), 55-60 m BPSL at  $\sim 45$  kyr,  $\sim 110$  m BPSL during the Last Glacial Maximum, and 40-50 m BPSL during the Pleistocene-Holocene transition ( $\sim 12$  kyr). Climatic and environmental conditions during the Last Interglacial Optimum ( $\sim 125$  kyr) were similar to present with the shoreline located  $\sim 2$  km inland, where the inner land of the modern Coorong occurs. A lagoon-estuarine system was established, dominated by *Ammonia aetana* intermittently exposed (signs of bleaching). During one interstadial of MIS 3 at  $\sim 45$  kyr, the mid shelf (80 km from the present shoreline) revealed a high-energy shallow neritic environment (highly reworked sediment) with dominance of *Elphidium advenum*, close to a lagoon with abundant by *A. aetana*. During the LGM, colder and drier conditions left the shelf almost completely exposed, with the river mouth situated at  $\sim 150$  km off the present shore towards the west, defined as a neritic environment dominated by *E. advenum* and *Cibicides refulgens*. The preservation of foraminifera shells at that time, indicated signs of transportation associated with tidal fluctuations. At the end of the Pleistocene, the climate was relatively warm and the inner part of the shelf ( $\sim 60$  km from the present coastline) showed a fast transgression from a lagoon-estuarine system dominated by *A. aetana* and *E. excavatum* (with signs of reduction) to a typical shore marine environment on the actual shoreline about 2 ka ( $\sim 14$ -12 kyr). Finally, the continuous transgression through the Holocene established the shelf into the present typical high-energy marine environment, with coarser bioclastic sediments, higher carbonate and quartz percentages, an increase in abundance, richness, and diversity of marine foraminifers; while at the edge of the shelf, planktonic species as *Globoconella inflata*, *Globigerinoides ruber* and *Cibicides* spp. are abundant, indicating a deep-water environment.

**O-4111**

## **Holocene coastal evolution of beach ridges in the sheltered Hervey Bay embayment, Southern Queensland, Australia**

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### **Abstract**

There are significant and increasing populations inhabiting the low-lying coasts around Hervey Bay, a 100 km wide embayment about 270 km north of Brisbane on the east coast of Australia. We investigated the progradation history of the coastal plain NW of the Burrum River to decipher the Holocene coastal evolution of Hervey Bay and to investigate the long-term storm hazard on this coast.

The area was mapped with the assistance of airborne LiDAR data and recent changes along the coast were determined from historical aerial photographs. The stratigraphy of the coastal plain and beach ridges was investigated using ground penetrating radar (GPR) surveys. OSL ages were recovered from the sandy beach ridges while cores collected in the back-barrier SE of the Burrum River were dated using C14 and analysed for grain size, optical characteristics and elemental composition.

Preliminary results show while the higher shoreward ridges were built in early Holocene, most of the strand plain was formed in the late Holocene. Only one specific storm layer was identified, which dated to before  $5415 \pm 30$  yrs BP. This general pattern supports the concept of declining sea-levels in this part of eastern Australia after a high stand at about 6.5 ka. At the southern end of the strand plain, 20 ridges younger than  $670 \pm 110$  yr spread over 1.4 km, suggesting rapid progradation at a rate of over 2 m/yr, which is one of the highest recorded among strand plains studied in Queensland. This high rate is attributed to a sea level fall of approximately 0.5 m in near historical times and to an increase in sediment availability in Hervey Bay. Given that a similarly high sedimentation rate is recorded SE of the river, it appears that sediment delivery from the river has increased substantially in the last 1000 years.

**O-4113**

## **Direct dating of human fossils and the ever changing story of human evolution**

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### **Abstract**

When dating valuable human fossils, any damage has to be kept to an absolute minimum. Over the years, we have developed virtually non-destructive protocols for ESR and U-series analyses. This has given us access to a number of important human fossils, including those from Florisbad, Naledi, Irhoud and Mislya. This presentation gives an overview how ESR and U-series dating has changed some of the perceptions of modern human evolution.

O-4114

## The timing of alluvial fan deposition along the northern coast of Chile constrained by luminescence and electron spin resonance dating

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### Abstract

Coastal alluvial fans (CAFs) in northern Chile are of crucial interest for studying the Quaternary environmental evolution of the hyper-arid Atacama Desert. This research, however, is limited by the small amount of chronological data currently available to constrain these CAF deposits. Optically stimulated luminescence (OSL) dating of quartz has proven challenging in these deposits due to unsuitable OSL signal properties. Therefore, we aim to establish a chronostratigraphic framework for CAFs between 21°S and 25°S by using a combination of post-infrared infrared (pIRIR) stimulated luminescence dating of K-feldspar and electron spin resonance (ESR) dating of quartz. Samples were taken from alluvial deposits, as well as from marine and aeolian sediments embedded in the CAF.

Preliminary numerical dating results can be summarized as follows: pIRIR dose distributions of alluvial fan samples are characterised by relatively high overdispersion and positive skewness, in contrast to marine and aeolian deposits. Measurement of modern analogue sediments indicates that this can be attributed to partial signal resetting, due to different transport mechanisms. Following the quartz multiple centre (MC) ESR dating approach, both the Al and the Ti centres were measured in order to evaluate whether full bleaching of the different centres has been achieved prior to deposition. While the Ti-H centre provides lower doses than the Ti-Li centres, in most cases the Al centre provides the highest dose values. This pattern is consistent with their respective bleaching kinetics and suggests that the Ti-H signal most likely provides the closest estimate to the true burial dose.

ESR ages (Ti-H, Ti-Li) are consistent with the luminescence dating results at 1 $\sigma$  for most of the samples. Differences between pIRIR and ESR age estimates might be explained by incomplete bleaching of the ESR signals during short-term debris-flow transport. First numerical ages date the lowermost marine terrace to the MIS 5, providing a maximum age for alluvial fan deposition directly at the coast. Marine terraces give insights into the tectonic activity in the area during the Late Pleistocene, leading to estimated uplift rates of ~0.3 m/ka. Aeolian sand interbeds in the alluvial fan complex and alluvial fan deposits date to ~60-30 ka and ~15 ka, giving insights into the palaeoclimate, regional geomorphology and wind pattern in the study area.

To conclude, our results show the need to develop reliable dating approaches in environments where the standard OSL dating procedures do not work. In this context, the conjunction of pIRIR and MC ESR dating can be considered as a promising tool to decipher Late Pleistocene landscape dynamics along the northern coast of Chile.

O-4115

## Amino acid racemisation dating of mammalian enamel: a UK proboscidean geochronology

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### Abstract

Construction of chronological frameworks capable of robustly estimating the age of mammalian remains are imperative to understanding a range of palaeontological enquiries. Direct dating of mammalian remains is extremely difficult beyond the limits of radiocarbon dating (~50 ka). Analysis of the predictable breakdown of proteins and amino acids in wide variety of calcium carbonate (CaCO<sub>3</sub>) based biominerals has been a powerful tool for Pleistocene age estimation (back to ~2.5 Ma), but to date, its application to mammalian remains has been challenging. By targeting a proteinaceous fraction found within the crystalline structure of biominerals (the intra-crystalline fraction), the difficulties associated with contamination, leaching and environmental influences are circumvented. We have assessed the suitability of tooth enamel for intra-crystalline protein decomposition (IcPD) dating by testing both the protein breakdown and the intrinsic properties of the inorganic crystal structure of enamel through simulated degradation experiments. We have found that a fraction of amino acids can be successfully isolated from enamel that are expected to remain stable over long time scales.

A geochronology based on the extent of amino acid racemisation in proboscidean enamel has been constructed from known age material, with an age range that shows the technique successfully dates material from the UK up to Late Pliocene in age. It is therefore now possible to provide direct age estimation for unknown age proboscidean material from the same temperature region (likely to be Northern Europe) through comparative assessment based on our existing framework. Enamel AAR has the potential to be expanded to a range of mammalian species and can be developed for additional geographic regions. The focus of this framework has been on Quaternary age samples, but due to the slower breakdown of the enamel proteins, the dating range of this method may extend much further back in time.

O-4116

## Multi-method age model of a long lake sediment sequence from Orakei maar palaeolake, Auckland, New Zealand

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### Abstract

Meaningful reconstructions of Quaternary palaeo-climate and -environmental reconstruction rely heavily on accurate and precise chronologies. Long and continuous lake sediment sequences are outstanding archives of past climatic change but, unless varved, depend on the development of detailed age models. Such models estimate the age-depth-relationship of the sequence from a limited number of dated horizons, which often carry large associated errors, age reversals, or minimum/maximum age constraints.

Approaches to chronology development for sediment sequences have seen major improvements such as more nuanced Bayesian accumulation models but still rarely reach the resolution and precision desired for the study objectives in the context of high-resolution palaeo-climatic correlations of global events. This is particularly true beyond the limits of the well-established and more precise radiocarbon dating method. Sediment archives older than 50 ka have often not been used to its full potential for the lack of chronology estimates. In such cases, alternative methods including correlative and relative dating methods may need to be employed. Currently, a standardised method of integrating absolute dating with wiggle-matched curves of comparable proxies between the unknown and a dated sequence is lacking.

Here we address this problem in the context of the Orakei maar palaeolake sequence from Auckland, New Zealand. This sediment record is a high-quality example of one of the rare high-resolution and continuous lacustrine archives of climatic variations in the southern hemisphere mid-latitudes over much of the last glacial cycle. Based on previous estimates, the Orakei sequence spans the interval ca. 126 cal ka BP to 9 cal ka BP.

The presented Orakei chronology is based on absolute ages from tephrochronology, radiocarbon dating and post-IR IRSL luminescence dating. Prior to 40 ka, tuning of relative palaeomagnetic intensity changes and meteoric Beryllium-10 flux to the global PISO-1500 palaeointensity stack between absolute age markers allows to establish a novel accumulation model for the Orakei sequence.

This approach allows us to generate a high-resolution age model suitable for correlation of millennial-scale oscillations from the SW Pacific to global records of past climate such as polar ice core, tropical lake and speleothem archives.

O-4117

## Direct dating of faulting in the absence of overlying sediments

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### Abstract

Past activity of active faults is typically estimated from deformed Quaternary sediments, containing a combination of measurable displacement markers and dateable material. In crystalline bedrock areas undergoing rapid erosion, faults can be observed geologically or geomorphologically without overlying dateable Quaternary units. For such faults, there is currently a lack of broadly applicable methodology to evaluate their activity indices, which in turn poses a threat to infrastructure and densely populated areas. In this study, we introduce a novel concept to evaluate fault activity from trapped charge in quartz – specifically, the optically stimulated luminescence (OSL) and electron spin resonance (ESR) signals. The level of saturation of these signals, alone or in combination, has the potential to quantify the activity of faults where slip rates are presently poorly constrained or unknown.

We show preliminary results for an outcrop of the Atotsugawa Fault (active fault in the central Japan). The fault core consists of fault gouge and breccia including granite clasts. Four test samples were taken, including a location previously dated by quartz OSL (Ganzawa et al., 2013) to  $200 \pm 200$  years, (broadly consistent with the last large earthquake at 1858). The equivalent dose ( $D_e$ ) and dose response curves were obtained using pulsed OSL to minimise signal contamination by feldspar OSL. Relatively uniform  $D_e$  values and  $n/N$  were calculated for all samples, and ranged between  $42 \pm 11$  ka and  $56 \pm 19$  ka, except for one younger sample with a higher environmental dose ( $19 \pm 5$  ka). Although all the apparent ages appear ca. two orders of magnitude older than those of Ganzawa et al. (2013), the relatively uniform values (mean age:  $47 \pm 4$  ka; mean fraction of saturation:  $0.33 \pm 0.02$ ) can be considered as representative of the activity of the Atotsugawa Fault during a similar timescale. These apparent ages, together with a trap depth of  $1.66 \pm 0.03$  eV and a frequency factor of  $1 \times 10^{13} \text{ s}^{-1}$  (Murray and Wintle, 1999), and an estimated recurrence interval of Atotsugawa Fault of 2.5 ka (Research Group of Atotsugawa Fault, 1989), were used to predict the fault shear heating that has repeatedly occurred during past large earthquakes. Our modelling suggests that flash heating of the fault gouge during each large earthquake is broadly equivalent to  $250 \text{ }^\circ\text{C}$  for 10 s. Inverting our exercise, we suggest that if one can estimate the degree of recurrent flash heating independently (e.g. via shearing experiments), it is in turn possible to calculate a recurrence interval for a given fault.

O-4118

## Implementation of violet stimulated luminescence (VSL) in sedimentary environments with complex behaving quartz

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### Abstract

Over the past decades, optically stimulated luminescence (OSL) dating has become a key tool in the study of the Quaternary. It can provide absolute ages ranging from decades to several hundred ka using standard procedures. Despite the power of the technique, demand for extending the age range has increased, resulting in a large concentration of effort in this respect. Violet stimulated luminescence (VSL) has been proposed as one approach for meeting this objective. It has been shown that VSL yields a luminescence response that saturates at higher doses than the conventional blue-OSL signal from quartz. This study focuses on the application of VSL to a sedimentary profile in the Atacama Desert which, based on the stratigraphy and previous knowledge of the area, is expected to extend beyond the age range of standard OSL.

Initial measurements on quartz extracts from the upper-most units, expected to be within the age range covered by blue-OSL, show complex behaviour. The derived signal is not dominated by the fast component and a given dose cannot be recovered using standard procedures. Based on this observation, it can be concluded that blue-OSL is not suitable for this sedimentary material and cannot provide reliable ages. In contrast, VSL from the same quartz extracts have a reproducible response. An extensive experimental study using VSL, including analyses on the effect of the stimulation temperature, the normalizing dose or the bleaching of the signal among other tests have been carried out to determine the most suitable measurement protocols and to confirm the reliability of the method to recover a given dose. Based on the results, equivalent doses using VSL and the corresponding ages have been estimated for eight units of this profile.

Ages have also been estimated from infrared stimulated luminescence (IRSL) of K-feldspar fraction from the same samples. Analysis on the effect of fading of the IRSL signal was not conclusive, hence no fading corrections were applied. However, dose recovery tests show the suitability of the applied protocol to recover a given dose.

Based on the experiments, both approaches appear to be suitable for measuring the equivalent doses of these samples but discrepancies between the derived ages are observed; IRSL ages are approximately 30 % larger than those from VSL. Both approaches show similar agreement with the geological context: 5 out of 7 of the IRSL and 6 out of 7 VSL ages are stratigraphically consistent however, given the lack of independent age control, further research is necessary to determine the sources of variability in the responses.

This study shows the complexity of luminescence dating of sedimentary material from the Atacama Desert and the need for a thorough study in order to obtain accurate independent age estimates.

O-4119

## Bulk sediment IRSL screening applied for high-resolution and fast age assessment of fluvial deposits in the Upper Rhine Plain

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### Abstract

For the reconstruction of past river dynamics it is essential to determine the age of fluvial deposits. Over the last two decades, luminescence dating has developed towards the most important geochronological tool in this context. As luminescence dating is laborious, the number of samples that can be processed are limited considering time and finances. Hence, luminescence chronologies are usually only punctual and delimited by sampling along obvious stratigraphic boarders (hiatuses). However, hiatuses are not always easy to recognise and their chronological hierarchy is usually not cognoscible. As a consequence, one may miss phases of deposition and by this bias the interpretation. The ultimate goal would be to establish close-to- continuous chronological records of fluvial deposition. While this is in principle possible using portable luminescence readers, this technique does not correct for variability in luminescence intensity caused by changes in sediment composition (e.g. feldspar content).

Presented here is case study from the Upper Rhine Plain where complex patterns of Holocene fluvial dynamics can be easily recognised on high-resolution elevation data (LIDAR). Investigated are six cores drilled along a transect through the Holocene flood plain of River Rhine near the town of Drusenheim. Besides sedimentological investigations we applied the approach of May et al. (2018) who use Ln/Tn IRSL measurements of natural sediment samples. By systematically sampling every 5 cm we receive high-resolution semi-quantitative age records that are complemented by proper IRSL and radiocarbon dating.

May J.-H., Marx S., Reynolds W., Clark-Balzan L., Jacobsen G., Preusser F. 2018. Establishing a chronological framework for a late Quaternary seasonal swamp in the Australian 'Top End'. *Quaternary Geochronology* 47, 81-92.

O-4120

## FAULT2SHA – Linking field geologists with seismic hazard modelers

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### Abstract

- Use of fault-related information in the assessment of seismic hazard is slowly finding its way in Europe. Progress is slow because the data collection process is time-consuming, the quality of data used to represent faults in databases is heterogeneous and methodologies to incorporate fault information in hazard studies are not necessarily agreed upon across Europe. Nevertheless, the motivation is high, spurred by the need to capture as best as possible the potential occurrence of larger-magnitude events, beyond those recorded in historical and instrumental seismicity catalogues or based on the “segmentation” concept in which the size of earthquake ruptures is controlled by segment geometries. Indeed, complex ruptures observed in recent events confirm the need to relax the “segmentation” concept. The 2016 Mw 7.8 Kaikōura, New Zealand earthquake, actually ruptured 21 different faults over 180 kilometers, a world record. This event raised numerous questions in the seismic hazard community, in terms of its capacity to anticipate such complex events. Complexity in terms of rupture geometry and slip distribution both at depth and at the surface is also characteristic of the most recent events that affected the Italian 2016 Central Apennines earthquake sequence. Thus one of the keys to improving the reliability of probabilistic seismic hazard assessment (PSHA) based on faults is not only mapping and characterizing faults (geometry and slip rates) but also considering all combinations of rupture scenarios that are physically possible in the seismic hazard estimates.
- In order to face these challenges the FAULT2SHA ESC WG (<https://fault2sha.net/>) is establishing natural laboratories, (i.e. Italy, Spain), where transdisciplinary issues are discussed among geophysicists, earthquake geologists, geodesists and seismologists. On the fault modelling side, the feasibility of methodologies (SHERIFS, FRESH and SUNFISH) to solve for the long-term rate of earthquake ruptures reflecting the complexity of fault systems (3D geometries and slip rate heterogeneities) was recently demonstrated. The objective of such methodologies is to maintain observed fault complexity, relax the segmentation hypothesis and empower earthquake geologists and geodesists to build fault-based seismic hazard models supported by field observations. Reliability of such approaches depend on the quality and quantity of available fault slip rate estimates, magnitude scaling relationships considered, as well as the knowledge of fault geometries at depth and of their mechanical behaviour (i.e. seismic versus aseismic). Comparing modelled results with available independent data is essential, to ensure that modelled fault-seismicity rates reflect at best our present day understanding of fault mechanics and crustal deformation processes in a given region. Comparison with instrumental, historical or paleoseismic seismicity rates, geomechanical results, geodetic data, and earthquake rupture dynamic simulations, are needed to collectively help in selecting the best choice among the different physically possible sets of rupture scenarios.

O-4121

## Constraining earthquake recurrence using lacustrine sediments: How many events do you need?

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### Abstract

It remains a topic of debate whether the inferred quasi-periodicity in many historical and paleoseismic records may be the result of the limited number of recorded events, or whether quasi-periodicity represents the typical nature of earthquake recurrence for most faults. In recent years, several long paleoseismic and paleotsunami records in lakes have been constructed that may encompass sufficient events to reliably assess recurrence parameters. Due to the typical continuous sedimentation regime in deep lakes, lacustrine records can provide a stable environment for the creation and preservation of paleoseismic data. Moreover, it can allow for excellent temporal resolution, so that variability in recurrence intervals can be accurately constrained.

Here, we firstly present the research strategy behind the construction of a long paleotsunami (Lake Huelde, 17 events) and paleoseismic (“shaking”) record (Lake Riñihue, 35 events) in South-Central Chile. Both records show some degree of quasi-periodicity with a coefficient of variation (CoV) of 0.68 and 0.50, respectively. Lake Huelde exhibits a bimodal pattern of tsunami recurrence intervals, whereas the Lake Rinihue data follows a more “classic” unimodal Weibull distribution. This difference can be explained by the different nature of the paleo-events, i.e. strong tsunami vs. strong shaking, and how this relates to the spatial distribution of tsunamigenic and seismogenic faults on a subduction zone.

Secondly, by developing synthetic recurrence patterns, we simulate the required amount of events to be able to accurately constrain some basic recurrence parameters. We find that this number strongly increases with recurrence pattern complexity and/or time independence. In case of a rather complex supercycle model or the time-independent Poissonian model, it seems that the standard deviations of the mean become possible to be estimated with 95% certainty only beyond a sample size of 10 and 16, respectively. More simple (unimodal) recurrence patterns may be constrained with similar certainty with only 5-6 events. We further evaluate these simulations by reviewing long lacustrine paleoseismic records worldwide. The influence of record length is analyzed by step-wise extending the most recent part of these records towards the entire record. For records that are believed to follow a Poissonian (CoV  $\sim 1$ ) or clustered (CoV  $> 1$ ) pattern, it seems that the CoV can only be reliably assessed beyond an event number of  $\sim 15-20$ . Records that are believed to be quasi-periodic (CoV 0.5-0.7) have a stable CoV after already  $\sim 8-10$  events. These findings based on both simulated as empirical data highlight the importance of sufficient event numbers in paleoseismic records for reliable assessment of earthquake recurrence parameters.

O-4122

## Active faulting in the Upper Rhine Graben: geomorphological and geophysical evidence

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### Abstract

The Upper Rhine Graben (URG) is the central part of the Central European Cenozoic Rift System (ECRIS) and one of the tectonically active regions in Europe. The URG extends from the Jura thrust and fold belt in the South near Basle city (Switzerland) to the Rhenish Massif in the North near Frankfurt and is limited by sinistral strike-slip faults on either sides. Seismic studies suggested the fault system at the eastern margin to be active, as the Basle earthquake 1356 AD was situated there. Ongoing earthquake activity testifies to active faulting, however, there are many faults and fault strands, many of them are regarded as normal faults, others as reactivated normal faults with a sinistral sense of movement. The URG is a low-strain setting with long recurrence intervals of large earthquakes. Moreover, the fault morphological signal is perturbed by anthropogenic land-use, the climate of the area, which is located in the temperate zone, and the erosion and sedimentation of the Rhine River. The eastern margin faults lack any neotectonic and paleoseismological investigations, in contrast to the western border faults that have been examined during the last decades, while the area encompasses critical facilities in a vulnerable region such as, dense population, agriculture, mining, geothermal facilities. Our projects in the frame of an IRSN study and the DFG-SPP AlpArray aim to fill this gap of knowledge in large and infrequent earthquakes, through a paleoseismological investigation of eastern side faults.

We used a multidisciplinary approach to improve the input data of seismotectonic models, which include faults and their activity potential in the calculation of seismic hazard assessment and are based on a weak data set at the moment. First results of different locations around Freiburg in the southern URG and around Karlsruhe are presented: the Rhine River fault system about 20 km SW of Freiburg, NE of Freiburg at the eastern border fault system about 10 km. At both sites we used a digital elevation model (DEM) derived from LiDAR-data (5x5m) and together with geophysical measurements performed with ground-penetrating radar (GPR) and electrical resistivity tomography in order to track and identify possible fault scarps. A detailed geomorphological study of the DEM was performed to identify and map superficial expressions of the neotectonic activity of the faults and deformed and offset alluvial terraces and fans. We apply ERT and GPR for imaging the geophysical contrasts at depth, such as faults and stratigraphy in detail. Nevertheless, for the unambiguous verification of these structures and the determination of key fault parameters, such as magnitude, age of last events, slip rate and return periods, additional paleoseismological trenches are needed, which will be the next step of the project.

O-4123

## Surface faulting pattern anomalies: lessons learned from the 2016 Central Italy seismic sequence

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### Abstract

With the aim to better understand the significance of local anomalies of coseismic surface faulting pattern and size, we have reviewed the characteristics of surface tectonic ruptures occurred along the Mt. Vettore - Mt. Bove – Mt. Banditella fault system during the seismic sequence hitting Central Italy in 2016.

The sequence was characterized by three main shocks on Aug. 24<sup>th</sup> (Mw=6.0), Oct. 26<sup>th</sup> (Mw=5.9) and Oct. 30<sup>th</sup> (Mw=6.5). Surface faulting associated to the first main shock was observed along the southeastern portion of the system (M. Vettore-M.Vettore fault), with vertical displacements up to 25 cm and ruptures continuous for at least 4.5 km.

The second main shock reactivated the northwestern part of the fault system: vertical displacements up to 10 cm were observed along the Cupi and Cornaccione faults, for an end-to-end rupture length of about 12 km.

The third main shock (Oct. 30<sup>th</sup>) ruptured the entire fault system for about 28 km and average vertical displacements in the order of some tens of cm, that locally reached about 2 meters.

In general, the overall pattern and size of observed surface faulting are consistent with the expected surface ruptures scenario associated to the observed magnitudes in a normal faulting environment with focal depths in the order of 5-10 km. However, a more detailed analysis has pointed out two anomalies:

- purely tectonic vertical displacements reaching values of about 2 meters, as those measured along the Cordone del Vettore fault, are generally associated to larger events ( $M > 7$ ). Such large offsets may better explained with a significant contribution of gravity, considering that the fault scarps are located at about 700 m above the base of a steep slope;
- rupture lengths associated to the Oct. 26<sup>th</sup> event (Mw=5.9) are generally constrained within a few km. Thus, an end to end rupture of about 12 km cannot be easily explained as purely tectonic: for this reason, some Authors have interpreted the ruptures along the Cornaccione fault as a not tectonic effect caused only by seismic shaking. However, our data collected on Oct. 28<sup>th</sup> along this fault point out a strong consistency in terms of location with surface faulting occurred on Oct. 30<sup>th</sup> along the same fault, even if with a significant difference of displacement amounts. Moreover, the aftershocks distribution indicates that also the ruptures produced during the 26<sup>th</sup> shock along the Cornaccione fault are mainly tectonic effects. These two examples of local anomalies of surface faulting pattern and extent show that this phenomenon may be very complex as it is influenced by several factors at local scale. This notion stresses once again the need of great care for a reliable assessment of seismic and fault displacement hazard based on paleoseismological investigations.

O-4124

## The seismicity models for the 2019 national Italian seismic hazard model

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### Abstract

In 2015, the CPS (*Centro Pericolosità Sismica*, Seismic Hazard Centre) of the Istituto Nazionale di Geofisica e Vulcanologia started to promote and coordinate the activities of a project aimed at producing the new national probabilistic seismic hazard model for Italy. We present the results of the activities of a task of this project, task 3: "seismicity models", that is focused on the definition of a set of seismicity models and on the analysis of their uncertainties. More than 30 researchers subdivided in 12 working groups produced 11 seismicity models covering the entire Italian territory, 1 models built *ad hoc* for the volcanic Etna area, 1 model for the seismicity of the Calabrian Arc, and 1 model for sources external to the Italian territory. The national models are built using different types of sources, methods, and input data. In particular, 5 models are based on area source and, with different approaches, on expected seismicity rates by means of fit of observations of the historical earthquake catalogue; 2 models are based on a mixed fixed-radius and adaptive radius and on Woo methodology for smoothing seismicity; 2 models used faults and background seismicity and; 2 models are based on geodetic data and they are independent from the historical seismicity.

\*MPS-T3 Working Group: Santulin M., Rebez A., Spallarossa D., Barani S., Monaco C., Rotondi R., Varini E., Basili R., Burrato P., Fracassi U, Kastelic V., Tarabusi G., Tiberti M.M., Valensise G., Vannoli P., Azzaro R., Barberi G., D'Amico S., Palano M., Tuvè T., Peruzza L., Gee R., Carafa M.M.C., Bird P., Murru M., Falcone G., Console R., Akinci A., Moschetti M.P., Taroni M., D'Agostino<sup>SEP</sup>N., Lai C. and Zuccolo E.

O-4125

## Surface rupture associated with a moderate intraplate earthquake: the Mw 6.2 Parina event (December 1st, 2016) in the Peruvian Altiplano

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### Abstract

Fault displacement and Seismic hazard analyses employ empirical relationships to predict potential earthquake magnitude (e. g., Wells and Coppersmith, 1994), probability functions of surface rupture and surface slip amount (e. g., Youngs et al; 2003). Those relationships share the common issue that they rely on a limited number of moderate-to-large magnitude ( $\geq 6.5$ ) and pre-2000 cases. Earthquakes from western US and Japan are largely represented, and intraplate cases are few. Here, we report surface faulting evidence that occurred during an intraplate and moderate earthquake in Peru. We present field and high-resolution data that improve the geodynamic knowledge of the region and provide clues to upgrade seismic hazard.

The 2016 Mw 6.2 Parina normal-faulting earthquake occurred within the high Andes of southern Peru, in a region with sparse seismicity and little geodetic horizontal strain. Field observations and high-resolution DEMs of the surface ruptures allow investigating the relationship between slip on the Parina Fault, local geomorphology and the regional tectonics. We mapped one major NW-SE-trending and 6-km-long segment, with up to  $\sim 30$  cm vertical slip (downthrown to the SW) and  $\sim 25$  cm tensional opening. Beyond a 4-km-long gap of surface rupture, a minor 2-km-long segment ruptured with smaller slip values (up to 8 cm), along the same fault zone. Surface slip is not much distributed off the major fault. The two mapped rupture traces directly coincides with the up-dip projection of the same co-seismic fault plane inferred from SAR interferograms, and therefore they may represent two distinct sections of the primary earthquake fault, separated by a surface gap. This gap occurs where surface geology is constituted of loose sediments. Interestingly, the ruptures coincide with 10-20 m high scarps cutting through Late Pleistocene fluvio-glacial deposits that are downthrown to the SW, and they form the southeastward extension of the larger Lagunillas-Mañazo fault system that trends NW-SE across the Peruvian Altiplano. A preliminary estimation leads to infer a repeated normal-sense slip on the Parina Fault since the last major glaciation ( $\sim 10-30$  ka), implying a vertical slip rate  $\sim 1$  mm/y.

Besides its regional interest in terms of active tectonics and geodynamics (Wimpenny et al., 2018), the Parina surface rupture constitutes a new case to enrich the pending SURE database with new accurate data, especially for intraplate events. This case also illustrates that the use of high-resolution techniques allows significantly the improvement of surface rupture characterization, potentially questioning the quality of datasets gathered in the past with vintage approaches. Those are arguments to support a deep revision of empirical relationships, based on catalogues of modern earthquakes.

O-4126

## Postglacial faults in Finnish Lapland

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### Abstract

Airborne LiDAR surveillance has revealed several postglacial fault (PGF) systems and a number of earthquake-induced deformations, such as paleolandslides and liquefaction features in the interior of the former Fennoscandian Ice Sheet. PGFs illustrate high-magnitude (up to  $M_w \approx 8.2$ ) earthquakes attributable to the release of lithospheric stresses within the glacial isostatic adjustment (Arvidsson, 1996). We applied shallow geophysics, trenchings and drillings to assess mechanisms and timing of PGFs and adjacent deformation morphologies in Finnish Lapland.

The PGF zones are characterized by a number of discrete 0.2–9.1 km long fault scarp segments which form longer PGF systems. A set of PGF systems further forms a PGF complex that is typically tens of kilometers long. At the moment, 18 PGF systems making up 9 PGF complexes have been discovered with general strike trending SW–NE (Mattila et al., 2018). Several trenched sites indicate that multiple rupturing events have taken place within PGF complexes. Stratigraphy of the trenched PGF segments and the age data of landslide-buried organic materials indicate that the non-stationary seismicity occurred episodically throughout the Holocene. Based on the <sup>14</sup>C datings at least three seismic episodes (9–11, 5–6 and 1–3 ky ago) have been found in western Finnish Lapland (Ojala et al., 2018). By applying scaling laws for faults from stable continental regions, we consider that a realistic moment magnitude range for the earthquakes that took place in Finnish Lapland are in the range of  $M_w \approx 4.9–7.5$ . These estimates are in accordance with maximum moment magnitude  $M_w \approx 6.9–7.5$  calculations based on the landslide volume-area data (Ojala et al., 2019). Since the fault instability over Fennoscandia occurred 13–9 ka BP (Wu et al., 1999), some bedforms, such as the Pulju moraine, may indicate subglacial seismic events (Sutinen et al., 2019).

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O-4127

## Variations in the character and geometry of grounding-zone wedges: a continuum of subglacial deposits?

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### Abstract

Grounding-zone wedges (GZWs) in marine palaeo-ice stream settings are now widely accepted as subglacial deposits formed at the palaeo-ice sheet margin as it stabilised for short periods during overall retreat. Thus, they are used as strong evidence for an episodic style of deglaciation, although they are often not well dated. Current models of GZW formation describe the build-up of asymmetric, often prograded deposits just beyond the grounding line when it is fronted by an ice shelf. The ice shelf is thought to be necessary in order to provide accommodation space at the grounding line in which a deposit can form; no such accommodation space is present at a tidewater margin. Here, we review the different styles of GZWs found on both northern and southern hemisphere palaeo-ice stream beds and discuss the reasons for the observed variability. We present new data from a suite of GZWs in Anvers Trough on the Western Antarctic Peninsula just beyond Palmer Deep and compare geometries, volumes and some aspects of their sedimentology with other well-studied examples from Antarctica and Greenland. Overall, the aim of this work is to progress ideas on GZW formation and their interpretation in the palaeo-glaciological record. We are interested in answering questions including: (1) What factors control the formation and geometry of GZWs? (2) Are the quoted formation times (decades to centuries) and volumes ( $10\text{-}10^2\text{ km}^3$ ) really representative for these landforms? (3) When is a GZW just a till sheet – do these landforms form a continuum of subglacial deposits? (4) What are the future avenues for this research?

O-4128

## Paleo-ice streams in Northeastern Iceland

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### Abstract

Ice streams exercised critical control on the dynamics of the Weichselian Icelandic Ice Sheet. Our project aims to advance our understanding of the configuration, geomorphologic imprint, dynamics and recessional history of palaeo-ice streams in NE-Iceland. Our approach is to study glacial landform associations and sedimentary records, using multiple glacial geological, geomorphological, remote sensing, geophysical and chronological methods. The project is designed to elucidate the relative timing and spatial distribution of fast ice flow, the absolute timing of ice-stream/ice-sheet recession and thinning, and the mechanisms contributing to fast flow and the genesis of streamlined subglacial bedforms. We have identified areas where ice streams have run partially uncontrolled by local topography. These include onset zones with reticulated ridges and ribbed moraines and trunk-flow zones with highly-attenuated streamlined bedforms, characterized by swarms of large drumlins. The flow patterns are highly convergent and distinct. The geomorphic record also shows time-transgressive shifts in ice stream directions, where their location got more topographic focusing, perhaps signifying change from glacial maximum situation to large-scale, rapid deglaciation. Sedimentological and stratigraphical studies have highlighted extensively deformed sediments associated with the ice stream paths, as well as evidence of basal sliding and heavy scouring of bedrock. The paleo-ice streams have terminated in the ocean, probably reaching towards the shelf edge. Presently, high-resolution bathymetrical-/geophysical-/sediment data are lacking from the shelf areas. The project can provide insight into marine-ice sheet instability and the vulnerability of marine-terminating ice streams to sea-level rise, and further our understanding of ice sheet deglaciation dynamics. An important benefit of this project will be the value of its results for constraining numerical models aimed at illuminating subglacial landform development and the evolution of the Iceland ice sheet during the last deglaciation.

O-4129

## Glacigenic Debris Flows along the NE Atlantic Margin Indicate Continuous High Sediment Supply during Shelf-Edge Glaciations

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### Abstract

High-latitude trough mouth fans are high-resolution paleoclimate and ice-sheet monitors. The stratigraphy of the North Sea Fan, a trough mouth fan at the northern North Sea margin, is dominated by glacigenic debris flows (GDFs), which indicate shelf-edge glaciations of the Norwegian Channel Ice Stream. The aims of this contribution are to characterize, quantify and date GDFs formed during the last glaciation. We use 16,000 km<sup>2</sup> of high-resolution processed 3D seismic data collected in 2017 and 2018 from the proximal North Sea Fan. These data allow to image the buried GDF packages in a resolution of 8 m vertically and 20 m horizontally. Chronologies previously established by piston cores from the distal part of the North Sea Fan allow constraining the ages of these debris flows. Six seismic horizons of GDFs have been picked with an in-line spacing of 150 m, followed by gridding, horizon attribute extraction, sediment volume calculations, and seismic geomorphological interpretation. The GDF package related to the last glaciation has a thickness of up to 400 m and is characterized by a homogenous seismic facies intercalated by five continuous high-amplitude reflections, which separate the package into six sub-units. The structure maps of these reflections show multiple sharp, 5-20 m deep channels. These SE-NE-oriented channels can be traced to the shelf break and occur with a lateral spacing of 5-20 km. Characterized by a low sinuosity, these channels diverge and converge over short distances. Structure maps show flat terrains between the channels. Maps generated by seismic attributes, however, show well-developed elongated bars and lobe-shaped features next to the channels as well as densely-spaced circular depressions with diameters of c. 30 m. The correlation of the five horizons with sediment cores of the distal part of the North Sea Fan indicate an age of 19-23 ka for these sediments. The up to 400 m thick GDF package, deposited within 4 kyr, correlates with a sedimentation rate of up to 100 m/kyr, and a sediment flux of 1500 km<sup>3</sup>/kyr for the study area. The six sub-units within the GDF package indicate that the Norwegian Channel Ice Stream oscillated six times during the last glaciation. Channels identified at multiple levels within the GDF package indicate that the sediment delivery from the Norwegian Channel Ice Stream was continuous, and did not occur in pulses of several decades. Channel-fed levees and debris lobes characterize the paleo-seafloor between the channels. The circular depressions, interpreted as pockmarks, indicate fluid escape events in some intra-channel areas during the deposition of the GDFs. This study highlights the capacity of high-quality 3D seismic data for the reconstruction of sedimentary processes and past ice-sheet dynamics significant for the climatic and oceanographic evolution of the study area.

O-4130

## Do glacial landforms have bed roughness signatures?

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### Abstract

Palaeo-glacial landforms can give insights into bed roughness that cannot be captured underneath contemporary ice streams. The bed of palaeo-ice sheets can be observed using high resolution Digital Terrain Models (DTMs) in its entirety, but the opportunity to learn more about bed roughness has yet to be fully realised. A few studies have focused on measuring bed roughness of palaeo-ice streams but palaeo-ice streams contain large areas of landforms, allowing glaciologists to measure bed roughness at high resolution. Using palaeo-glacial landscapes, we can test whether specific landforms have characteristic bed roughness signatures. If specific glacial landform assemblages have a characteristic bed roughness signature, these roughness attributes can be used to suggest where certain landform assemblages exist underneath contemporary ice sheets. Glacial landforms have been identified underneath very small areas of contemporary ice streams, but using bed roughness signatures could increase the known areas where landforms exist. This would provide more detail about contemporary ice sheet beds, such as the link between ice speed and types of landforms, and could improve the reconstruction of palaeo-ice streams.

In order to test these hypotheses transects were established over glacial landform assemblages (including mega grooves, mega scale glacial lineations and drumlins) in the UK and high resolution NEXTMap DTM (5 m) was used to calculate bed roughness. Transect spacing and orientation were investigated to ascertain if they affected roughness measurements. We find that landforms composed of sediment are smoother compared to bedrock derived landforms. Landforms with a higher elongation ratio have a more anisotropic bed roughness than landforms with a lower elongation ratio. The results show how transect orientation in relation to palaeo-ice flow direction is likely to be an important part of defining landform bed roughness signatures. The combination of total roughness and anisotropy of roughness (difference between roughness parallel and orthogonal to ice flow) does suggest that some landform assemblages do have a characteristic roughness signature.

O-4131

## Reconstructing the dynamics of palaeo-ice stream lateral shear margins from landforms and stratigraphic records

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### Abstract

Lateral shear margins (LSM) form along the sides of an ice stream due to the steep velocity gradient across the narrow boundary separating fast and slow ice flow. Processes taking place along these margins are thought to play an important role in the long-term behaviour of ice streams. For example, migration of LSM can affect ice stream width, which can lead to changes in ice and sediment discharge to ice stream terminus. It is still unclear what controls the initial location of LSM, but their behaviour appears to be sensitive to basal conditions and feedbacks between migration rate and the local temperature field. We have examined the geological record of a number of palaeo-ice stream LSMs from the Canadian glacial landscape to get insights into their long-term dynamics. We used geomorphological mapping, airborne and ground geophysics, as well as targeted stratigraphic and till provenance analysis and data classification techniques. Our results show evidence for lateral migration of LSM, especially for the large palaeo-ice streams thought to have operated over several thousand years. Certain LSM are characterized by stratified drumlins containing stacked till sheets of contrasting dominant provenance (i.e. proximal vs distal), which we interpret as evidence of oscillations in the position of the LSM across zones a few kilometers wide. Some of these zones are located along regional fault systems suggesting a possible bedrock control on LSM position, notably in upstream regions. Other LSM investigated in this study show less evidence for lateral migration and, in some cases, better developed LSM moraines. The relationship with bedrock structures and properties, and other potential controlling factors (e.g. scale of ice stream, duration) will need to be further investigated.

O-4132

## Ice streams in the Laurentide Ice Sheet during the last deglaciation

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### Abstract

The Laurentide Ice Sheet (including the Innuitian Ice Sheet) constituted the largest ice mass in the Northern Hemisphere during the Last Glacial Maximum. Reconstructions based on the geomorphological record show that it was drained by a network of ice streams not dissimilar from those observed in the present day ice sheets in Greenland and Antarctica. The configuration of the ice drainage network changed with the ice margin retreat during the deglaciation, which we reconstruct using the available ice margin chronology. The regional stability of the ice drainage network was dependent on the pace of the ice retreat. Marine margins in the north featured topographically controlled ice streams occupying pronounced troughs on the continental shelf and operating long into the Late Glacial. In contrast, ice streams draining towards the terrestrial margin in the west and southwest were more transient. The most dynamic changes in the ice drainage network were seen in connection with the collapse of the saddle between the Cordilleran and Laurentide ice sheets on the Interior Plains. Here, a rapid change in the direction of ice streaming is recorded in multiple cross-cutting ice stream tracks. The retreat of the western Laurentide margin onto the rigid bed of the Canadian Shield marked a pronounced change in the ice streaming network; ice streams became broader and less frequent. The final collapse of the ice sheet after the Younger Dryas was accompanied by brief deglacial ice streams that likely originated in response to the rapid changes in the ice sheet geometry. Future research might attempt to replicate our empirical results with high-resolution numerical models. Successful numerical modelling of the last deglaciation that would match the reconstructed ice sheet evolution, including its ice drainage pattern, would allow for producing reliable scenarios of the long-term fate of the modern ice sheets.

O-4133

## The onshore imprint of the Northeast Greenland ice stream and 79N ice ice shelf

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### Abstract

Understanding the impacts of climate change on ice sheets and the subsequent changes to global sea-level over 100 - 1000yr timescales are fundamental scientific and societal challenges. This project focuses on the Northeast Greenland Ice Stream (NEGIS); a key sector of the Greenland ice sheet (GrIS) because it controls ice flux into the NE Atlantic (an area sensitive to freshwater input) and it holds a sea-level equivalent (SLE) of ~1.4m. This sector of the ice sheet is predicted to be vulnerable to future climatic changes and is also known to have undergone dramatic retreat during the Holocene Thermal Maximum. The project aims to reconstruct the past behaviour of NEGIS in order to calibrate and validate the sensitivity of 3D numerical models that can predict ice stream-shelf dynamics over 100 - 1000yr timescales.

Along the north edge of 79N abraded terrain, erratic spreads and lateral moraines record warm-based ice up to 600-850m asl, with the ice stream coalescent with local ice caps to the north as ice moved offshore at the LGM. During early deglaciation a series ice contact deltas mark ice stream/ice cap decoupling, surface thinning and the formation of ice-dammed lakes along the margin of 79N. These may mark an upstream response to early ice recession from the continental shelf edge around 19.7 – 15.6 ka cal. BP.

The transition from ice stream to ice shelf in 79N occurred between 12 – 10 ka cal. BP, and the migration of the ice stream/shelf system onshore can be tracked using new geophysical and sedimentological data. Once within the confines of the 79N fjord the ice shelf retreated and disintegrated ~80 km upstream of the present ice shelf margin by ~ 8.0 ka cal. BP. This led to a period of open marine conditions in 79N fjord during the Holocene Thermal Maximum, as demonstrated by epishelf lake and marine sediments which contain whale, seal, mollusc and fish remains. However, post 4.0 ka cal. BP Neoglacial cooling triggered ice stream/shelf regrowth resulting in eastward grounding line migration and the cessation of marine conditions in the epishelf lake at Blaso. This ice advance/thickening phase culminated in the formation of prominent LIA ice shelf moraine systems adjacent to the 79N ice shelf.

O-4134

## Spatial Behavior of Humans Across Scales: Mobility – Migration – Dispersal

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### Abstract

Dispersal events of early humans are diagnosed on the basis of evidence of their presence in time and space, i.e. spatiotemporal shifts in the geographical distribution of hominin fossils. Corresponding to the punctuated distribution of the evidence large scale shifts like Out of Africa events and the initial occupation of the Eurasian continent are predominantly described on large spatial and temporal scales. For modelling purposes, diffusion models directed by features of the environment seem to be considered appropriate to reflect dispersal on such scales.

Large scale shifts result, however, from regional shifts of populations and seasonal and/or rather local mobility patterns of groups. They need to be studied on smaller scales and they require more sophisticated quantitative models for spatiotemporal movement patterns. Two basic strategies of mobility of hunter-gatherer groups are distinguished, i.e. logistical and residential strategies. A residential strategy is pursued when resource availability is predictable and does not undergo major shifts, while humans follow a logistical strategy, when resource distribution is patchy and changes radically in a seasonal manner. Hominin groups should therefore adopt different mobility strategies, depending on the extent of seasonal shifts in habitat productivity. The resulting hypothesis is tested by linking the Neanderthal archaeological record with seasonal shifts in habitat productivity around the last interglacial.

Both strategies moreover involve different spatial requirements and should therefore lead to different migration behaviors. Migrations will be targeted towards areas with improved resource availability. Moreover, particular routes can be inferred. Migration routes which are not entirely circular (i.e. do not involve returns to the exact point of departure) lead to dispersal. On this level, encounters with other groups and as well as human and non-human competitors should be integrated. The interpretation of dispersals resulting from group based mobility strategies and seasonal migrations requires more sophisticated modelling approaches, than represented by diffusion models.

Environmental models should reflect changes in food resource availability, e.g. by being based on relative changes in productivity and a migration analysis of large herbivores. In such environments, groups of agents should pursue mobility strategies and chose them in accordance to resource availability. Therefore, agents should explore their environment through movement and vision. They should monitor the actual state of the environment and share this information with other group members. Furthermore, they should be able to save past states of the environment within their exploration area to decide the appropriate mobility strategy.

In this contribution a variety of quantitative models will be presented. Furthermore, we examine links between them and explore their potential to be transferred into an agent-based modelling context.

O-4135

## Agent-based modeling of hominin spatial interactions in Europe: EMPT Dispersal and Mobility simulations developed in the METHOD IFG

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### Abstract

The Early Middle Pleistocene transition (EMPT) occurs between about 1 to 0.6 million years and is characterized by drastic climatic changes which affected the structure and organization of ecosystems on a global scale. Stone tools and human fossils from sites located in southwestern Europe (i.e. Guadix-Baza Basin and Atapuerca, Spain; Pirro-Nord, Italy) document hominin presence in Europe at least at 1.4 million years. However, occupation patterns throughout the EMPT ranging approximately from 1.6 to 0.4 million years remain unclear as a consequence of significant technological shifts and hiatus of occupations possibly derived from multiple arrivals of populations. Due to the punctual structure of the fossil and archeological records across large time spans, it is challenging to derive the dynamics of the occupation patterns in Europe exclusively on this basis. In order to understand past hominin distribution, it is necessary to assess driving factors and mechanisms behind the spatial interactions of hominins. We apply agent-based modeling to address the question of hominin occupation patterns during the EMPT in Europe. This method permits integrating up-to-date environmental models with models of spatial interactions in dynamic simulations.

In this talk, we present two exemplary models on different spatio-temporal scales that have been developed within the “Modeling Environmental Changes and Hominin Dispersals around the Mid-Pleistocene Revolution” (METHOD) IFG. Firstly, we present the “MPR Hominin Dispersal ABM” designed to examine the dispersal of stone tool technologies from Africa into Eurasia. Here, the agents represent hominin groups that exchange tool technology in various ways. Because of the large spatio-temporal scale of the model, the dynamically changing environment takes into account warm and cold phases as well as changing sea levels. Secondly, we use the “MoReDoH ABM” where an agent represents a hominin individual moving across the landscape to gather resources. We compare different mobility strategies of a hominin group within a particular region of the Baza Basin (Spain). In this case, the environmental dynamics reflect seasonal changes because this model considers mobility and migration on a regional scale.

These two examples led us to discuss about the application of agent-based modeling to test hypotheses of spatial interactions at different scales. Once a model is implemented, we can assess the effect of certain factors by explicitly



including or excluding them. With the aid of computational simulation we may then support or refuse common hypotheses in order to help in gaining an understanding about the spatial and foraging behavior of extinct hominins.

O-4136

## A Multiagent Framework for Simulation-Based Analysis of Early Human Mobility Strategies

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### Abstract

Hunter-gatherer populations need to be mobile. They have to forage in small parties for food and other resources as well as adapt to seasonal changes by moving larger groups to places with advantageous conditions. There are two extreme strategies known for this spatiotemporal behavior (with a range of mixed variants in between): The logistic strategy (1) in which groups remain in one area while focusing mainly on foraging activities to fulfill their needs and the residential strategy (2) in which entire groups move frequently from one area to another while depending less on foraging parties. Which strategy is most beneficial depends on resource abundance, heterogeneity, distribution (i.e., patchiness), as well as amount of seasonal change. For recent hunter-gatherer populations, these behavioral strategies are directly observable. In contrast, early human spatiotemporal behavior in the Pleistocene can only be assessed from the sparse archeological record that results from specific mobility patterns.

In order to complement the archeological evidence of human mobility, we present a multiagent-based modeling and simulation framework for analyzing different movement strategies. Our framework allows for representing reconstructed as well as artificially generated environments for systematic spatiotemporal strategy evaluation. We show how to implement seasonality and man-made changes in the environment which drive the agents' mobility patterns. Moreover, we present an agent architecture which facilitates complex behavior of agent groups. By making individual decisions, the agents adapt to the environmental conditions, resulting in optimally fitted strategies. Using artificial intelligence methods, particularly machine learning and evolutionary computation, our framework thus provides a testbed for hypothesis-driven experimentation with early human mobility.

To demonstrate its application, we furthermore present the design and results of a simulation-based mobility strategy analysis. Specifically, we evaluate the hypothesis that small seasonal changes in environmental net primary productivity (i.e., resource availability) favor logistical mobility patterns whereas higher change rates and more patchy resource distributions result in a tendency toward residential mobility strategies. We present the results of that study and discuss how our simulation framework can be used to analyze such a research hypothesis.

O-4137

## Modeling ancient cannibals as optimal foragers

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### Abstract

Cannibalism is a practice documented in several hominin species since the Early Pleistocene. However, the causes and meaning of consuming other humans are still hotly debated. The reasons proposed to explain this behaviour range from social and cultural motivations to purely nutritional causes. Behavioural Ecology provides a theoretical framework to understand human behaviour based on the assumption that humans, like any other animal, act to increase their reproductive fitness. In that theoretical framework, the Optimal Foraging Theory (OFT, Pyke et al., 1977) establishes that foragers confronted by a number of options adopt the strategy that maximizes their fitness and that this is equivalent to maximize nutrient return and minimize acquisition cost. We show here how cannibalism may be understood in the context of the OFT taking as an example the oldest case of cannibalism registered in the archaeological record.

The remains of seven hominins (*Homo antecessor*) with unquestionable signs of cannibalism were found in the TD6.2 unit of the Gran Dolina site (Sierra de Atapuerca, Spain), dated to c. 0.9 Ma. The TD6.2 fossil assemblage also includes a large collection of fossils of other 16 species of large mammals, and nine of them show cut marks and other evidence of human consumption. We apply a Prey Choice model based on MacArthur and Pianka's (1966) diet breadth model to the TD6.2 assemblage to evaluate whether *Homo antecessor* behaved as an optimal forager and selected its food resources according to their energetic return rate, as predicted by the model. Analyzed in this way, humans appear as a high-ranked prey type, i.e. a prey which produces a high energetic return at a low cost. Moreover, the abundance of the different prey types in the TD6.2 assemblage is proportional to the abundance of those resources in the environment (their estimated population densities), as predicted by the OFT. Thus, cannibalism in *Homo antecessor* may be explained just because *H. antecessor* behaved as an optimal forager and humans were a high ranked resource type.

However, although it is an optimal behaviour to obtain energy, cannibalism is not an optimal strategy to increase reproductive fitness if it is practice as a habit. Other humans are also potential sexual mates and necessary allies to warrant survival. Thus, OFT allows us to explain why anthropophagy is present in many ancient human societies, but behavioural ecology also explains why cannibalism cannot be a dominant practice.

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**O-4138**

## **Featuring hominins as actors in the MPR scenarios**

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### **Abstract**

The Mid-Pleistocene Revolution (MPR) was a period of profound ecosystem reconfiguration around 1 Ma. It is generally accepted that those environmental changes affected the survival opportunities and the distribution patterns of humans in Europe. Modeling the behavioural responses of humans to the changing environments of the MPR entails the energetic characterization of hominins. By “energetic characterization” we mean that it is necessary to infer their daily energetic requirements as well as their energetic expenditure.

The energetic requirements of a hominin are determined by its palaeophysiology, and they are mainly affected by the species body size, but also vary with age, sex and physiological stage. However, palaeophysiology also affects the energetic cost of the daily activities necessary to survive and reproduce. The energetic requirements of ancient hominins may be estimated by extrapolation of the predictive equations experimentally developed for recent humans and based on body size, age and sex.

Concerning the cost of daily activities, however, a specific research program on experimental energetics is required. That experimental program should involve the re-enactment of the basic daily activities of a hunter-gatherer in a number of volunteers to measure their energetic cost and to identify the possible influence of body composition and architecture on the energetic expenditure. Eventually, those experimental data may be extrapolated to ancient hominins. Such an experimental research program is currently under development at CENIEH. The activities recreated up to date include the catchment of raw materials (Vidal-Cordasco et al. 2017a), gathering of vegetable resources (Prado-Nóvoa et al, 2017a), and stone knapping (Mateos et al. 2018). Other experimental studies were carried out to estimate the cost of walking and burden transport during foraging activities (Vidal-Cordasco et al, 2017b). Additional research, currently under development, include the energetic expenditure of butchering animal carcasses and digging in search of underground plant resources, as well as further experiments on locomotion. All these experiments are performed by individuals of different ages (adults, adolescents and children), both genders and in different reproductive stages (e. g. pregnant and lactating women), since all those factors affect energetic expenditure. The objective of this ambitious research program is to establish the daily energetic expenditure profile of any individual in a hunter-gatherer population as a function of its age, sex and physiological stage.

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O-4139

## Evolutionary response of early human behavior during the Mid-Pleistocene Transition in East Asia

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### Abstract

Mid-Pleistocene climate transition (MPT), occurring at ca. 1.25–0.8 Ma<sup>1-3</sup>, is an important stage of Quaternary period. After MPT, into the Middle Pleistocene, the length and intensity of the glacial-interglacial cycles significantly increased, with the dominant periodicity of high-latitude climate oscillations changing from 41 ka to 100 ka<sup>1-3</sup>. During the MPT, a series of changes documented in the archaeological records as well, such as the density of the artifacts and the technique innovations changed dramatically from the beginning to the end of the MPT.

Recent years, a series of archaeological researches, revealed several important sites and provide a comprehensive understanding of the cognitive ability of early humans East Asia<sup>4-6</sup>. In North China, a sample of the Nihewan sites will be selected in order to assess the cognitive ability of early humans. For example, the Cenjiawan site, with a relative high refitting rate of stone artefacts (33.4 %, 462 pieces in 1383), can be used to reconstruct knapping sequences, which in turn allows evaluation of planning depth<sup>4</sup>. The Donggutuo site, with a high percentage of retouched pieces (10.2%), can also be used to learn about tool production skills of early hominins<sup>5</sup>. In Central and South China, Yunxian Man site and sites in Bose Basin give good examples to evaluate the cognitive ability of early human populations. The Large-cutting-tools (LCT) of Bose Basin represent a target morphology and increasing LCT refinement<sup>6</sup>.

The MPT should be a key period tied directly to the archaeological records, and a series of questions should be highlighted, including assessment of how early hominins adapted and survived in changing environments of East Asia; whether early humans innovated their technologies and landscape behaviors over MPT.

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O-4140

## Testing palaeoclimate reconstructions for the Acheulean in southern Africa using climate models

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### Abstract

Recent palaeoenvironmental reconstructions at the archaeological significant site of Wonderwerk Cave, in the interior of South Africa, revealed a significantly wetter environment and non-analogous vegetation structure in the Early Pleistocene. This includes the presence of grasses following the C<sub>3</sub> and the C<sub>4</sub> photosynthetic pathway, whereas after the mid-Pleistocene transition C<sub>3</sub> grasses are declining<sup>1</sup>. They are not a part of the local vegetation during the Holocene at all. This contribution is exploring the drivers behind such a shift in vegetation using a vegetation model (LPX) driven by General Circulation Model (GCM) climate reconstructions. We modelled vegetation for glacial climates under different levels of CO<sub>2</sub> to test if a change to lower CO<sub>2</sub> levels at c. 800ka led to the spread of C<sub>4</sub> grasses at the expense of C<sub>3</sub> grasses due to more severe stress. The largest change was observed between 150ppm and 250ppm CO<sub>2</sub>. Our results confirm the trends observed in the palaeoenvironmental studies for the southern Kalahari region. Other areas of eastern South Africa and East Africa, which already have a substantial C<sub>4</sub> grass component before the mid-Pleistocene revolution, are less effected. This has implications for hominin responses during the later phase of the Early Stone Age as seen in the rich Acheulean cultural record of the Wonderwerk Cave region, which contrasts with a much sparser late Pleistocene record.

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**O-4141**

## **Past glacier fluctuations in the Rwenzori Mountains, Uganda, and implications for tropical temperature during and since the last ice age**

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### **Abstract**

The tropics comprise nearly half the Earth's surface and are the primary source of latent heat and water vapor to the global atmosphere. Through phenomena such as the El Niño Southern Oscillation, the region is also the dominant control on modern interannual climate variability. The tropics today are undergoing rapid change; high-altitude regions are warming at a rate nearly twice the global average. Determining how the tropics will respond to future warming is fundamental to projecting accurately the impacts of global climate change, and has direct ramifications for the billions who live in low-latitude regions. One approach to assessing the likely impact of the tropics in future climate scenarios is to establish their role in previous climate transitions using proxy records of past temperature. Tropical glaciers are particularly sensitive to changes in temperature and thus make excellent paleo-thermometers. Determining the timing and magnitude of past changes in tropical glacier extent therefore provides a window into past temperature in the low latitudes. The equatorial Rwenzori Mountains, Uganda, represent the most extensive alpine-glacier environment in Africa. We use beryllium-10 surface-exposure dating to determine a chronology of glacier fluctuations in the Rwenzori during and since the Last Glacial Maximum (~30 ka to present), the most detailed such chronology from Africa. We also compare these results to similar chronologies produced from the South American tropics. Our results indicate that glaciers across the tropics, both in Africa and the low-latitude Andes, fluctuated in unison during and following the last ice age. This pattern indicates that tropical glaciers responded to a common forcing mechanism over this time, most likely temperature. The apparent synchrony of temperature change in the low latitudes over the last ~30 ka has direct implications for the roll of greenhouse gases and high-latitude ice-sheet and sea-ice dynamics in setting tropical, and global, temperature over millennial timescales.

**O-4142**

## **Diatomite evidence for a southern African late Quaternary palaeolake at 3,400m.asl**

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### **Abstract**

The eastern Lesotho highlands is commonly termed the 'water tower' of southern Africa. The region experiences a mean annual rainfall of >1,600mm, and supplies the South African highveld with water via the Lesotho Highlands Water Project. Unique for a region with such abundant moisture availability, is the absence of natural lakes. Mafadi Summit hosts the highest altitude wetland in southern Africa, located at the bottom of a bowl-shaped depression at 3,480 m.asl. Palaeoenvironmental reconstructions for the site, based on pollen, diatoms and sedimentary properties, reveal considerable fluctuations in hydrology and the spatial extent of this wetland. For example, diatom and pollen records suggest that the depression was occupied by standing water about 8,400-8,000 cal yr BP. However, upslope of this wetland are a number of notable diatomite outcrops at varying elevations. These are hypothesised to represent palaeo-water levels, and if this is correct, reveal a substantial palaeolake at the site which would likely date to the Last Glacial Maximum, when regional moisture levels were heightened. Here we report on satellite remote sensing of the diatomite deposits, and diatom analysis from two sediment cores extracted from these diatomite outcrops. The primary aims are to determine the age and spatial extent of the diatomite outcrops, and the depth of the standing surface waters, which may uncover the first definitive lake in the eastern Lesotho Highlands. This record also contributes to the paucity of palaeoclimatic records for the Maloti-Drakensberg.

O-4143

## A data base of hydroclimate-driven lake-level variability in eastern and southern Africa throughout the late Pleistocene and Holocene

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### Abstract

Our understanding of African hydroclimate dynamics on time scales longer than a few decades is largely dependent on natural climate archives. While still at least an order of magnitude lower than in the northern temperate zone, central and southern Africa have seen a substantial increase in the number of published paleoclimate reconstructions in recent decades, many of which have been extracted from (paleo-) lake deposits. Arguably the most universal relationship between climate and a lake ecosystem, especially in endorheic basins, is the control of the precipitation-evaporation balance (P-E) on lake volume (itself a function of lake depth and surface area). We present a research data base of published information on lake depth ('lake status') of more than 50 (paleo-) lake sites in eastern and southern Africa over the last 50,000 years. This data base provides a tool for assessing hydroclimatic changes at multiple time scales which can be compared to other syntheses of ecosystem change or to paleoclimate modelling products. Importantly, the inclusion of details on chronological and proxy support for each individual site allows a necessary quality control of the available paleolimnological evidence. Using the data base, we elucidate and discuss spatio-temporal patterns of hydroclimate change in eastern and southern Africa during globally recognized decade- to millennium-scale events. A first focus is the deglaciation, during which a sequence of events (Heinrich Stadial 1, Younger Dryas) brought severe hydroclimate disruption to much of the African continent. A second focus is the last millennium, for which the spatial patterns of wetness and drought throughout equatorial East Africa are examined more deeply, illustrating the complicated hydroclimatic variability that strongly impacts the region's ecosystems on time scales relevant to human societies.

**O-4144**

**A multiproxy record of Meghalayan change from a paleommarsh at the southern margin of the Kalahari.**

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**Abstract**

In this study we investigate the timing and nature of relatively wet conditions in the late Holocene by examining a multiproxy paleoenvironmental record from Kathu Pan, a paleommarsh located at the southern edge of the dry Kalahari region. In a region where organic proxy records are scarce, Kathu Pan provides a unique record of changes in past environmental conditions. Pollen, spore, charcoal, and stable isotope records were obtained from organic deposits from Kathu Pan and examined within a radiocarbon-constrained chronological framework. Kathu Pan records register a wet phase occurring between 4.8 ka and 2.5 ka cal BP. Local environmental conditions at Kathu Pan shift gradually starting around terminal Northgrippian ~4.8 ka cal BP. With the beginning of the Meghalayan Stage (~4.2 ka cal BP), Kathu Pan reaches peak values for positive moisture balance indicating local marsh conditions; these changes are marked by increased organic content, dominance of Cyperaceae pollen, presence of freshwater fungi, and  $\delta^{13}\text{C}$  values consistent with C3 vegetation. The wet phase lasts ca. 2000 years until an abrupt shift to arid conditions occurs c. 2.5 ka cal BP leading to a change in local hydro-climate that effectively terminates the accumulation of organic matter.

O-4145

## Desert lakes in the late Quaternary: Hydroclimate variability in the southern African interior.

Sallie Burrough<sup>1</sup>, Joy Singarayer<sup>2</sup>, Charlie Williams<sup>3</sup>, Martin Hipondoka<sup>4</sup>, Rob Bryant<sup>5</sup>, Frank Eckardt<sup>6</sup>

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### Abstract

Despite a long history of investigation, late Quaternary hydroclimate of southern Africa's dry interior, remains poorly understood. This is due in part to a lack of robust palaeo-archives, and in part to the complexity of local hydrological & ecological responses to climate change. An increasing suite of climate model simulations suggest a wetter than present Last Glacial Maximum and a drier than present mid-Holocene "African Arid Period" in the interior of southern Africa. In addition, there appears to be distinct sub-continental spatial variability of rainfall patterns governed by the differing behaviour of the tropical rainbelt over continental and coastal regions. In some cases, model data suggest large catchments, such as that of the Makgadikgadi basin, may integrate these differing spatial patterns of rainfall in their basin response adding a level of complexity to regional palaeoenvironmental records. Major hydrological change is predicted at a number of scales including on a ~20 kyr precessional cycle and a high-amplitude response to millennial/submillennial-scale forcing at high latitudes. Using available palaeo-hydrological-records, we test these model driven hypotheses and attempt to shed light on southern Africa's elusive hydroclimate history.

O-4146

## Enhanced Mediterranean water cycle explains increased humidity during MIS 3 in North Africa

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### Abstract

We report a new fluid inclusion dataset from Northeast Libyan speleothem SC-06-01, which is the largest speleothem fluid inclusion dataset for North Africa to date. The stalagmite was sampled in Susah cave, a low altitude coastal site, in Cyrenaica, on the northern slope of the Jebel Al-Akhdar. Speleothem fluid inclusions from latest Marine Isotope Stage (MIS) 4 and throughout MIS 3 (~67 to ~30kaBP) confirm the hypothesis that past humid periods in this region reflect westerly rainfall advected through the Atlantic storm track. However, most of this moisture was sourced from the Western Mediterranean, with little direct admixture of water evaporated from the Atlantic. Moreover, we identify a second moisture source likely associated with enhanced convective rainfall within the Eastern Mediterranean. The relative importance of the western and eastern moisture sources seems to differ between the humid phases recorded in SC-06-01. During humid phases forced by precession, fluid inclusions record compositions consistent with both sources, but the 52.5–50.5ka interval forced by obliquity reveals only a western source. This is a key result, showing that although the amount of atmospheric moisture advections changes, the structure of the atmospheric circulation over the Mediterranean does not fundamentally change during orbital cycles. Consequently, an arid belt must have been retained between the Intertropical Convergence Zone and the mid-latitude winter storm corridor during MIS 3 pluvials.

**O-4148**

## **How Bayesian modelling can revolutionise the science behind past climate change**

Andrew Parnell, Niamh Cahill  
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### **Abstract**

Climate scientists are famous for their poor use and understanding of statistical approaches. In this talk I will discuss some of the common problems in the statistical reconstruction of past climate and point out how Bayesian inference can partly solve some of these challenges. Examples will be provided from the reconstruction of past climate from pollen proxies and the estimation of past and present sea level rise.

O-4149

## Combining a proxy synthesis and climate simulations for spatial reconstructions of European climate using Bayesian filtering

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### Abstract

Probabilistic spatial reconstructions of past climate states are valuable to quantitatively study the climate system under different forcing conditions because they combine the information contained in a proxy synthesis in a comprehensible product. Unfortunately, they are subject to a complex uncertainty structure due to complicated proxy-climate relations and sparse data, which makes interpolation between samples difficult. Bayesian statistics features promising properties to handle these issues like the possibility to include multiple sources of information and to quantify uncertainties in a statistically rigorous way.

We present a Bayesian filtering framework that combines a network of pollen and macrofossil samples with a spatial prior distribution estimated from a multi-model ensemble of climate simulations. Different formulations of the prior distribution, which are motivated by data assimilation and postprocessing literature, are compared. To transfer the vegetation data into (local) climate information, we apply a forward version of the probabilistic indicator taxa model. The Bayesian inference is performed using Markov chain Monte Carlo methods.

Mean temperature of the warmest and coldest month in Europe during the mid-Holocene are reconstructed using a published pollen and macrofossil synthesis in combination with the PMIP3 mid-Holocene ensemble. The performance of the different prior distribution formulations are assessed using identical twin and cross-validation experiments. Our framework is flexible and extensions like including additional proxy types and extended paleosimulation ensembles can be envisaged.

O-4150

## Searching for the deglaciation: sampling spatio-temporal climate uncertainty for simulating ice sheet evolution

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### Abstract

Ice sheet models fail to reproduce reconstructed patterns of Northern Hemisphere ice sheet retreat through the last deglaciation (21,000-6,000 years ago) without tuning of the climate input. This is the main barrier to understanding the role of ice sheets in past abrupt climate and sea level changes. The primary reason for this failure, is the large uncertainty in past climate change, which cannot be tackled by conventional uncertainty quantification methods because of the complexity, multidimensionality and large volume of climate data.

We developed a novel statistical method at the cutting edge of machine learning to systematically explore the uncertainty in the temporal and spatial evolution of temperature through the last deglaciation. It combines output from transient General Circulation Model (GCM) simulations of the last 21,000 years (from the FAMOUS and CCSM3 climate models) with proxy records of surface temperature changes. The method consists of decomposing the pattern of variability through time and space within the ensemble of transient climate simulations. Bayesian statistical methods were used to combine these patterns of variability to generate thousands of time-evolving climate fields that match reconstructed temperatures within their envelopes of uncertainty. We used this ensemble of plausible deglacial climates to drive 1500 simulations of the North American ice sheet evolution 21,000-6,000 years ago, where climate and ice sheet parameters were simultaneously varied. We designed a metric to assess how well the results match the reconstructed evolution of ice sheet extent (Dyke, 2004) and ice volume. Three waves of simulations were run, refining the uncertain climate inputs and ice sheet parameters after each wave to find simulations that best matched reconstructed ice sheet evolution. A subset of the best simulations shows that ice extent is well simulated at the last glacial maximum (21,000 years ago). Some errors occur in the pattern of ice retreat in the interior of the continent, calling for further refinements of this innovative method and more climate model and observational data (currently being generated internationally).

Our work demonstrates how observations and models of climate and ice sheets can be combined within a Bayesian statistical framework to better understand the co-evolution of climate and ice sheets in the past. This approach of running ensembles of simulations is crucial for understanding the response of ice sheets to past climate changes and the potential triggering of ice sheet instabilities, which lead to rapid sea level changes.

O-4151

## Quantifying the Information Content of Relative Sea-level and Geodetic Data for Constraint on North American GIA Models

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### Abstract

The data required for making substantive improvements to glacial isostatic adjustment (GIA) models over the North American continent and environs are now available. New data include the traditional relative sea-level (RSL) records of the last glacial cycle, enriched in value by expansions in spatial and temporal coverage, and those derived from modern geodesy, including spaceborne gravimetry and land motion recorded by GPS stations. Recent analysis of the latter by Kreemer et al. (2018) reveal that an untapped source of potential GIA constraint may emerge by examining the horizontal velocities and strain rate field, both in model and data representations. Using Bayesian statistics and concepts derived from information theory, we analyze results from an ensemble of thousands of forward GIA models. From the resulting statistics we are able to characterize, quantify and intercompare the information content provided by each subset of data for constraining GIA. There is great value in isolating each of the subsets of RSL, vertical and horizontal GPS velocity fields (and horizontal strain rates) as such illuminations provide information for planning additional field work at remote shorelines and potentially viable new geodetic sites.

We consider variations of ice history, through a set of scaling coefficients, as well as the mantle viscosity profile. Our goal is to estimate the relative gain in model confidence that each dataset provides for better constraining mantle structure and ice history input parameters, the range of common solutions between all datasets as well as the redundancy of information between them.

O-4152

## Estimating global sea level over the late Holocene using a spatio-temporal empirical Bayesian hierarchical framework

Erica Ashe<sup>1</sup>, Nicole Khan<sup>2,3</sup>, Benjamin Horton<sup>2</sup>, Robert Kopp<sup>1</sup>

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### Abstract

Many global, regional and local-scale processes affect relative sea-level (RSL) change across the globe, and constraining the magnitude of these contributions, their variability, and the recent effect of climate in the past can give insight into future sea-level rise. To our knowledge, no global sea-level (GSL) change estimates, based on the statistical synthesis of a global database extend back over the last ~4,000 years. The increasing availability and geographical coverage of continuous, high-resolution RSL reconstructions provides a new opportunity to formally estimate GSL in relation to climate and quantify the contributions to RSL change over this time period.

Using the semiempirical, hierarchical model of Kopp et al. (2016; K16), we re-asses the relationship between temperature and GSL variability over the late Holocene (past ~4000 years). We have compiled a global atlas of late Holocene sea-level index points from near, intermediate and far field sites. The atlas consists of over 6,000 sea-level index points, which show relative sea-level (RSL) varied between > 50 m and < -8 m over the past 4000 years. We apply the K16 model to the atlas and compare the results to the temperature reconstruction of Marcott et al., 2013.

This statistical model deconstructs RSL, quantifying contributions from global, regional linear, regional non-linear, and local-scale processes using a spatio-temporal empirical Bayesian hierarchical framework with prior distributions defined by various glacial isostatic adjustment (GIA) models. We assess the sensitivity of the model to these priors as well as to the information gain from potential new data at various times and spatial locations. We produce a GMSL estimate for the last 4000 years, compare it to global temperature time series, and place the current rates of GSL rise in the context of the recent geologic past.

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**O-4153**

## **Bayesian improvements to $^{210}\text{Pb}$ dating**

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### **Abstract**

Dating with  $^{210}\text{Pb}$  has been instrumental in providing chronologies for sedimentary deposits back to around 100-150 years ago — a key period to understanding recent human and environmental dynamics yet where  $^{14}\text{C}$  dating is often problematic owing to major wiggles in the  $^{14}\text{C}$  calibration curve. Currently popular  $^{210}\text{Pb}$  age-models such as the Constant Rate of Supply (CRS) or Constant Initial Concentration (CIC) are incapable of including alternative types of dating information, and are often in disagreement with other dating information.

Through simulations of sediment accumulation, we highlight these and other problems of the CRS and CIC models, such as the underestimation of age uncertainties, the dependence on correctly estimating a core's entire  $^{210}\text{Pb}$  inventory, and issues with separating supported from unsupported  $^{210}\text{Pb}$ .

We present a Bayesian age-modelling approach (Aquino et al. 2018) that solves the above problems, and show how our method can include other types of dating information such as from  $^{137}\text{Cs}$  or radiocarbon, produce more reliable uncertainty estimates, and extend  $^{210}\text{Pb}$  chronologies decades further back in time than currently possible.

### Reference

Aquino Lopez, M.A., Blaauw, M., Christen, J.A., Sanderson, N., 2018. Bayesian analysis of  $^{210}\text{Pb}$  dating. *Journal of Agricultural, Biological, and Environmental Statistics* 23, 317-333 (Open Access)

O-4155

## Sociocultural trends and innovations over 13,000 years of plant use in the Atacama Desert, Chile.

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### Abstract

Throughout the most extreme environments on Earth, such as the Kalahari Desert or the Arctic, hunter-gatherer populations found resourceful ways to acquire dietary requirements provided by plant consumption (fibers, vitamins and minerals). Here, we demonstrate that something similar occurred in the Atacama Desert, arguably the driest place in the world, where wild plants are scarce and unevenly distributed across distinct eco-geographical zones. We assembled available archaeobotanical data from sites dating back from the initial regional colonization (ca. 13,000 cal yrs BP) until the Inka times (ca. 450 cal yrs BP) to generate the most exhaustive database for the long-term exploitation of plants in the Atacama. Our sequential analysis shows that both mobile hunter-gatherer and agro-sedentary populations not only acquired and managed plant resources from different regional eco-geographical zones (coastal, intermediate and high Andean regions), but also from distant regions (>600 km) such as trans-Andean tropical forest ecosystems. Indeed, from very early on in the cultural sequence, the Atacama's people established long-distance interaction routes for accessing a diverse array of plant resources. Several cultivars (e.g. *Capsicum* sp., *Chenopodium quinoa*, *Ipomoea batatas*, *Lagenaria siceraria*, *Manihot esculenta*, and *Zea mays*) started to appear in the region by the Late Archaic (6,000-3,700 cal. yrs BP). The consolidation of a wide range of farming crops took place during the regional Formative period (3,700-1,500 cal yrs BP), now including *Amaranthus* sp., *Arachys hypogaea*, *Cucurbita maxima* and *C. moschata*, *Erythroxylum* sp., *Phaseolus* spp., *Solanum* spp., as well Leguminosae trees (*Prosopis* and *Geoffroea decorticans*). All crops recorded in the Atacama were seemingly introduced from other Andean regions or even Mesoamerica, rather than locally domesticated. Albeit the irrigated-agriculture was progressively adopted, it came to complement hunter-gathering strategies as the use and management of wild resources did no cease (i.e. Cyperaceae, Cactaceae, *Tessaria*). By contrasting the trends of plant utilization with socio-cultural changes, paleodemographic and climatic fluctuations, we show that the "Green Revolution" of the Formative period coincides with an exponential increase in the number of social groups inhabiting the Atacama Desert, as well as with the transformative process that characterizes most of the spheres of these communities. The cultivation of this set of edible plants persisted even under the rule of centralized societies such the Inka, implying that for them, agricultural transformations were more related to the intensification of the production of target crops instead of innovating with new cultigens. Even today, the plant-based part of our diets heavily relies in many of these cultivars, particularly maize, squash, gourd, and beans. This means that a relevant part of our life can be traced back to at least 3,000 years ago, to the times of the "Green Revolution".

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O-4156

## Living in Andean dead ends: human-environmental interactions at the fringes of the Northern Ice Field.

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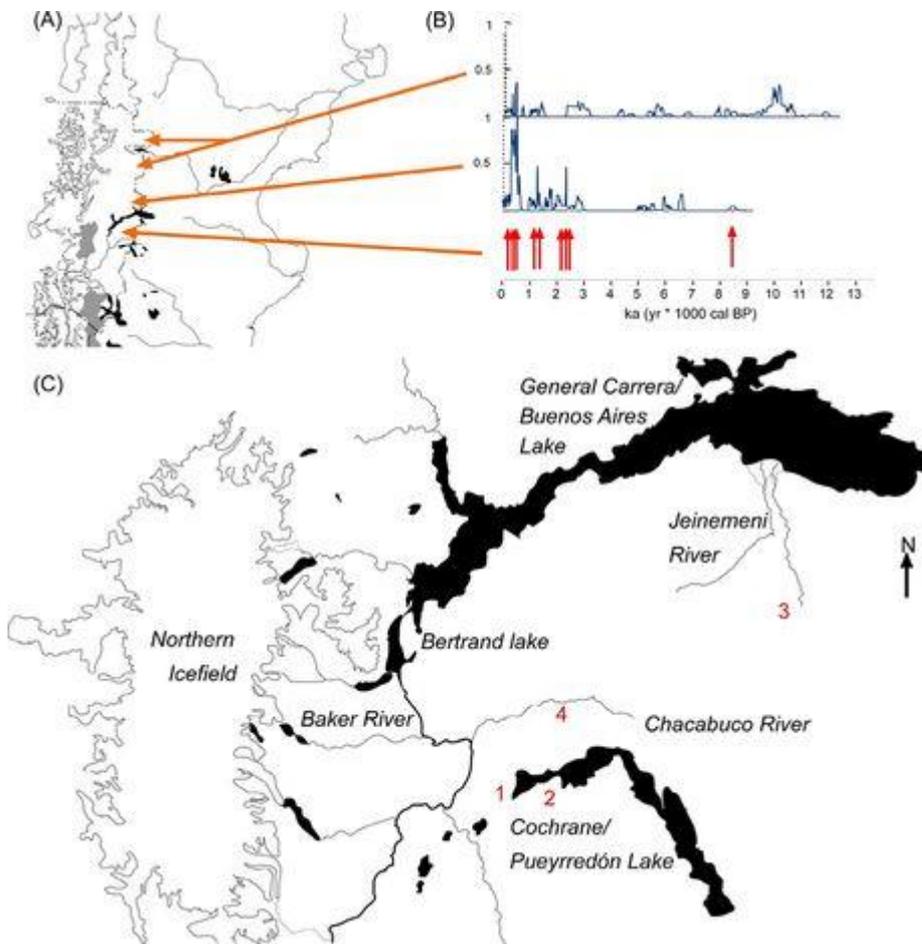
### Abstract

Andean dead ends in Central Western Patagonia (CWP) represent ideal landscapes to address the differential role of hunter-gatherer occupations and human/environment interactions, yet they remain understudied. As marginally occupied areas, these are highly sensitive to changes in mobility and land use, and thus informative of human processes occurring at broader spatial scales. The sector bounded by the General Carrera/Buenos Aires (GCBA) and Cochrane/Pueyrredón (CP) lakes, the Baker River (BR) and the Northern Ice field (NIF) stands as a remarkable example of dead end. Our goal is to study human/environmental interactions by combining archaeological (occupational redundancy, variability in technology and subsistence, and changes in mobility) and paleoenvironmental (pollen, charcoal) records.

Paleoenvironmental records based on pollen records located within the forest do not show major changes particularly during the Holocene due to the over-representation of *Nothofagus* pollen. However, those located at the forest-steppe ecotone further north (44.5°S; Lago Shaman and Mallín El Embudo) show the gradual development of the forest after 14ka peaking between 8-5ka as a response to higher humidity and unmarked seasonality, while the late Holocene was characterized by highly variable conditions. At 47°S, the pollen record of Mallín La Frontera, also in the forest-steppe ecotone, shows an initial amelioration in environmental conditions after ca. 8.2ka followed by a reversal to colder conditions between ca. 7.4-6.5 ka followed by variable climatic conditions up to 3.7ka. After 3.7ka and up to the present, a gradual shift to more stable and temperate conditions occurred. Mire pollen records within the forest at 47°S (Laguna Anónima and Mallín Casanova) show a decrease of forest pollen after 2ka.

The spatial characteristics of the area east of the NIF and the distribution of known archaeological sites suggests geographical barriers such as the GCBA and CP Lakes, as well as the BR, acted as bounds constraining mobility during the Holocene. The initial exploration of this area occurred ca. 8ka as indicated by the earliest records of Alero Entrada Baker and sites south of the CP Lakes. This occurred once these environments became attractive to populations of eastern steppes. Cave sites, however prone to accumulate anthropogenic sediments and artifacts, are characterized by temporal discontinuities, with limited periods of sustained human presence during the late Holocene.

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(A) Andean dead ends of CWP, (B) human radiocarbon chronology, (C) area east of the NIF and paleoenvironmental records (1) Laguna Maldonado, (2) Laguna Anónima, (3) Mallín La Frontera, (4) Augusta Lake.

O-4157

## A deep-time perspective for the human-environment interaction in the Atacama Desert

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### Abstract

The Atacama Desert encompasses contrasting arid bioclimates across the abrupt relief that rises up rapidly from the Pacific coast of South America to the high-elevation Altiplano. Albeit this rugged landscape imposes harsh living conditions for humans, this territory has been occupied since the early peopling of the Americas, allowing the establishment of different socio-economic systems (i.e. hunting-gathering, agriculture, industrialization). In this sense, an evolutionary study in deep-time for the human-environment interaction in the Atacama provides a meaningful perspective for exploring feedback mechanisms accounting for the long-term dynamic of socio-ecological systems in extreme environments. By means of integrating archeological and paleoenvironmental records for the inland Atacama Desert (18°-25°S), we discuss how social behaviours and biophysical systems have been reciprocally influenced during the past 14,000 years. This task involved the systematization of data for: 1) long-term paleodemographic trends, 2) technological production/innovations, 3) natural environmental variability, and 4) anthropogenic disturbances. We verify that the paleodemographic dynamic over the last 14,000 years was coupled to changes in the regional hydroclimate. Nevertheless, by adjusting/incorporating adaptative strategies or technologies, these societies could sustain continuous population growth and social wealth, even when relatively adverse climate conditions persisted at different timescales. Such progressive cultural changes improved their capacity for engineering regional ecosystems through time, particularly in productive environments such as wetlands or ravines. Indeed, activities maintained either by hunter-gatherers or agrarian societies around these areas, led to cumulative and pervasive impacts on different biophysical patterns including biodiversity, water storages, air-quality, nutrient cycling and land-use. Our results preclude the notion of pristine landscapes before the regional Industrialization (ca. 1850 AD), but more importantly, suggest that the recent socio-environmental history of the inland Atacama is the result of long-term processes that operated uninterruptedly since Pre-Columbian times. We evince several regimes shift and tipping points in the coevolution of the human-environment interaction (e.g Neolithization, Inca expansion, Spaniard colonization), all of which were conducive to scale up the anthropogenic impact on ecosystems. This implies that contemporary environmental issues represent an inevitable regime shift resulting from long-term positive feedback loops between socio-cultural and ecological inheritances.

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O-4158

## From hunter-gatherers to the Spanish conquest (3000 - 450 cal bp) assessing ecosystem regime shifts and anthropic impacts in central Chile

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### Abstract

The presence of human groups in a given ecosystem promotes complex interactions and feedbacks between cultural innovations and the social and natural systems they inhabit. Due to a low prehistoric population followed by a drastic increase in historical times, it is often assumed that the Mediterranean ecosystems of central Chile, which today dominates most of the country's production and economy, are classic examples of "natural" versus "anthropogenic" impacts during the late Holocene. A strong anthropic impact has indeed occurred since the Spanish colonization (450 b.p) onwards, with animal husbandry, ranching, farming and more recently forestry plantations among the activities most responsible. Archaeological studies in central Chile, however, have shown that the development of agricultural activities began c. 2000 cal yr BP. This would have been accompanied by an important demographic increase and intensification of resource use. Such an increase in human activity would have acted as major agents of change in these ecosystems which could predate by at least a thousand years previous assumptions regarding these impacts.

We present an approach to reconstructing the paleodemography of central Chile through the use of a summed probability distribution (SPD) of archaeological dates (integrating radiocarbon and thermoluminescence dates) that spans the last 3000 years. We compare our regional SPD to two lacustrine sedimentary records: Lago Vichuquén and Laguna El Piojo. The Vichuquén record reflects human activity in this easily accessed coastal basin since before the Spanish conquest, whereas the high-elevation Laguna El Piojo is difficult to reach and its climate precludes long-term settlements. Pulses of increased human activity beginning c. 2000 cal yr BP can be evidenced from increased local fire frequency (macro-carbon particles) and through biogeochemical indicators associated with shifts in nutrient cycles and sources ( $\delta^{15}\text{N}$ ,  $\delta^{13}\text{C}$  and C/N). These cultural and ecological landscape transformations are relevant for the long-term assessment of mediterranean ecosystems, as productive activities have only increased in magnitude and intensity in these regions over time.

O-4159

## Reconstructing Vegetation Changes in Response to Holocene Climatic Variability in East Turkana, Kenya.

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### Abstract

During the Holocene the East African region experienced rapid climatic events, driven principally by orbital forcing and the monsoon insolation. The most prominent event recorded is the African Humid Period (AHP) during the early Holocene (~10ka to 8ka). The mid Holocene (~8ka to 5ka) was characterised by rapid shifts between wetter and drier climates. Dry climates have so far been consistent since late Holocene to present. Archaeological evidence from the Holocene deposits, the Galana Boi, indicate changes in subsistence activities from hunting, gathering and fishing during the early Holocene wetter period, to pastoralism in the mid-late Holocene period. High mobility and resource exchange is also associated with drier climates.

Little is known about the vegetation structure and the response to changing climates. This paper presents phytolith data analysed from five Holocene sites occupied during different time periods: FxJj108 (~9.6ka-~6ka), FxJj27 (~9.3ka to ~4.2ka), Gajj4 (~4.2ka), FwJj25 (~4.2ka to ~1.34ka) and FwJj5 (~0.93ka). Although phytolith counts were low, especially grass short silica cells (GSSCs), it was possible to identify changes in vegetation structure/habitats and their temporal variation using both a general abundance approach and phytolith indices: aridity index (Iph) and tree density (D:P).

Our data show that Holocene vegetation structure was generally dominated by woodlands/ shrublands with some grasslands. However, early- and mid-Holocene assemblages had significant proportions of aquatic indicators: palms, sedges, sponge spicules and diatoms, which suggest the existence of riverine/riparian habitats with fresh/spring water resources and episodes of seasonally high humidity.

Late Holocene assemblages indicate grasslands dominated by Chloridoideae arid grasses that have persisted to present. Iph index shows high variation especially during the mid-Holocene period while the D:P indices have shown the tree cover was mostly moderately to highly dense, which resembles present day Sudanian vegetation structure (grassy woodlands/shublands). The results concur with previous studies, that Holocene climates were highly variable.

O-4160

## Human impacts on chironomid communities in Irish lakes across timescales

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### Abstract

Resolving human and climatic influences on lake sedimentary records is an ongoing challenge in palaeolimnology, especially in an Irish context where humans have had a substantial influence on the landscape since at least the mid-Holocene. This comparative study focuses on the interpretation of chironomid (non-biting midge) subfossils in lake sediment records in Ireland, where agriculture, and particularly pastoral farming, has been a predominant control on lake ecology since the transition to farm-based economies in the Early Neolithic ca. 3700 BCE. Due to their unique life history traits, chironomids are effective indicators of past environmental change. Chironomid communities are affected by a variety of inter-related environmental variables including temperature, lake water dissolved oxygen, benthic substrate and lake nutrient status, and disentangling the climate signal from direct human influences can be challenging.

This study integrates previously published and new records from the recent and distant past to investigate the utility and performance of chironomids as ecological indicators of land-use change through time. Chironomids are combined with lake sediment geochemistry ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$  and C:N), fossil pollen and other analyses to investigate the impacts of land-use change on lake ecology. Sediment records from seven lakes across Ireland were used to ascertain regional trends from prehistoric to modern time periods. Redundancy analysis (RDA) and partial RDAs showed that  $\delta^{15}\text{N}$  and non-arboreal pollen indicative of grassland/pasture (NAPP) were the predominant controlling factors of chironomid community compositional change during the Irish Neolithic (4000 - 2500 BCE) and Bronze Age (2500 - 750 BCE). Bronze Age farming had a considerably greater impact on all lake systems than Neolithic farming, as indicated by a higher proportion of eutrophic taxa and a geochemical signal consistent with increased erosion and nutrient inputs. Cultural eutrophication also led to the local extirpation of several oligotrophic chironomid taxa present in the natural pre-impacted lake systems. Relative impacts increase in the modern records, where threshold-style changes in lake ecology correspond to local and national-scale changes in land use practice, such as increased use of fertilisers and agricultural intensification. Correspondence Analysis (CA) with modern inter-lake and intra-lake chironomid surface samples shows that Irish lakes typically reach 'modern' conditions ranging from the late Medieval (1150 - 1550 CE) to the mid-20<sup>th</sup> century.

Within this context of impacted Irish landscapes, we review attempts at Irish summer temperature reconstructions for both the distant and recent past. Strategies for rectifying the climate and cultural eutrophication signals in Irish lakes are explored. We conclude with recommendations for integrating multi-proxy indicators to more effectively disentangle chironomid-inferred temperature and eutrophication records from lakes within human-impacted landscapes.

O-4161

## Early human occupation during Late Pleistocene-Early Holocene transition in the highlands of the Southern Atacama Desert (24.5°S, Northern Chile)

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### Abstract

During the Late Pleistocene-Early Holocene an extensive humid event known as the Central Atacama Pluvial Event (CAPE II) characterized by increased rainfall on the western slope of the Andes resulted in higher lake levels above 4000masl and increased groundwater table levels, leading to the formation of extensive wetlands at ca. 3000 masl. A large number of early sites were found during this period (ca. 12.6-11 and 10.5-9.5ka) along the borders of the Imilac and Punta Negra high altitude basins (ca. 3000 masl). However, at the end of the early Holocene (8.5ka), humid environmental conditions turned into extreme arid ones, coinciding with the abandonment of the sites, once the favorable conditions and resources disappeared. However, little is known about the occupations in higher altitudes during the Late Pleistocene-Early Holocene even when the presence of several ravines that drain into both high altitude basins and therefore, could have facilitate an easy mobility between the highlands and the Imilac and Punta Negra basins. Recent surveys conducted in the heads and highlands of the ravines (Guaqueros, Zorras, Zorritas, Lullailloco, 3.900-4.200 masl) showed a high abundance of biotic resources (specially vicuñas and guanacos) and the presence of early sites in each of them. Among the recovered diagnostic elements, monofacial artifacts widely represented in the early occupations of Imilac and Punta Negra stand out, as well as triangular projectile tips, typical of early occupations at local and regional scales. However, there are large differences in the lithic raw materials since these would be rather local or belonging to other sources different from those located in the Punta Negra (basalt) and Imilac (calcedony). The sites correspond mostly to open-air camps located on fluvial terraces around dejection cones that may have been active during times of high humidity. To date, only one site corresponding to the mid Holocene has been recorded under a rockshelter located at the head of the Lullailloco ravine. Palaeoenvironmental evidence from highlands including fossil rodent middens records and palaeowetlands deposits into the ravines support the climatic scenarios of the Late Pleistocene-early Holocene at the local scale and provided a clear idea of landscape and depositional environments evolution from the early occupation stages to the final abandonment during the mid-Holocene. FONDECYT #1181627

O-4162

## Implications of climate variability in Patagonia and Tierra del Fuego for the interpretation of paleo-climate records

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### Abstract

Patagonia and Tierra del Fuego provide a unique natural laboratory to explore climate, climate variability, and climate history of the mid to high latitudes of the Southern Hemisphere. Actually, the *cono sur* of South America forms the only relevant land mass at these latitudes, connecting Pacific and Atlantic Ocean through the Strait of Magellan, and exhibiting close links to climate variability at nearby Antarctic Peninsula. Highly relevant for our knowledge within the global climate system is the response of glaciers to climate forcing in the area as it is related to global sea level and regional climate feedbacks both for the past, the current transient climate, and future climate projections.

Since the turn of the century and based on groundbreaking earlier works a multitude of paleo-climate information has been established based on dendro-climatology, sediments, stalagmites, bore cores, from sediment stratigraphy, moraine mapping and through many other investigations. Glacier studies both empirical and based on modeling have revealed a multitude of information on glacier variability in recent decades. Despite these impressive advances in our understanding of climate variability and glacier response in past, present and future, considerable uncertainties and relevant knowledge gaps are existent. Many, especially the more remote areas of Patagonia and Tierra del Fuego remain, if not uncharted then nonetheless seriously understudied with only few study sites being explored in details, and only few established and still existing long-term monitoring sites. These limitations make it difficult to bring paleo-climate records into proper context regarding both, their temporal and spatial significance. Especially, tremendous climatic east-west and north-south gradients across and along the Andes mountain zone make it difficult to provide stringent and consistent interpretation of paleo-climate records from disjunctive locations.

The keynote lecture tries to bring together some of the more recent findings regarding climate and glacier modeling and climate characterization with relevance to paleo-climate record interpretation, and related to climate variability and glacier change in the late Holocene. Implications of inter-annual climate variability related to Antarctica (Southern Annular Mode) and tropical to sub-tropical forcing (El Niño Southern Oscillation) will be discussed related to both, the glacier mass balance and snow cover variability and the temporal patterns of weather types over Patagonia and Tierra del Fuego.

O-4163

## (A)synchronous Glacier margin variation: preliminary insights from south-western Islands of Chile

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### Abstract

Whilst a number of detailed geochronological records have been produced that constraint the horizontal and vertical dimension of the Patagonian Ice Sheet (PIS) during the last glacial period, all but two chronologies have been established at the former eastern terminating margins. The western portion of the PIS covered the hyper-humid terrestrial-marine transition area where glacier dynamics were probably very different from the semi-arid eastern terrestrial counterparts. Strong correlation exists ( $r=0.8$ ) between southern westerly wind strength and precipitation west of the Andean divide (Garreaud et al., 2013), making glacier chronologies from the PIS' former western terminating margin more suitable to answer question about local to hemispheric palaeoclimatic shifts during the Quaternary. In order to better understand glacier-climate interactions in southern Patagonia comprehensive chronologies of glacier expansion and recession across a range of longitudes and latitudes are needed. In this study, erratic boulder, bedrock and pebble samples were collected marking glacier extent and thickness at sites on the previously un-studied western-most Chilean Islands (52-55°S, 67-73°W). Cosmogenic surface exposure ages (<sup>10</sup>Be, <sup>26</sup>Al, <sup>36</sup>Cl) from these samples provide insight into the suitability of the geochronological approach as well as a first order understanding of latitudinal (a)synchronicity of glacier extension and thinning rates in the hyper-humid fjords of south-western Patagonia.

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O-4164

## The former Patagonian Ice Sheet at 45°S; Glacier-climate insights from the Ñirehuao glacier lobe

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### Abstract

We present a new geomorphic map, moraine chronology, and modeling results for a glacial valley in central Chilean Patagonia (45°S) representing the first detailed geomorphic study of the valley. The Ñirehuao lobe of the former Patagonian Ice Sheet left behind a series of moraines that allow us to reconstruct the timing and magnitude of climate changes during the last two glaciations in the area. Geomorphic mapping combined with field observation demonstrates that two glacial lobes coalesced during MIS 6, and potentially MIS 8, but were bifurcated by bedrock during MIS 2. We date the MIS 6 advance at  $154 \pm 9.8$  ka (mean and 1 sigma uncertainty; n=10; no outliers omitted) using precise <sup>10</sup>Be surface exposure dating of glacially deposited moraine boulders. We date the MIS 2 advance at  $23.9 \pm 2.6$  ka (mean and 1 sigma uncertainty; n=15; no outliers omitted). The youngest intact MIS 2 moraine has an exposure ages of ~21 ka and is fringed by ice margin channels and shorelines of a paleo proglacial lake. We apply the University of Maine Ice Sheet Model to estimate the temperature and precipitation departures necessary to allow the glacier to expand to the dated and mapped extents, and compare Ñirehuao model results with those from the southern tip of South America at the Strait of Magellan. Paired with prior work, we help define the timing of Patagonian glaciations during MIS 8, 6, 4 and 2. Establishment of such detailed glacier records and modeling studies for southern South America are necessary to test proposed mechanisms for Quaternary glacial cycles, and ultimately to help us understand variability in the global climate system.

O-4165

## Anatomy of climate reversals and changes in the Southern Westerly Winds during the Last Glacial Termination in northwestern Patagonia

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### Abstract

Paleoclimate records from the middle and high latitudes of the Southern Hemisphere have documented a (or several) climate reversal(s) during the Last Glacial Termination (T1: 17.8-11.7 ka, ka=1000 cal yr BP). Its (their) very existence, timing, direction, and geographic extent have been debated in the literature for decades, including the mechanisms involved in its (their) origin and propagation. Empirical and modeling studies have proposed that variations of the Southern Westerly Winds (SWW) were key drivers of climate changes through T1 at zonal, hemispheric and global scales. The timing, structure and geographic variability of paleoclimate signals through T1 in Patagonia, however, have not been studied in detail. Here we examine the vegetation and fire regimes before, during, and after the Antarctic Cold Reversal (ACR: 14.8-12.9 ka) and Younger Dryas (YD: 12.9-11.7 ka) chronozones, using multiple pollen and macroscopic charcoal records from small closed-basin lakes located along climatic gradients in northwestern Patagonia (NWP, 41°-43°S). Paleoclimate records from this region are relevant for documenting past changes in the SWW because local precipitation is strongly correlated with low-level wind velocities, affecting the modern vegetation, disturbance regimes and glacier mass balance along the western coast of southern South America. Palynological studies indicate that evergreen temperate rainforest expanded rapidly into the lowlands of NWP in response to warming and collapse of the Patagonian Ice Sheet at 17.8 ka. Vegetation changes ensued, including spread of the cold-tolerant hygrophilous conifer *Podocarpus nubigena* during the most recent half of T1.

We examined the chronology and relative magnitude of the *Podocarpus nubigena* signal in 19 NWP sites and observe the following: (i) all sites show very low abundance or absence before to the ACR (17.8-14.8 ka); (ii) all sites show significant increases during the ACR, the largest-magnitude increases are evident in the wettest sectors; (iii) the majority of sites (11) show steady declines during the YD; and (iv) all sites feature further declines and/or virtual disappearance during the early Holocene. We also observe that most sites show increases in fire activity during the YD and the early Holocene.

We conclude that a cold reversal took place between 14.8-11.7 ka in NWP with cold/wet conditions during the ACR and cold/dry conditions during the YD, brought by increased SWW influence and a subsequent decline, respectively. These results correspond in timing with readvances of Patagonian glaciers during the ACR and subsequent recession during YD time. We posit that the SWW were a fundamental link between the middle and high latitudes of the Southern Hemisphere during T1 and, according to some authors, the tropics and the Northern Hemisphere.

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**O-4166**

## **Glacier dynamics during a phase of Late Quaternary warming in Patagonia reconstructed from sediment-landform associations and surface exposure dating**

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### **Abstract**

The geomorphological record in glaciated landscapes can provide important information for the study of the response of glaciers to rapid climate change. This study presents a new reconstruction and chronology of the glacial history of the northern Monte San Lorenzo ice cap, southern South America during a period of accelerated warming and deglaciation (ca. 13.0-11.0 ka) following the Antarctic Cold Reversal. We use both remote sensing and field geomorphological mapping to produce a detailed geomorphological map of the valleys to the north of Monte San Lorenzo. Sediment-landform assemblages identified and mapped include lateral and terminal moraine ridges, flutes, deltas, ice-contact fans, palaeoshorelines, kame terraces and outwash plains. We map 14 primary ice limits, 7 newly identified, and 7 extended from previous studies. We devise landsystem models to formalise and document spatial and temporal changes in glacial process and environments. These show an evolution through glaciolacustrine to land-terminating, mountain valley and paraglacial landsystems, with local and regional topography, ice-dammed lakes and climate acting as key controls on landform and landsystem development. Newly acquired cosmogenic nuclide surface exposure ages of boulders found on moraine ridge crests, alongside recalculated and recalibrated ages from the published literature, allows us to develop a Bayesian age model from 4 ice limits to constrain rates of glacier recession. Combining this and further existing chronological data with detailed geomorphological mapping, we produce a spatial and temporal reconstruction of the northern ice margin of the Monte San Lorenzo ice cap during rapid deglaciation. Our work underpins a numerical model (PISM) of the ice cap, and provides an important insight into the response of temperate Patagonian glaciers to rapidly-warming climate.

O-4167

## Assessing the synchronicity of ice limits in Patagonia with new geochronological data from ~42 – 44 °S

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### Abstract

During the last glaciation, the north-south transect of Patagonia was influenced to varying extents by the Southern Westerlies, which supplied precipitation to the Patagonian Ice Sheet. The latitudinal transect of Patagonia can provide a natural laboratory to study past equatorial or poleward shifts in the position of the Southern Westerlies during the last glaciation, and the associated responses of the ice sheet to precipitation changes. Here we target the unstudied region 42°S to 44°S at the NE sector of the former Patagonian Ice Sheet (70-71°W) to assess whether ice limits in this region are in-phase with southern Patagonia. If the Southern Westerlies shifted towards the equator during the last glaciation, we could expect that the maximum extent and subsequent deglaciation in the northern region of the former Patagonian Ice Sheet was out-of-phase with the southern sector. Here we present new age constraints on multiple limits of ice lobes in the Epuen (42 °S), Esquel (43 °S) and Rio Pico (44 °S) valleys using luminescence and cosmogenic nuclide dating. There is excellent agreement between the cosmogenic nuclide ages for the moraine boulders and luminescence ages for the associated outwash plains. The new ages suggest that multiple ice limits are preserved between 42 - 44 °S and were deposited from ca. 27 to 17 ka. This is similar to ice limits in the Chilean Lake District (41-43 °S, 72-73°W; Denton et al. 1999), at Lago Buenos Aires (46 °S; Douglass et al. 2006; Kaplan et al. 2004; Smedley et al. 2016), Lago Pueyrredon (47 °S; Hein et al. 2010), the Strait of Magellan and Bahia Inútil (53 °S; Kaplan et al. 2010; McCulloch et al. 2005). Therefore, it is unlikely that latitudinal shifts in the Southern Westerlies caused asynchronous ice expansion across the north-south transect of Patagonia during the last glaciation. However, it is possible that the influence of the Southern Westerlies works on shorter timescales than the millennial-scale timescales studied here; thus, we require higher-resolution datasets to detect past changes in ice extent.

O-4168

## Extensive glacier advance in Patagonia during the Antarctic Cold Reversal

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### Abstract

Constraining the timing and spatial extent of millennial-scale climate events during the Late Glacial is crucial for deciphering the underlying drivers of climate change. Late Glacial ice marginal positions remain poorly constrained in central Patagonia, and palaeoecological proxies show equivocal evidence for the nature of climate change. Here, we present geomorphological mapping along with new <sup>10</sup>Be ages and optically stimulated luminescence (OSL) ages that constrain the timing of glacial advances and palaeolake development at Lago Belgrano (47.9°S) on the eastern side of the San Lorenzo massif. <sup>10</sup>Be ages from prominent arcuate moraines bounding Lago Belgrano reveal an extensive re-advance toward the end of the Antarctic Cold Reversal (ACR, ~ 14.5 – 12.9 ka). Subsequently, ice retreated rapidly to near its present day configuration during the northern hemisphere Younger Dryas (YD; ~12.9-11.7 ka). <sup>10</sup>Be ages from lateral moraines ca. 7 km from the present day glacier margin suggest a period of stabilization during the YD. This stabilization was brief on the basis of <sup>10</sup>Be dating of raised shorelines and OSL dating of glaciolacustrine sediments, which indicate an ice-dammed lake formed, and then drained during the YD. Our data provide firm evidence for extensive ice in central Patagonia until the end of the ACR and suggest close climate coupling of the southern mid-latitudes and Antarctica.

O-4169

## A comparative analysis of African Plio-Pleistocene patterns of environmental variability and biological evolutionary implications

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### Abstract

Environmental variability has been hypothesized to play an important role as a driver of evolution, specifically through its role as a selective agent towards adaptation to unpredictable environments. In particular, variability selection has been proposed as an important factor in the radiation and extinction of hominins in Africa. To date, most attempts to evaluate the variability selection hypothesis have examined correlations between evolutionary events and either theoretical drivers of variability, such as insolation, or single paleoenvironmental indicators with an eye towards identifying episodes of higher variability. Here we report on a meta-analysis of patterns of variability in 30 long (>400 kyr) and highly resolved paleoenvironmental records from on and around the African continent spanning the last 5.3 Ma. These records include published marine and lacustrine cores, as well as outcrop archives of sedimentological, geochemical and paleoecological change. Our analysis uses a new normalization metric (comparison of binned standard deviations in detrended z-score time series) to allow comparison of different types of data across the Plio-Pleistocene study interval. The variability mean time series is strongly correlated with available long SST records around Africa, the  $\delta^{18}\text{O}$  global marine stack and insolation, but not with  $\text{CO}_2$ . Consistent with prior studies (Potts and Faith, 2015), we observe a strong 400 kyr cyclicity in the variability means time series, strongly suggesting orbital forcing as an important driver of Neogene environmental variability in Africa. However, this cyclicity is superimposed on a long-term trend toward increasing variability throughout the last 3.5 Ma. Furthermore, major increases in variability predate the onset of significant Northern Hemisphere glaciation. Our findings suggest that if environmental variability selection during the Plio-Pleistocene in Africa has been an important evolutionary selective agent, then it is likely that those selective pressures have intensified through much of the course of human evolution.

Potts, R. and Faith, J.T., 2015, *Journal of Human Evol.* 87:5-20.

O-4170

## Climate change and early hominin evolution: is the fossil record of suitable quality to test climate-forcing hypotheses?

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### Abstract

In recent decades, a number of studies have compared Plio-Pleistocene palaeoclimate records with various aspects of the early hominin fossil record, including speciation, extinction and species diversity. When events within the palaeoclimatological and palaeontological domains are temporally coincident, a causal relationship is often assumed, and hypotheses are put forward to explain the possible evolutionary mechanisms for these relationships. Key to this approach is the assumption that the observed pattern of hominin speciation, extinction and diversity reflects genuine evolutionary processes. Alternative explanations for the observed macro-evolutionary patterns, such as uneven geological and anthropogenic sampling, must also be investigated.

We present a detailed examination of early hominin diversity dynamics through time, including both taxic and phylogenetically corrected diversity estimates. We also compare these estimates to sampling metrics for rock availability (hominin-, primate-, and mammal-bearing formations) and collection effort, in order to assess the geological and anthropogenic controls on the sampling of the early hominin fossil record. Taxic diversity, primate-bearing formations, and collection effort show strong positive correlations, raising the possibility that some features of hominin diversity may, in fact, represent systematic sampling biases, rather than a genuine evolutionary signal. We find no evidence of pulsed turnover in the early hominin fossil record or any link to climate proxies and, instead, argue that the appearance of pulsed change is an artefact of uneven sampling.

The results demonstrate that the hominin fossil record is currently characterised by highly uncertain stratigraphic ranges and inaccurate estimates of hominin diversity, influenced primarily by fluctuations in local and regional sampling intensity. It is clear that a far more complete hominin fossil record is required before hypotheses of climate forcing can be rigorously tested; in the meantime, inferences based on larger faunal or archaeological datasets may provide more reliable comparisons with discreet climatic events.

O-4171

## Environmental changes at the root of human origins: mammalian and pedogenic carbonate isotopic evidence for Mid-Pliocene Warm Period, Turkana Basin

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### Abstract

Evidence for tool making at the Lomekwi-3 archaeological site and C<sub>4</sub> dietary inputs between 4-3 Ma signal exploitation of open ecosystems prior to genus *Homo*. In the Turkana Basin (Kenya), the mixed C<sub>3</sub>-C<sub>4</sub> feeding *K. platytops* has significantly lower enamel carbonate d<sup>18</sup>O (EC) values than those of the C<sub>3</sub>-feeding *A. anamensis*, which may signal changes in water dependency, faunivory and/or habitat structure use. *Homo erectus* at the Oldowan site complex, Lokalalei-1 and 2C, shows the lowest d<sup>18</sup>O<sub>EC</sub> value of all Turkana hominins sampled to date and a mixed C<sub>3</sub>-C<sub>4</sub> diet. In this study we contextualize hominin diet shifts and technological innovations by comparing new and previously published pedogenic carbonate (PC) d<sup>13</sup>C and d<sup>18</sup>O values and mammalian d<sup>13</sup>C<sub>EC</sub> and d<sup>18</sup>O<sub>EC</sub> values collected in proximity to the Lomekwi-3 archaeological site (~3.3 Ma) to those of Kanapoi paleontological site (~4.1 Ma) and the Lokalalei archaeological site complex (~2.3 Ma) located in the western Turkana Basin. Mammalian taxa sampled include: Hippopotamidae, Elephantidae, Giraffidae, Rhinocerotidae, Alcelaphini, Aepycerotini, Homininae. We find comparable d<sup>13</sup>C<sub>PC</sub> values from all site environments; d<sup>13</sup>C<sub>EC</sub> values indicate that only hominins changed feeding category. Pedogenic carbonates and mammalian taxa, including hominins, show a ~2‰ shift in d<sup>18</sup>O<sub>PC/EC</sub> values between Kanapoi and Lomekwi-3, and return toward previous d<sup>18</sup>O<sub>PC/EC</sub> values at Lokalalei. Moreover, new factorial correspondence analysis based on abundance of specimens among bovid tribes and mesowear studies on the fossil mammal communities in the area from 3.97 to 2.53 Ma show a similar trend. These data are suggestive of a large-scale climatic change, potentially the Mid-Pliocene Warm Period.

**O-4172**

**U–Pb-dated flowstones restrict South African early hominin record to dry climate phases.**

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**Abstract**

The Cradle of Humankind (Cradle) in South Africa is home to a rich collection of early human (hominin) fossils, preserved in dolomite caves. Flowstones, horizontally bedded layers of calcium carbonate, are ubiquitous features at all the sites. The flowstone serve the dual purpose of providing ages for the fossiliferous sediments sandwiched between them (via uranium-lead dating) and as indicators of past climate regimes by their presence alone, being associated with increased effective precipitation. Massive flowstones of several meters thick are not uncommon and hint at prolonged periods of significantly increased precipitation. Uranium-lead (U-Pb) dating of cave carbonates has reached a level of maturity where it can be applied with ease and precision. Flowstones from eight caves across the Cradle have produced a total of twenty eight U-Pb ages. This represents the most comprehensive and direct chronology to date for these sites and associated early hominin fossils. The flowstone layers can be seen as analogous to the tuff layers in east Africa, which are used to both correlate and date the fossil bearing sediments. To solve the problem of necessarily large uncertainties on individual ages, a kernel density estimate is used to sum together the U-Pb age data into a single record of flowstone growth intervals (FGIs). This record spans from 3.2 to 1.3 million years ago, with six major FGIs identified, with flowstone forming in at least two caves during the same time interval. These intervals are interpreted as major wet phases, during which caves were most likely closed and not receiving sediments/bones from outside, allowing for massive flowstone development. The six interceding time windows are interpreted as drier phases, during which the fossiliferous sediments accumulated into open caves. This implies that the fossil record from these caves is highly punctuated, with much time unrecorded. This makes it impossible to falsify hypotheses of punctuated equilibrium and turnover pulses. The fossil bearing deposits also carry an inherent 'dry phase' bias, placing the hominins in a dry adapted fauna. The inability to observe behaviours during wet periods constrains our ability to evaluate hypotheses of hominin adaptation using the Cradle record. While the periods of cave closure leave temporal gaps in the South African fossil record, the flowstones themselves provide valuable insights into both local and pan-African climate variability.

O-4173

## Using multiple chronometers to establish a long, directly-dated lacustrine record: constraining >600,000 years of environmental change at Chew Bahir, Ethiopia

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### Abstract

There is much debate regarding the role of climate and environmental change in human evolution and dispersal. Despite eastern Africa being regarded as a key location in the story of the emergence of anatomically modern humans (AMH) and their subsequent dispersal out of Africa, there is a paucity of long, well-dated climate records in this region. To address this issue, duplicate deep-drill sediment cores were retrieved from the Chew Bahir basin in the south Ethiopian Rift, extending to 279 m and 266 m below the present sediment surface. Chew Bahir is located in a climatically sensitive region, lying between the boundaries of various influencing air masses and wind systems (i.e. the Intertropical Convergence Zone (ITCZ), the Congo Air Boundary, and the Indian Ocean monsoon). Critically, the site is also located close to the earliest eastern African AMH site of Omo Kibish, and close to the proposed dispersal routes for AMH out of Africa.

The climate and environmental history of Chew Bahir was reconstructed from a ~290 m composite core using various proxy datasets, including core-scanned XRF geochemical data, XRD mineralogy, MSCL logging, grain size analysis, biological proxies, and isotopic datasets (see other papers on Chew Bahir at this meeting). Key to these sensitive records of climate and environmental change is the establishment of a reliable chronology. The Chew Bahir sediments were directly-dated using multiple chronometers, including radiocarbon, argon-argon, and optically stimulated luminescence dating, combined with correlations to known-age tephtras. A Bayesian age-depth model was developed based on these ages. The resulting chronology forms one of the longest independently dated lacustrine sediment records from eastern Africa, spanning the entire timescale of modern human evolution and dispersal, and encompassing the transition from Acheulean to Middle Stone Age (MSA) technology, and subsequently to Later Stone Age (LSA) technology.

O-4174

## The 600,000-year palaeoenvironmental record from Chew Bahir, Ethiopia: testing hypotheses of climate change and human origins

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### Abstract

Most current hypotheses of climatic influence on human physical and cultural evolution focus on the role of climatic variability in selecting for behavioural flexibility and cognitive development. Those changes are thought to have allowed selected populations to expand geographically and exploit a wider range of habitats, prey and material resources. Similarly, abrupt climatic transitions may have caused differential survival among and within human populations, depending on their vulnerability to climatic extremes, with water resources being especially critical.

Located close to the Omo Kibish, site of the earliest known *Homo sapiens* fossils in east Africa, Chew Bahir, a playa lake in the south Ethiopian Rift, has yielded a 290 m-long core record that spans the last ~600,000 years. That time interval covers the entire history of modern human origins and dispersal, encompassing a number of significant behavioural innovations. With a high temporal resolution of up to tens of years, geochemical and biological indicators from the Chew Bahir core allow close examination of changing amplitude and frequency of past hydroclimatic variation and the rapidity of climatic change. By analysis of the core data across critical transitions in the archaeological record, we aim to show how the Chew Bahir record can contribute to a developing understanding of the consequences of climatic change for early human populations.

O-4175

## The paleoecology of 'Ubeidiya, Israel: results from a multi-proxy ecometric study and implication to early *Homo* adaptation in the Levant.

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### Abstract

The role played in human evolution by climate and its fluctuations has significant implications regarding the fundamental niche and behavioral plasticity of early *Homo* that ultimately led to out-of-Africa dispersal and global colonization. From an evolutionary perspective, the concordance of range boundaries and niche limits suggests that adaptation (or intraspecific evolution) is necessary for range expansion. At the same time, this implies that natural selection serves as a constraint on dispersal. It is clear there are still outstanding and mutually exclusive hypotheses regarding the role that the environment may have played in promoting early pan–continental migrations of *Homo*. Early *Homo* either had a poor capacity for adaptation to novel environments, resulting in dependency on grasslands to provide a biogeographical corridor; or was capable of rapidly adapting to novel extrinsic factors through intrinsic, and/or behavioral factors unique to humans.

'Ubeidiya, Israel, is an early Pleistocene site dated to 1.6 – 1.2 Ma and has revealed extensive lithic artifact and faunal assemblages as well as scant hominin remains. Excavated since 1959, there have been several paleoecological reconstructions of the site with discordant results. Here we present results from new suite of ecometric methods obtained on both large and small mammals including stable isotopes, tooth wear (mesowear and microwear) and compare them to other taxon-specific ecometric paleoecological reconstructions.

Tooth wear of ungulates point to a low level of grass in the diet of ungulates with increase perception compared to today. However, surprisingly, stable isotope results of cervids point to a C<sub>4</sub> vegetation diet or a mixed C<sub>3</sub> vegetation diet under higher water stress level compared to today. Reconciling these discordances are interpreted through the different spatial and temporal resolution of each proxy; the dietary flexibility of each taxon, migration, and the season animals died. The incongruent results may be explained by the unique taphonomy of each study population. Indeed, the tooth wear results were obtained on well-preserved unbroken teeth probably derived from individuals who died in or near the vicinity of paleolake 'Ubeidiya suggesting a low abrasive diet. In contrast, the stable isotope samples came from well-rounded and abraded specimens that may have been transported long distances from their native ecology to the shores of lake reflecting a dryer environment. Overall, cross continent taxon-specific comparisons suggest that 'Ubeidiya African taxa incorporate less grass in their diet compared to their East African penecontemporaneous counterparts, but Eurasian taxa incorporate a similar amount of grass in their diet as Eurasian species.

The ecology of early *Homo* in the Levant shortly after the dispersal from Africa present a region with low levels of herbaceous vegetation and a high proportion of browse vegetation, suggesting environmental conditions that would have provided novel selective pressures on early *Homo* population.

O-4176

## The upper age limit of feldspar luminescence dating: a comparison of natural and laboratory dose response curves

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### Abstract

In the luminescence dating of old and/or high dose rate samples (i.e. with absorbed doses >200 Gy) feldspar is usually preferred over quartz because of the extended dose response curve; with a typical  $D_0$  of ~400 Gy, feldspar laboratory signals are usually within 3% of saturation by ~1.4 kGy. Especially since the identification of a more stable feldspar post-IR IRSL signal by Thomsen et al. (2008), several post-IR IRSL measurement protocols have been proposed and tested (e.g. Buylaert et al., 2012; Li and Li, 2012; Li et al., 2013). Although these different protocols have proved successful in dating different sedimentary environments, a number of studies have reported a dependence of the laboratory dose response curve shape on test dose size (Colarossi et al., 2018; Yi et al., 2016). This is of concern, because a prerequisite for accurate dose determination in luminescence dating is that the laboratory dose response curve matches the natural dose response curve. Several studies have investigated this for quartz signals (e.g. Chapot et al., 2012; Timar-Gabor and Wintle, 2013) but such a dataset for feldspar is limited to a single study by Li and Li (2012) with relatively few samples in true field saturation.

Here we investigate the form of both natural and laboratory dose response curves for different feldspar signals (IRSL, post-IR IRSL, IRPL,...), measurement protocols (SAR, MAAD) and normalization procedures using a set of 30 samples with independent age control from Luochuan (central Chinese Loess Plateau). Our samples range in age from mid-Holocene to the Tertiary-Quaternary boundary at 2.6 Ma with several samples presumably in full field saturation (absorbed doses >2 kGy); this ensures that the saturation level of the natural dose response curve is clearly defined. Our first results suggest that for a standard SAR post-IR IRSL<sub>290</sub> protocol the practical upper dose limit for these feldspar samples is 800-900 Gy; beyond this natural and laboratory response curves begin to deviate significantly. Thus although it may be possible to determine a dose above 900 Gy, this dose is unlikely to be an accurate measurement of the burial dose. At least for this signal and protocol it appears that the upper age limit in Chinese loess is ~250 ka. Ages beyond this limit should be interpreted with caution.

Buylaert et al. (2012) *Boreas* 41, 435-451

Chapot et al. (2012) *Radiation Measurements* 47, 1045-1052

Colarossi et al. (2018) *Radiation Measurements* 109, 35-44

Li and Li (2012) *Quaternary Geochronology* 10, 24-31

Li et al. (2013) *Quaternary Geochronology* 17, 55-67

Thomsen et al. (2008) *Radiation Measurements* 43, 1474-1486



Timar-Gabor and Wintle (2013) Quaternary Geochronology 18, 34-40

O-4177

## Luminescence dating of Quartzite and Granite Cobbles from wadi terraces in the Eastern Desert, Egypt

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### Abstract

Optically stimulated luminescence (OSL) dating of rock surfaces has developed into a useful method for providing chronological context to archaeological sites and features. OSL-dating of rock surfaces can be applied in settings where other dating methods are not suitable (e.g., high-erosion environments without finer sediments, deposits where bleaching is limited, direct dating of stone structures). In our study, we apply rock surface dating to cobbles and a boulder which were collected from terraces in Wadi Sodmein in the Eastern Desert, Egypt. Artefacts of different ages (Middle Stone Age to Neolithic) have been discovered on the surfaces of several of these terraces (Kindermann et al., 2018). No artefacts have so far been found interbedded in the terrace sediments; therefore, the terraces pre-date the oldest artefacts. Our goal is to investigate the possibility of using OSL dating techniques to determine burial ages for quartzite and granite cobbles and boulders from the terrace surfaces and bodies, which would provide a maximum age for our ancestors' footprint on these terraces. The collected samples were either interbedded in the desert pavements or buried in the terrace bodies. Cores from quartzite and granite cobbles were extracted and cut into approximately 0.7 mm thin slices. Measurements of normalized, natural luminescence intensity ( $L_n/T_n$ ) were used to investigate the bleaching profiles of the cobbles. The quartzite cobbles have been bleached throughout during the exposure at the terrace surfaces. The translucent mineralogy of the quartzite appears to transmit light through the entire cobbles. The larger boulder has been bleached to approximately 40 mm of depth from the exposed side. In Wadi Sodmein, we observe a difference in light attenuation between translucent and more opaque lithologies, since the buried surface of a granite cobble is near saturation and no difference in  $L_n/T_n$  is observable in the depth profile. We exposed quartzite and granite cobbles that had been buried in the terrace bodies, on a rooftop in a village near Wadi Sodmein, to further investigate their luminescence characteristics. The cobbles will be collected and their luminescence characteristics will be investigated after one year of exposure. Future investigations will also focus on investigating more granite cobbles and on sampling cobbles that are buried in the wadi terraces.

Kindermann, K., Van Peer, P., Henselowsky, F., 2018. At the lakeshore—An Early Nubian Complex site linked with lacustrine sediments (Eastern Desert, Egypt). *Quaternary International* 485, 131–139.  
<https://doi.org/10.1016/j.quaint.2017.11.006>.

O-4178

## A new single grain luminescence chronology for a key late Quaternary terrestrial archive: Voordrag, KwaZulu-Natal, eastern South Africa

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### Abstract

Donga (gully) incision at Voordrag, located at ~945 m elevation in the Drakensberg, eastern South Africa, has exposed a near-continuous succession (~18 m composite thickness) of colluvium and interbedded palaeosols. This succession represents a key Quaternary terrestrial archive for this part of southern Africa, having preserved a semi-continuous record of depositional and pedogenetic phases with little evidence of erosive events until the late Holocene. The intercalated nature of the colluvial sediments and palaeosols enables the use of both luminescence dating techniques and radiocarbon dating, respectively, to constrain the sedimentary record at Voordrag. The availability of multiple chronometers at this site, offers a valuable opportunity for cross-corroboration of the dating techniques employed.

This study compares new luminescence ages for the colluvial sediments from the Voordrag sequence, determined using the optically stimulated luminescence (OSL) signal from single grains of quartz and the post-infrared infrared stimulated luminescence (post-IR IRSL) signal from single grains of K-rich feldspar. These quartz and feldspar luminescence ages are compared to each other, and to the bulk radiocarbon dating of the palaeosol horizons from the previous chronology of Clarke et al. (2003). Key findings include the ability of the post-IR IRSL signal from single grains of K-feldspar to accurately date the heterogeneously-bleached colluvial sediments throughout the sedimentary sequence at Voordrag. Agreement between the single grain quartz OSL ages, the single grain K-feldspar post-IR IRSL ages, and the previously published radiocarbon ages is also noteworthy. The oldest single grain quartz OSL ages are also shown to increasingly underestimate the true depositional age of the sediments; unusually, the age constraint for these saturated OSL ages ( $\geq \sim 24$  ka) can be provided by radiocarbon dating due to the high environmental dose rate at the site. The new luminescence ages generated in this study, combine with the previous radiocarbon-based chronology of Clarke et al. (2003), to provide a new age model for the Voordrag sequence, facilitating a revised interpretation of this important South African terrestrial archive.

Clarke et al. (2003). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 197, 199-212.

O-4179

## Geomolecular dating: integrating OSL chronology and Molecular dating of the Late Quaternary paleorecords from South East Coast of India

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### Abstract

A transdisciplinary “Geomolecular” approach had been attempted to construct a temporal scale for bacterial evolution by tying the paleoecological events that took place at known geological past to specific branch points in the genealogical tree relating the 16S ribosomal RNAs of eubacteria. Optically Stimulated Luminescence (OSL) dating was carried out in 25m core sediments at 1.5m resolution in two paleobeach ridges namely Vettaikaraniruppu (VKI: 10.572514 N, 79.835111 E) and Korukkai (KUI: 10.535717 N, 79.711936 E) located 2.6Km and 16.6Km inland respectively, along the Cauvery Delta, Tamil Nadu, South East Coast of India. OSL dating revealed the age of the VKI sediments from  $3.36 \pm 0.42$  (VKI-2: 2.8m) to  $146.64 \pm 36.81$  kaBP (VKI-14: 24.5m). VKI sediments formed during Middle Holocene Transgression of  $9.27 \pm 1.22$  and  $6.45 \pm 1.32$  kaBP started from 12.0m and lasted till 5.6m depth respectively. The rate of sedimentation during  $9.27 \pm 1.22$  (VKI-7: 12.0m) and  $3.36 \pm 0.42$  kaBP was found to be higher than the rate of sedimentation between  $58.25 \pm 12.81$  (VKI-8: 14.0m) and  $9.27 \pm 1.22$  kaBP. The VKI sediments formed between 14.0m and 12.0m depths denoted a hiatus period. The age of the KUI sediments ranged from  $19.22 \pm 8.65$  (KUI-3: 3.2m) to  $145.51 \pm 27.92$  kaBP (KUI-16: 22.7m). A hiatus of sedimentation was observed in the age range of  $76.4 \pm 40.59$  (KUI-12a: 16.6m) and  $125.00 \pm 5.26$  ka BP (KUI-12F: 17.2m). VKI-12 (21.0m) and KUI-12 (17.2m) sediments were dated to  $122.10 \pm 39.00$  and  $125.00 \pm 5.26$  ka BP which coincided with Last Interglacial Transgression. Further, VKI and KUI sediments were also dated to Marine Isotopic Stages (MIS). Molecular clocks of these stratigraphically estimated paleoecological sediments VKI-2 (2.8m), VKI-5 (7.2m), VKI-8 (13.6m), VKI-10 (16.9m), VKI-12 (21.0m) and VKI-14 (24.5m); KUI-3 (3.2m), KUI-7 (9.0m), KUI-11 (14.5m), KUI-12 (17.2m) and KUI-16 (24.2m) was constructed based on the Operational Taxonomic Units (OTUs) obtained by 16S rDNA Next Generation Sequencing using Bayesian Evolutionary Analysis Sampling Trees (BEAST) software program. The mean age estimates (in millions of years) of these Late Quaternary sediments depicted the molecular evolution of bacteria to be falling under Paleogene, Cretaceous period and extended till the origin of heterotrophic bacteria i.e. about  $3 \times 10^9$  years. In modern evolutionary divergence analysis, the role of geological information extends beyond providing a timescale, for informing molecular rate variation across the tree. Geological information which formerly gave a temporal scale to molecular branch lengths, now substantially tells how rates of molecular evolution of bacteria varies across the genealogical trees through Geomolecular dating.

O-4180

## Feasibility study of $^{210}\text{Pb}$ -chronology in distinct marine ecosystems of coral reefs, seagrass, mangrove, and coastal sea

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### Abstract

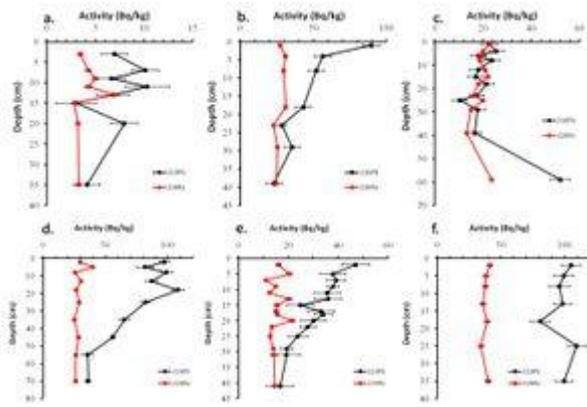
The  $^{210}\text{Pb}$ -chronology has been successfully applied in marine sediments to reconstruct past environmental change. However, the physical settings of marine sediments significantly vary among different marine ecosystems, greatly affecting the excess  $^{210}\text{Pb}$  patterns and its application in sediment geochronology. A comparative study of excess  $^{210}\text{Pb}$  patterns in marine sediments collected from distinct marine ecosystems is rarely investigated. In the present study, six sediment cores collected from typical marine ecosystems of coral reefs, seagrass, mangrove, and coastal sea were measured using High Purity Germanium  $\gamma$  spectrometry to validate and extend the availability of  $^{210}\text{Pb}$ -chronology in distinct marine ecosystems.

As for coral reefs (Fig. 1a), the activities of  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  ranged from 3~11 Bq/kg and 2~7 Bq/kg. A slight excess of  $^{210}\text{Pb}$  was also observed relative to  $^{226}\text{Ra}$ . It was noted that the  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  activities in coral reefs were the lowest relative to that in other sediment cores due to the carbonate component and large grain size for these sediments in coral reefs. The activities of  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  were in the range of 22~89 Bq/kg and 22~31 Bq/kg in seagrass ecosystem (Fig. 1b). The excess  $^{210}\text{Pb}$  was exponentially decreased along with the depth of sediment, benefiting construction of sedimentary chronology. In the mangrove ecosystem (Fig. 1c), the activities of  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  in sediment varied within the ranges of 10~52 Bq/kg and 13~24 Bq/kg. A reversible pattern of excess  $^{210}\text{Pb}$  was observed. The excess  $^{210}\text{Pb}$  was observed in the deep layer rather than the surface layer of sediment, indicating high intensification of human/biological disturbance in the easily accessible mangrove ecosystems. Three sediment cores including sandy (Fig. 1d and Fig. 1e) and muddy sediment (Fig. 1f) were collected in coastal sea. In muddy sediment, the activities of  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  ranged from 80~110 Bq/kg and 35~42 Bq/kg. A significant excess  $^{210}\text{Pb}$  was observed in the bottom layer sediment (35 cm) and destroy the availability of  $^{210}\text{Pb}$ -chronology. In sandy sediment,  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  activities ranged from 16~47 Bq/kg and 12~21 Bq/kg. The mixing layer was also observed in the upper zone of sediment (0~13cm) due to biological disturbance. The sediment chronology could be constructed based on the exponential curve of excess  $^{210}\text{Pb}$  in the sublayer sediment (depth >13 cm).

Overall, the typical patterns of excess  $^{210}\text{Pb}$  were simultaneously displayed for distinct marine ecosystems of coral reefs, seagrass, mangrove, and coastal sea. Our results would also benefit our comprehensive understanding of the variable behaviors of  $^{210}\text{Pb}/^{226}\text{Ra}$  in distinct marine ecosystems for tracking specific marine processes and extending the availability of  $^{210}\text{Pb}$ -chronology.



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O-4181

## Testing the uncertainties of age-depth models based on coupled $^{14}\text{C}$ and $^{210}\text{Pb}$ data

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### Abstract

$^{14}\text{C}$  and  $^{210}\text{Pb}$  methods are regularly used to determine ages and accumulation rates of peat, fen and lake sediments. The overall aim is to estimate the age of discrete layers, which were analysed for environmental proxies. Ideally, the age-depth models should fit the investigated proxy in terms of resolution and give precise results. Nevertheless, the differences in the nature of dating methods and statistical treatment of data need to be considered.

Both  $^{14}\text{C}$  and  $^{210}\text{Pb}$  signals are integrated over a considerable period. Moreover, they originate from different sources.  $^{210}\text{Pb}$  is bound to aerosols and trapped by peat while  $^{14}\text{C}$  is bound from atmospheric  $\text{CO}_2$  by photosynthesis. Hence,  $^{210}\text{Pb}$  gives the time span during which the aerosol has been buried, whereas the  $^{14}\text{C}$  date gives the time of death of a plant.

After the analysis, the results are usually combined into an age-depth model. This process involves statistical treatment of data during which specific assumptions and simplifications are made. Depending on the algorithm, they lead to alterations in modelled ages compared to unmodelled data. Principally it is a desired result—increasing the robustness and decreasing the uncertainty of the age-depth model. In worse cases models alter the modelled ages to an unacceptable extent, which may be overlooked if the results are treated automatically.

We test the performance of various age-depth modelling algorithms (OxCal P\_Sequence, Bacon, clam, MOD-AGE) on a few selected true datasets where  $^{14}\text{C}$  and  $^{210}\text{Pb}$  data overlap and are used simultaneously. Afterwards, a point estimate is selected and used for proxy analysis on a time scale and for calculation of the accumulation rates. Together with the thickness of analysed samples they provide an information about the time resolution of proxy analysis. While the age-depth curves, except outstanding circumstances, give relatively similar answers within 95% uncertainty ranges, the differences are observed in point estimates and accumulation rate, and they may be relevant for the palaeoenvironmental studies. With this exercise we attempt to assess the uncertainty beyond simple age errors reported from the measurements and age-depth modelling.

O-4182

## Constructing age-depth models in long terrestrial records across the Mediterranean; the importance of philosophical analysis

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### Abstract

Constructing chronologies is a fundamental component of Quaternary research, and a constellation of different techniques have been both developed and employed in undertaking this critical task. Often dating methods are separated as either being 'independent' (e.g. radiometric methods) or alignment-based (e.g. where ages from target records such as the Greenland ice-core record, are imported via proxy-stratigraphic correlations). Ideally all chronologies would be formed from several lines of dating evidence with the production of a single, agreed chronology as the end goal of such research. Indeed, the "final" or "finished" chronology is a refrain often heard from Quaternary scientists, but does this really exist and what does this really mean?

Of course different lines of chronological evidence are often in marked disagreement, and the process in which one chronology is 'picked' or developed over another is often not fully explored, or worse contradictory data may never be published (or swept under the carpet with '*Occam's broom*'). Recent developments in historical sciences (Currie, 2018) concerning the nature of traces, over and under determination of the past and the value of investigative scaffolding in assessing hypotheses, may throw some light on how different chronologies continue to exist despite the range of dating techniques and evidence that continue to drive debate. These ideas may also help to understand the nature of evidence and the importance of the existing explanatory frameworks for refining competing hypotheses and discriminating between them.

Here using several case studies from the Mediterranean terrestrial record we explore these issues, highlight age-model offsets on the order of  $10^{4\sim5}$  years, which arise depending on which chronological information is accepted or rejected. We argue that all conflicting data should be published, thus helping prevent against the formation and persistence of 'coherent myths' (*sensu* Oldfield, 2001) and increase our understanding of the kind of chronological offsets feasible and fully allows multiple working hypotheses to exist and be considered.

O-4183

## **Sedimentary structure and composition of sand blows and sand dikes formed by the 2018 Iburi-Tobu Earthquake, Hokkaido, Japan**

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### **Abstract**

The M6.7 Hokkaido Iburi-Tobu Earthquake of September 6th, 2018, left sand blows and sand dikes result from liquefaction at Tomakomai, Atsuma, and Mukawa, where the distance from the epicenter is less than 20 km and Japanese seismic intensity scale is more than 6. We investigated distribution, shape, sedimentary structure and composition of the new deposits. Sand blows are mainly observed in flat areas on coast and estuaries that have undergone artificial modification. Size of the sand blows varies from several tens of centimeters to several meters in diameter. Each sand blow has a vent or vent system that aligned along a fissure. Sand blows are composed by fine to coast sand, mud, pebbles and various size of pumice. A layered structure is commonly seen in the cross-section. In most of the case, mud, pumice, and sand are deposited in order from the bottom to the top of the deposit. There is little evidence that blowing sand has eroded and involved the surrounding topsoil as it rises, as a composition including diatom assemblage is significantly different between them. It seems that the mixed layer of sand and pumice in the landfill soil liquefied and sand and pumice separated in the layer. Then they ejected with mud from the accumulated light particles near to the vent. The sand dikes are observed by trenching or by using a handy geoslicer. Most of the dikes are not straight, they are curved or bent along the boundary of the inhomogeneous medium around them. The width of the dikes vary from 1 mm to 10 cm, and they are filled with sand or pebbles that are the same materials as those came out at the final stage of the ejection. There are dikes that are clogged from the bottom with pumice and coarse sand. In those dikes, the size of the particle filling the dike decreased upward with the clogged location as the boundary. Thus, a feature of sand blow and sand dike can be complicated reflecting the size and density characteristics of the particles constituting the liquefaction layer. The precise description of the new sand blows and sand dikes can provide a better understanding of the liquefaction process and also can be useful for the identification and evaluation of paleo liquefaction deposits.

O-4184

## Earthquake damage recorded along the Roman Eifel Aqueduct (Lower Rhine Embayment, Germany)

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### Abstract

The Lower Rhine Embayment and adjacent areas are characterised by neotectonic deformation resulting in differential crustal movement. Slip rates along the fault systems are very low ( $< 0.1\text{mm/a}$ ). Significant earthquakes are known to have occurred in the past but the faulting behaviour is not adequately known which hampers the risks assessment. We analysed the archaeological record of the largest Roman aqueduct north of the Alps. This so called Eifel Aqueduct is 95.4 km long, has its source in the Eifel mountains and supplied the ancient city of Cologne with calcareous fresh water. The aqueduct crosses major faults of the Lower Rhine Embayment perpendicular.

Analyses of the aqueduct's gradient gives weak evidence for creep along the Kirspenich Fault resulting in differential movement of hanging and foot wall in the order of a few centimetres. Vertical offsets of 15 and 35 cm are documented exactly where the aqueduct crosses the Holzheim Fault system close to the city of Mechernich. Here, also structural damage of the aqueduct is recorded and archaeological evidence exists for repair works on the aqueduct. We interpret these observations as well as the construction of a 4 km long deviation as necessary measures to keep the aqueduct operational after earthquake damage. The timing of the event falls within the period of aqueduct operation which is reconstructed to be between  $80\pm 10$  CE to  $270\pm 10$  CE. Supporting evidence for earthquake activity within this period is seen in the roof collapse of the nearby Kakus cave.

O-4185

## Post-seismic deformation evaluated from logarithmic and exponential transients in GNSS trajectory models

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### Abstract

For the past few decades, modern geodetic techniques have allowed us to detect and measure post-seismic deformation occurring at the surface. However, the overall interaction between the viscous upper mantle and the much stiffer elastic lithosphere in the aftermath of an earthquake, which drives such deformation, is not yet fully understood. We know that we can model GNSS time series manifesting postseismic transient displacements almost equally well using trajectory models constructed with single or double logarithmic or exponential transients. The logarithmic form is associated with rate and state friction theory and afterslip, while the exponential form is associated with bulk viscoelastic relaxation. It is believed that afterslip is the dominant driver of post-seismic displacement transients immediately after an earthquake, but eventually, it is superseded by viscoelastic relaxation of co-seismic stresses. We assess the relative explanatory value of double logarithmic, double exponential and hybrid transient forms when used in GNSS station trajectory models, focusing on GNSS time series with strong post-seismic transient signals and better than typical signal-to-noise ratios. We also look into the spatial distribution of the accumulated post-seismic displacements. We find that the double logarithmic transient typically provides slightly better fits than the hybrid transient model in which the logarithmic component is assigned shorter decay time scale parameters than the exponential component, and both models provided much better fits than the double exponential form. Therefore, the hypothesis that short-term transient behavior associated with afterslip is eventually dominated by longer time scale transient behavior associated with viscous relaxation receives no support from this study. The observations can be explained just as well – and even slightly better – by the hypothesis that the entire post-seismic transient (7 years of post-seismic measurements) was driven by afterslip. Finally, we found that while the largest observed coseismic displacements occurred at coastal GNSS stations, the largest accumulated postseismic displacements occurred well inland, suggesting if postseismic deformation is driven by afterslip, then much of that afterslip occurred below (i.e. inland of) the seismic rupture zone.

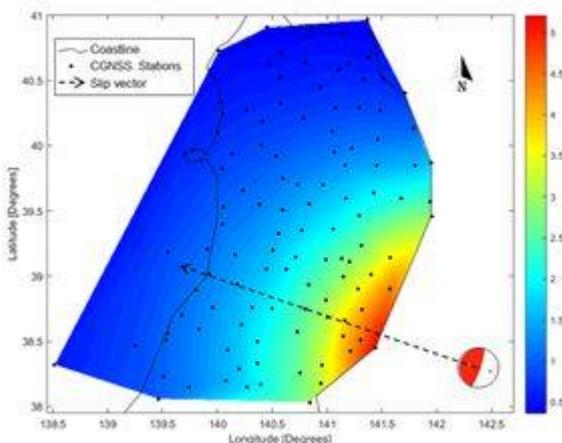


Figure 1. Coseismic jump magnitude showing maximum values at southeastern coastal stations, and approximately symmetrical about the slip vector corresponding to the Centroid Moment Tensor.

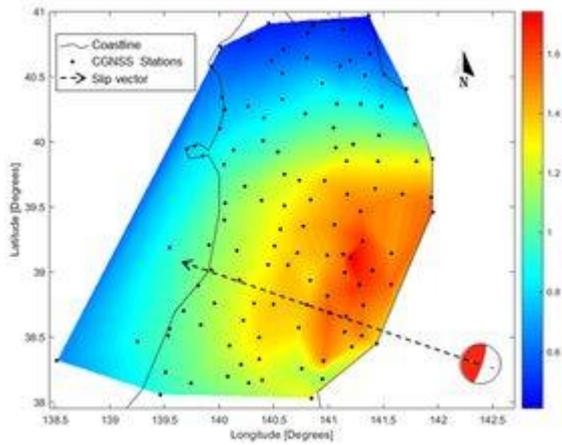


Figure 2. Accumulated postseismic displacements (7 years after the main shock). Maximum values located further inland.

O-4186

## Post-glacial deformation of the eastern Magallanes-Fagnano transform fault system, Tierra del Fuego, Argentina

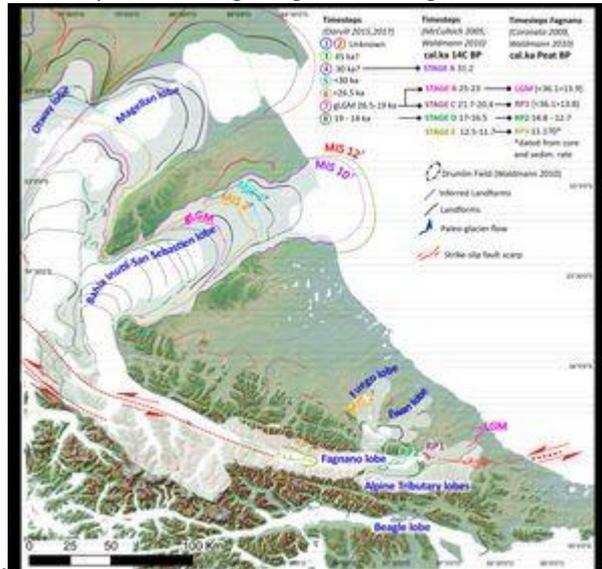
Sandrine Roy<sup>1</sup>, Riccardo Vassallo<sup>1</sup>, Joseph Martinod<sup>1</sup>, Matías Ghiglione<sup>2</sup>, Christian Sue<sup>3</sup>, Pascal Allemand<sup>4</sup>

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### Abstract

Tierra del Fuego is crosscut by a major transform fault, the Magallanes-Fagnano Fault that accommodates sinistral strike-slip motion between Scotia and South America plates. The present-day relative velocity between these plates estimated using GPS measurements is  $5.9 \pm 0.2$  mm.yr<sup>-1</sup>. Major events occurred along this fault in 1879 and 1949. The 1949 magnitude was  $M_w \sim 7.5-7.8$  with several aftershocks of similar magnitude, but the precise localization of corresponding rupture zones is not possible using seismological data. Since the onset of strike-slip, suggested at the Late-Miocene, glacial advances have rejuvenated most of the rupture markers (figure 1). Until now, the Quaternary slip rate remained unknown and investigations regarding the last 1949 ruptures were scarce. In this work, we focus on the fault behavior associated with the post-glacial stress regime over its 80-km inland eastern section, using beryllium cosmogenic-nuclide dating, combined with high-resolution Pleiades imagery and fieldwork analyses of geomorphological markers. We identified a dead valley in which the drainage network has been abandoned following the retreat of a Würmian glacier. We dated the abandoned drainage within the valley at  $< 18 \pm 2$  ky, which fixes the beginning of the tectonic deformation record. We quantified the sinistral offset accommodated by the fault across this valley of  $115 \pm 5$  m. These results yield a minimum  $6.4 \pm 0.9$  mm.yr<sup>-1</sup> slip-rate since 18 ky. Our study shows that in this context geomorphic and instantaneous fault slip rates are mostly the same, suggesting a steady fault behavior since glaciers retreat. On the other hand, we mapped the superficial ruptures that resulted from the 1949 earthquake and its aftershocks. We measured several man-made features left-laterally shifted. Two fences are crosscut with horizontal displacements of respectively  $4 \text{ m} \pm 0.2 \text{ m}$  and  $6.5 \text{ m} \pm 0.5 \text{ m}$ . A third sinistral offset of  $6.2 \pm 1 \text{ m}$  has been measured in the foundation of an abandoned broken bridge that spanned over the fault line. Therefore, we suggest that surface-ruptures length associated with the 1949 earthquake are greater than previously

estimated. If these offsets are characteristic for main earthquakes along Magallanes-Fagnano Fault, their recurrence



period should be in the order of one thousand years.

Figure1:Glacial records of Tierra del Fuego and Magallanes-Fagnano strike-slip fault, after Darvill et al. 2015, 2017, McCulloch et al. 2005, Coronato et al. 2009, Waldmann et al. 2010.

O-4187

## First evidence of Holocene surface rupture at the Carboneras fault (Southeastern Iberia)

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### Abstract

The Carboneras Fault belongs to the Eastern Betics Shear Zone in southeastern Iberia. Due to the scarcity of instrumental seismicity and moderate to large earthquakes in the historical record, paleoseismic studies are needed to better assess the seismic hazard of this fault. This study aims to refine the paleoseismic parameters (slip-rate, recurrence, slip per event, ...) analyzing, for the first time, the southeastern trace of the La Serrata duplex. The Carboneras Fault is a 150 km long left-lateral strike-slip fault. La Serrata Range, is a 12 km contractional duplex, defined as one of the four on-shore segments, that has been the subject of another paleoseismic study in the northwestern trace. This analyzed site area is located on the apex of a Late Pleistocene alluvial fan. The paleoseismic survey consisted in 13 trenches and 12 slices, performed in two different phases. The stratigraphy of the fan consists of two large and wide channel systems that incise into an older fan surface that has a carbonate caliche crust on top. An alternation of loose gravel channels, and wide layers of debris and mud flows forms the filling of those large channels. In the trenches dug perpendicular to the fault evidence for 4 to 5 events were found defined by capped faults, with the youngest fault trace affecting the top soil layer. The trenches dug parallel to the fault evidenced up to 16 channels. Eight of these channels were used as piercing lines for offset measurements. The incremental offsets of the different channels suggest a continuous fault activity throughout the Late Pleistocene. The preliminary radiocarbon dating from the first phase yielded slip-rates approximately ranging between 0.2 and 0.5 mm/yr for the southeastern trace of La Serrata. The youngest affected channel is offset about 2 to 3 meters, which probably corresponds to a maximum slip per event as it is the last event recorded. This would scale with a Mw 7.0-7.2 earthquake and to a rupture length of about 46 to 58 km, implying a review of the actual segmentation model of the fault. This last event could correspond to the Almeria's 1522 (EMS IX) earthquake. New radiocarbon and OSL datings are in progress to test this hypothesis.

**O-4188**

## **Geological and seismotectonic investigations at a site of a planned NPP in the region of moderate seismicity**

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### **Abstract**

The Krško Basin (SE Slovenia) is the site of an existing nuclear power plant (NPP) and a new unit is being considered. In support of an assessment of site suitability, new geologic and seismotectonic investigations were performed from 2013 through 2018. Seismic safety is the focus of the investigations with one emphasis on fault capability and another on seismic source characterization for a probabilistic analysis of ground motion hazard. The recent project (2015 – 2018) was performed by a team composed of RIZZO International and the Geological Survey of Slovenia (GeoZS).

The basin has a relatively complex geological history attributed to its geotectonic position at the junction of the Alps, Dinarides and the Pannonian Basin. The geological, in particular the structural, interpretation is further complicated by the succession of Quaternary and Neogene (soft) sediments and overlying pre-Neogene (hard) rocks. Regardless of the complexity, an in-depth understanding of the geology, especially the neotectonic setting, is essential.

The recent field and laboratory investigations comprised an integrated suite of geomorphological, geophysical, geological, geochronological, and paleoseismological studies. Special focus was given to the potentially active faults nearest to the site; the Orlica and Artiče faults.

Previously available geological, seismological, geophysical and geomorphological data compiled by a consortium of organizations in 2008 – 2013 have now been refined by data collected during subsequent investigations, including those of the most recent project. The refinements are based on work performed within the 25-km radius of the proposed second NPP sites between 2013 and 2018, including: geomorphological analyses and reconnaissance field mapping, 8.8 km of high resolution, shallow P- and S-wave reflection seismic profiles, and 3.1 km of shallow SRT and ERT profiles. This work led to the selection of three paleoseismological trench sites where trench walls were logged, and 62 samples of Quaternary sediment samples were dated.

This work provides a relevant case study in which complex geological problems are being addressed using state-of-the-art and state-of-the-practice methods. Given the complexity of the region, the multi-methodological approach is important for reducing uncertainty and providing important insights to the tectonic setting.

O-4189

### 3-D analysis of shear-deformation bands in unconsolidated Pleistocene sands with ground-penetrating radar: Implications for paleoseismological studies

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#### Abstract

Deformation bands developed in unconsolidated sediments are of great value for paleoseismological studies, because they can indicate tectonic activity that occurs along blind faults. With ground-penetrating radar (GPR), we analysed an array of shear-deformation bands that occur in Pleistocene glacial fluvial Gilbert-type delta sediments in northern Germany. A dense grid of GPR profiles with a spacing of 0.6 m was measured on top of a 20 m-long outcrop that exposes shear-deformation bands. This allowed to directly tie features in the radargram to the exposure. The shear-deformation bands exposed in the 2-D outcrop have a normal sense of displacement in a range of 1 to 24 cm and the bands form a northeastwardly-dipping array. The array consists of seven major shear-deformation bands with a spacing of 1 to 2 m. Individual bands have dip-angles between 30° and 58° and the thicknesses vary between 1 and 3 centimetres. Two shorter antithetic bands are developed in the array and have higher dip angles. The shear-deformation bands can be clearly imaged in the radargrams, where they are partly represented by inclined reflectors and partly by the offset of reflectors. Thin sections of sediment samples show that the analysed shear-deformation bands have a denser grain packing than the host sediment. Thus, they have a lower porosity and smaller pore sizes and therefore, in the vadose zone, the shear-deformation bands have a higher water content due to enhanced capillary forces. This, together with a partially-developed weak calcite cementation and the distinct offset along the bands, are the main reasons for the clear and unambiguous expression of the shear-deformation bands in the radar survey. For a 3-D interpretation of the 2-D radargrams, a 3-D geometrical model was reconstructed. The 3-D model shows that the bands have near-planar geometries that can be traced throughout the entire sediment volume. With the 3-D analysis, it is further possible to derive the orientation and geometry of the bands and allows a correlation of the bands with the regional fault pattern. The shear-deformation bands in this study follow the trend of the regional faults, thus indicating a direct relationship of the deformation bands to the deep-seated faults. We therefore conclude that the analysed shear-deformation bands formed in the process zone above the fault tip-lines, as near-surface expression of fault movement at depth. The results imply that deformation bands can serve as indicators of deeper fault movement and thus are important structural elements that can help to better estimate the seismic hazard potential of a region.

O-4190

## Interactions between landslides and glacier advances during the Alpine Lateglacial of the Eastern Alps

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### Abstract

Glacial erosion during the Alpine Last Glacial Maximum (AlpLGM) resulted in an enhanced relief with oversteepened slopes. The classical textbook view of mass movements starting after ice-decay during the Alpine Lateglacial (ALG, c. 19-11.7 ka) has been challenged by the increased number of numerical dates of rockslides and rock avalanches. Most of the dated catastrophic rock slope failures occurred during the Holocene and only a minority are of ALG age. However, systematic geological fieldwork accompanied by several dating techniques showed complex, direct and indirect links between glacial and gravitational processes during the ALG. Paraglacial rock slope failures had in some cases a considerable impact on glacier dynamics during the stadials. This includes (1) landslide-dammed lakes and their influence on glacier advances and (2) debris-covered (or mantled) glacier systems due to rock avalanche activity during glacier advances resulting in the formation of huge moraines and in large palaeoglacier extents. In addition, such an impact results in (3) changes of the valley topography and, hence, in very different conditions for following glacier advances compared to previous ones.

Based on recent geochronological data, especially results of surface exposure dating with cosmogenic nuclides, this contribution demonstrates the impact of various paraglacial mass movement-types (deep-seated gravitational slope deformations, rockslides and rock avalanches) on the landscape and on glacier advances. The record of gravitational processes covers the period from the onset of deglaciation during the phase of ice-decay (20-19 ka), the Gschnitz stadial (17-16 ka) and the Egesen stadial (Younger Dryas, 12.8-11.7 ka).

The examples also show that gravitational deposits could serve as an excellent marker to improve the stratigraphy of the ALG considering the whole landscape evolution since the AlpLGM.

O-4191

## Contribution of glacial and debris flow agents in Holocene landscape transformation of mountainous valleys, Kola Peninsula, NW Russia

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### Abstract

Actual landscapes of the Kola Peninsula Mountains are regarded as products of the expansive Late Pleistocene glaciations followed by an intensive erosion those caused deep troughs and valleys networks. At present, specific slushflow process appears to be one of the essential agents of valley sediment transport alongside the normal fluvial erosion. Despite widespread hazardous manifestations, only the latter is considered when reconstructing the Holocene evolution of initial glacial valley topography. However, detailed study of a series of mountain river basins and adjoining piedmonts revealed a significant role of debris flows and slushflows in their transformation. To reliably distinguish landforms and deposits of different origin we applied a combination of remote sensing data interpretation, small-scale mapping, and field investigation of geomorphic patterns and textural-structural properties of stratigraphic sequences. Grain size analysis,  $^{232}\text{Th}$  fingerprinting, and  $^{14}\text{C}$  dating of buried organic-rich lenses allowed revealing the age, succession and magnitude of paleogeographical events and factors of valley lithodynamics changes since the Late Pleistocene-Holocene transition.

Western and southern parts of the mountains substantially penetrated by the continental ice are filled with corresponding deposits up to 700 m a.s.l. those subsequently became the main source of debris flows. Large (10-20 m high, 4 km<sup>2</sup>) coarse debris fans are found downstream the deep cuts in glaciolacustrine and glaciofluvial bodies. In contrast, middle reaches of some smaller valleys are completely devoid of any sediment removed by the recent extreme slushflows. In some valleys, initially lacking continental drifts, the position of ice front accumulations at piedmonts controlled the local base levels, distance and lateral distribution of debris flows. Discrete bodies in their middle reaches prove to be ancient tributary debris flow fans.

Thus, during the late deglaciation and the Early Holocene, debris flows played a leading role in sediment transport leaving large geomorphic footprints inconsistent with modern runoff conditions. Asynchronous melting of continental and mountain glaciers caused moraine-dammed lakes those breaches led to the largest of debris flow events. Later, distinct decrease of their transportation capacity and frequency occurred due to reduction of both water and sediment sources. They were broadly succumbed by slushflows with much lower clastic content (<12%), which explains smaller (<1-2 m high, 0.1-0.2 km<sup>2</sup>) actual accumulations. However, higher erosional potential of those phenomena causes direct incising of glacial and debris flow landforms. Integrated 40  $^{14}\text{C}$  dates for peats or primitive soils in fans and taluses, attributed to landscape stability periods, indicate several stages of increased slushflow and slope activity over the second part of Holocene. Even low-magnitude but high frequency slushflow episodes almost paralyze normal fluvial process. Disregarding such intensive landscape transformation agents through the Holocene causes difficulties in regional correlations of the postglacial mountain basins development.

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O-4192

## Paraglacial relaxation and postglacial landscape change in Great Britain

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### Abstract

Great Britain was strongly affected by multiple glaciations during the Quaternary, and these have left a clear erosional and depositional signature in the physical geography of today's landscape, and in both terrestrial and offshore (shelf) environments. This signature is manifested in patterns of landscape topography and relief; the distribution and properties of surficial sediments; soil types; and the geography of rivers and coasts. Further, the inheritance of past glacial action has strongly affected postglacial (lateglacial and Holocene) patterns of ecosystem development; patterns and processes of human occupation and landscape change from the Mesolithic onwards; and the physical and ecological properties and processes taking place in today's landscape. As such, Great Britain can be considered to have a significant but not widely discussed paraglacial inheritance. This study examines evidence for this inheritance, describing case studies from upland (mountain), lowland (river) and coastal settings across Great Britain. This comparison highlights that fact that different environments have been imprinted in different ways by paraglacial landscape responses during the postglacial period – termed paraglacial landscape relaxation – and that different physical settings exhibit different levels of sensitivity to be affected by paraglacial processes. Examining the dynamics of these different settings to past climatic events (continental-scale deglaciation) can be used as a proxy for landscape sensitivity under future climate change (global warming).

**O-4193**

## **Rock glaciers climatic and dynamic monitoring in the subtropical Andes of northwestern Argentina**

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### **Abstract**

The subtropical Andes of northwestern Argentina have ranges that reach more than 6000 m a.s.l. At high-altitudes, arid and cold conditions prevail, and rock glaciers are one of the most widespread features. Active rock glaciers exist above 4500 m a.s.l. where precipitation is less than 500 mm/yr. In this contribution we present the results of the geomorphological mapping, and climatic and dynamic monitoring of two active rock glaciers: the Varas rock glacier (VRG) and Lizoite rock glacier (LRG).

We used differential GPS to accurately measure the position of a network of boulders once a year to establish the rock glaciers superficial flow. In order to know the climatic conditions affecting both rock glaciers, we installed a weather station on their surface to record hourly air and soil temperature, global solar radiation and relative humidity.

The VRG is situated above 4500 m a.s.l (23° 12' 9.12"S, 65° 3' 43.31"W) in the Cordillera Oriental. Based on the position, it is classified as a talus-derived rock glacier, indicating a periglacial origin. A network of 24 boulders was monitored every year between 2012 and 2016 using a differential GPS. During the entire period of measurement, the VRG registered movements between 125 and 5 cm/yr, except for four boulders which did not move. Over the five years of monitoring, the mean annual air temperature remained above 0 °C (between 2.6 and 3.5 °C), and only for four months the mean temperature was negative. Mean annual temperatures at 5 and 50 cm depth range between 4.7-6.1 and 4.6-5.0, respectively.

The LRG is located in a glacial cirque in the Sierra de Santa Victoria of the Cordillera Oriental (22°11'41.70"S, 65°11'29.95"W). It is located above 4552 m a.s.l. and presents morphological characteristics that denote activity. Two years of thermal monitoring show positive air and soil temperature. The mean annual air temperature ranges between 3.1-4.1°C; the soil temperature at 5 cm depth ranges between 5.8-7.2°C; and the soil temperature at 50 cm ranges between 5-6.1°C. The superficial flow of the rock glacier, based on the measurement of 20 boulders, ranges from 3.5 to 14.7 cm/yr. In the front of the glacier there is a small lake, from which sediment cores were taken for paleoclimatic studies.

Both rock glaciers are under positive air temperatures and bellow the regional 0° C isotherm altitude (5000 m a.s.l.). 106 years of temperature instrumental record located at La Quiaca station (3459 m a.s.l.) reveals a warming trend of 0.8 °C during the last century. Therefore, it is possible that the Cordillera Oriental rock glaciers (i.e., VRG and LRG) are not in equilibrium or fully adapted to the current climatic conditions.

**O-4194**

## **Slope instability driven by permafrost degradation in the Central Andes of Argentina**

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### **Abstract**

Landslides in the Central Andes of Argentina is a poorly studied but important topic, as these events could affect local streamflow system and water resources (Hermanns et al., 2011). As the study area has an arid to semi-arid climate, the only available source of drinking water for the neighboring settlements such as San Juan city, is melt-water from winter snow accumulation, high altitude glaciers and periglacial landforms. This means that, in the case of medium to large volume landslide, it could seriously affect the water quality, or even completely impound drainage system by natural dams. The basins fed by the Mercedario's Peak (around 32°S and 70°W) have a high local relief caused by glacial erosion and straining tectonic activity, which makes the area prone to landsliding (Costa and Schuster, 1988). After a thorough mass removal inventory carried out with remote sensing technics and field work it was noted that almost 30% of the studied 68.300Ha is affected by diverse types of gravitational processes including slowly creeping permafrost. Rock falls are the most extended events and accumulate in talus slopes and debris cones under outcrop with steeply dipping slopes (>50°) placed over 3500m asl (coincident with the lower limit of the periglacial environment). These slopes are normally densely fractured by regional structures and/or freeze-thaw action. Debris flows accumulate in alluvial cones and fans and are the second most extensive landforms, originating above the 3500m asl limit, while earth flows are more frequent but less extensive and its source area is directly associated with rock glaciers. Deep gravitational events are extensive but infrequent, being derived from lateral moraines. Rock avalanches are more frequent but smaller in size and there is no direct correlation with the type of lithology. The rest are represented by complex events and moraine collapses. Regarding the triggering and/or slope debilitating factors, it was noted that rock falls and small rock avalanches are frequent in glacial slopes with intense freeze-thaw action. Deep gravitational events on moraines could be a consequence of ice-core melting and debutressing action (Fischer et al., 2013). The first effect could also explain other irregular moraine collapses. The source area of flow type events such as debris and earth flows also indicate a strong periglacial correlation. These results show that large landslides, debris and earth flows are directly linked to the release of melt water of periglacial landforms. As the lower landforms within the basins have suffered from these phenomena, it is estimated that, in a global warming context, the ascent of the 0°C isotherm will affect periglacial landforms placed on the upper catchments increasing the frequency of water saturated debris or earth flow events.

O-4195

## The phasing of hydroclimatic, environmental, and geomorphic changes during the Last Glacial-Interglacial Transition in the Vale of Pickering, Northeast England.

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### Abstract

It has been suggested that during the Last Glacial-Interglacial Transition (LGIT; c. 18-8 ka BP), shifts in hydrological, ecological and geomorphic systems (collectively termed as landscape changes here) occurred out of phase with abrupt climatic changes as observed in the Greenland ice-cores. These phase differences have been attributed to several variables including paraglacial readjustment, isostatic rebound, effective precipitation, soil development, and anthropogenic activity. At present however, the lack of holistic reconstructions of hydrological, ecological and geomorphic change precludes confident assessments into the driving mechanisms of landscape changes, and their phasing with abrupt climatic transitions.

The Vale of Pickering (VoP) in NE England has great potential to address this issue because it contains internationally important archives of: (1) the retreat of the BIIS during the last deglaciation (at c. 17.3 ka BP); (2) fluvial processes operating in the River Derwent catchment; (3) high-resolution palaeoenvironmental/palaeoclimatic records; (4) evidence of human occupation phases through the LGIT. This poster will present holistic palaeoenvironmental reconstructions through the two major warming phases of the LGIT, with the aims of synthesising the timing and phasing of changes in hydroclimatic, ecological, and fluvial systems in association with phases of human occupation in the valley.

Reconstructions show that landscape changes in the VoP lagged the major warming intervals in the LGIT by multiple centuries. In the Lateglacial Interstadial, low ecological activity and groundwater availability, coupled with ephemeral fluvial activity persisted in the valley for c. 700 years after climatic amelioration (and c. 3300 years after deglaciation), reflecting the roles of paraglacial and isostatic readjustment in limiting biogenic productivity and hydrological stability. At the start of the Holocene, the lag in landscape response was significantly shorter (c. 250 years) with more rapid readjustments in biogenic productivity and the hydrological system in the absence of paraglacial readjustment processes. In both instances, substantial human presence in the VoP only occurred after the step change in ecological, hydrological, and geomorphic systems towards archetypal 'interglacial' modes (i.e. stable and perennial rivers systems, high water tables, forested environs), demonstrating that local environmental conditions were not synchronous with regional climatic transitions, and were the principal factor controlling intervals of human occupation in the valley.

**O-4197**

## **The last glacial Dead Sea region: vegetation history, fire activity, and biome modeling**

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### **Abstract**

The southern Levant is a key region for studying vegetation developments in relation to climate dynamics and hominine migration processes in the past due to the sensitivity of the vegetation to climate variations and the long history of different anthropogenic occupation phases. However, paleoenvironmental conditions in the southern Levant during the Pleistocene were still insufficiently understood. Therefore, we investigated the vegetation and fire history of the Dead Sea region during the last glacial. We present a new palynological study inferred from sediments of Lake Lisan, the last glacial precursor of the Dead Sea. The sediments were recovered within an ICDP campaign from the center of the modern Dead Sea. The palynological results suggest that Irano-Turanian steppe and Saharo-Arabian desert vegetation prevailed in the Dead Sea region during the investigated period (ca. 88,000–14,000 years BP). Nevertheless, Mediterranean woodland elements significantly contributed to the vegetation composition suggesting moderate amounts of available water for plants. The early last glacial was characterized by dynamic climate conditions with pronounced dry phases and a high but unstable fire activity. Anatomically modern humans entered the southern Levant during a climatically stable phase (late MIS 4–MIS 3) with diverse habitats, constant moisture availability, and low fire activity. MIS 2 was the coldest phase of the investigated timeframe causing changes in woodland composition and a widespread occurrence of steppe. We used a biome modeling approach to access regional vegetation pattern under changing climate conditions and to evaluate different climate scenarios for the last glacial Levant. The study gains new insights into environmental responses of the Dead Sea region to climate variations through time. It contributes towards our understanding of paleoenvironmental conditions in the southern Levant, which functioned as an important corridor for human migration processes.

**O-4198**

## **Was human dispersal out of Africa limited to Pleistocene wet periods across the arid and hyper-arid Levantine Corridor?**

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### **Abstract**

During the last decades, a debate developed among scholars regarding the geographical distribution, environmental conditions and climatic context of human dispersal routes connecting East Africa and Asia via the Southern Levant. Most scholars stressed the necessity of wet climatic periods for overcoming the hyper-arid zone of the Eastern Sahara or the Arabian Desert, together serving as a major physical barrier along these potential routes.

In light of this long debate, a re-evaluation of the physical conditions along the Levantine Corridor was carried out, focusing on the natural water availability in its most arid and hyper-arid zone. Based on high-resolution mapping of present natural water resources along a 400 km north to south transect located between the Mediterranean coast and the southern tip of the Sinai Peninsula, the following conclusions were reached, offering new insight on the subject:

1. The river Nile and its most eastern branch – the historical Pelusian arm – provided the perfect green and wet link between eastern Africa and the southern Levant via the Mediterranean coastal plain of the Sinai Peninsula, during the Pleistocene. The constant availability of fresh water on the surface and at a shallow depth along this route characterize it as the main dispersal corridor across the Saharan desert, with no need to synchronize the utilization of this route with “wet” climate periods.
2. The Negev and the Sinai deserts, which are located across the Levantine Corridor, form together a wide desert strip to the south of the Mediterranean coast. At present, these regions are experiencing aridity to hyper-aridity under the dry Holocene climate. Based on their geodiversity and climate, this strip demonstrates a variety of natural water resources that can presently support the transit and wandering of groups of humans, even in regions receiving only 20-30 mm of average annual precipitation.
3. Based on environmental and paleoclimate evidence, these harsh environmental conditions prevailed during most of the interglacial Holocene and, probably, during past interglacial phases. However, the large variety of archeological evidence proves that this region was almost constantly occupied by human societies, regardless of its harsh conditions.
4. Environmental reconstructions of the last late Pleistocene glacial phase indicate that the region was even more humid relative to the present hyper-dry climate. Therefore, human dispersal across the region was even easier during glacial times.
5. The utilization of the geodiversity by ancient societies was, and still is, a key factor for water availability in hyper-arid zones. Groups of hunters and gatherers could move and survive in this desert environment during past climates, covering both glacial and interglacial periods. Therefore, there is no need to attribute human dispersal across the hyper-arid zone between Africa and the Southern Levant only to “humid” climatic phases.

O-4199

## An Early Pleistocene lake-wetland sequence in the Levantine corridor: reconstructing the environmental conditions during initial African dispersal of *Homo*

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### Abstract

The Saharo-Arabian desert belt has experienced significant environmental and climatic changes throughout the Pleistocene. These variations are evidenced by the presence of widespread deposits that indicate pluvial intervals (as expressed by lacustrine and wetland deposits, alluvial fans, paleosols, and speleothems) or hyper-arid periods (deserts and ergs). One of these pluvial intervals is represented by an Early Pleistocene lacustrine sequence that occupied an area of ~300 km<sup>2</sup> in the present extremely arid southern Negev desert: Lake Kuntila.

Several studies were previously carried out on this sedimentary sequence, with the aim of reconstructing the paleoenvironmental settings, mainly through methodological investigation of the microfauna assemblages. These previous studies show that the lacustrine sequence consists of chalky limestone with some banks of massive limestone alternating with marly to sandy-marly beds rich in gastropods, ostracods, fish remains, and charophytes. The fossil assemblage indicates a freshwater to hypersaline environment with salinity ranging between 0.5‰ and 70‰. Based on archeological artifacts corresponding to the Acheulean culture found on a nearby alluvial terrace, the top of the lacustrine sequence was assigned with a Lower Paleolithic age (~2.6-1.7 Ma).

The current study presents new results that expand our knowledge on the chronology and environmental settings of this lake system. Paleomagnetic measurements show a lower, normal polarity zone and a reverse interval in the upper part of the section. Considering previous exposure ages between 1.9 and 1.6 Ma measured on the pavement at the top of the columnar section, we correlate the observed polarity pattern with the top of Olduvai and the lowermost part of chron C1r. Hence, the Kuntila lacustrine sequence can be dated to approximately 1.9-1.7 Ma.

New analysis of the biological diversity show that the sequence mainly contains remains of very few species of ostracods, mostly recrystallized steinkerns of the euryhaline *Cyprideis torosa* and few shells of *Ilyocypris* (which is typical for freshwater and running water) or *Candona* (freshwater environments). The current study is further complemented by elemental analysis of the lithological sequence ( $\mu$ XRF), and allows to better understand the environmental settings prevailing in the region during the Early Pleistocene and to propose several mechanisms for the expansion of humid conditions at these latitudes.

**O-4200**

## **Dead Sea pollen – a key to environmental setting of early modern humans in the southern Levant**

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### **Abstract**

The southern Levant is controlled by the Mediterranean climate in the north and the Saharo-Arabian desert climate in the south. The regional climate is linked to both mid-latitude and sub-tropical atmospheric-oceanic systems. Previous paleoclimatic studies of cave and lacustrine sediments have refined our knowledge of the last interglacial conditions. Yet, the pattern and trigger of the climatic change remain elusive due to the inconsistencies implied by different paleoenvironmental records. The Dead Sea is an invaluable archive hosting a long history of the regional environment. In 2010, Dead Sea deep drilling cores were retrieved allowing high-resolution multi-proxy analyses for the past c. 220 ka. On this basis, we present detailed palynological results from the Dead Sea, discussing past vegetation changes and climatic conditions in the southern Levant.

The glacial periods were semi-arid, characterized by dispersal of steppe and desert. The transition into the last interglacial was warm and hyper-arid, suggested by the predominance of desert components and virtual absence of Mediterranean trees. The last interglacial was marked by arboreal diversity maximum with strong seasonal contrast indicated by notable sclerophyllous expansion. Combining previous archaeological findings, our study suggests that the diverse ecosystems involving rich flora and fauna supported the survival and dispersal of anatomically modern humans in the southern Levant.

O-4201

## Depositional environments, pollen, phytoliths, and fauna from MIS 9 to MIS 1 in the central Azraq Basin, Jordan

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### Abstract

The central part of the Azraq Basin (Eastern Jordanian Desert) represents an oasis at the crossroads between the Levant and the Syro-Arabian deserts. Such a reliable and resource-rich landscape in this arid region would have been important refugium for hominins throughout the Middle and Late Pleistocene. This paper presents the results of pollen and phytolith analysis from various soundings and excavation profiles throughout the Greater Azraq Oasis Area (GAOA).

Section NF-1, dated to the late MIS 9, is located on the highest identified lacustrine terrace. The sequence produced pollen dominated by Thymeleaceae and Leguminosae shrubs and grasses. Phytolith assemblages indicate more C<sub>4</sub> than C<sub>3</sub> grasses, which suggests a warm, but humid environment.

Shishan Marsh 1 archaeological site (SM1) comprises deposits represent a continuously drying lake dated to late MIS 8-early MIS 7. Aquatic grasses, sedges, and cattail, with large amounts of Chenopodiaceae shrubs dominate the pollen spectra. Phytolith assemblages indicate that the grasses consist mainly of *Phragmites* (reeds). The faunal remains identified from this deposit include *Panthera leo*, *Gazella* sp., *Bos* cf. primigenius, *Camelus* sp., *Equus* spp. *Stephanorhinus hemitoechus*, *Palaeoloxodon* cf. recki, and *Elephas* cf. *hysudricus* (Pokines et al. 2018, Quat. Res.). Late Acheulean material is associated with this deposit (Nowell et al. 2017, J. of Arch. Sci).

Located within a lacustrine terrace above the historic Druze Marsh, Section DV-1 is deposit dated to the late MIS 6. Pollen spectra include grasses and woody species such as Thymeleaceae and Oleaceae. Phytoliths indicate the presence of C<sub>3</sub> and C<sub>4</sub> terrestrial grasses and aquatic grasses (*Phragmites*). The deposit produced some Middle Palaeolithic-style Levallois flakes and remains of *Equus* sp.

Located in soundings into the former bed of the Druze Marsh, section DM-8 contains a sequence representing the transition from marsh to lacustrine facies dated to MIS 5b-5a. The combined pollen spectra includes terrestrial and aquatic grasses and woody species of the Leguminosae family and *Pistacia*. A few *Quercus* pollen grains, probably far-flung, appear in some of the deposits. The palustrine facies of this deposit also contained Middle Palaeolithic Levallois technology.

Located in the Shishan Marsh, section SM-6 contains a marsh deposit sequence spanning the LGM to the Holocene. Although aquatics dominate the pollen spectra, the non-aquatic pollen sequence shows a transition from Artemisia-dominated desert to a Chenopodiaceae dominated desert. The lower part of the deposit produced early Epipaleolithic material.

In summary, the combination of pollen and phytoliths at these localities complement one another to produce a more complete reconstruction of vegetation patterns from MIS 9-1. It becomes evident that during high lake stands



grasses dominate this part of the Azraq basin. During low lake levels, aquatic taxa stand out against a background of more desert-like vegetation of *Chenopodiaceae* and/or *Artemisia*.

O-4202

## A multi-proxy study of late Pleistocene environmental variability in Israel's Hula Valley

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### Abstract

The Epipaleolithic (c. 23 to 11.5 ka cal BP) was a period of rapid and remarkable environmental and cultural change in the southern Levant as nomadic bands of hunter-gatherers transitioned to life in sedentary communities. While climate warmed following the Last Glacial Maximum, published proxy reconstructions of late Glacial environmental conditions have produced conflicting precipitation histories for this region where water availability was likely particularly important.

Here, we have undertaken a multi-proxy examination of lacustrine sediments collected from the open-air archaeological site Jordan River Dureijat (JRD), located on the east bank of the Jordan River in the Hula Valley (northeast Israel). A three meter sedimentary sequence exposed during the archaeological excavation was sampled continuously at a vertical resolution of one centimeter and composes alternating units of homogenous dark grey silt, each approximately 10-40 cm thick, and horizons rich in mollusk remains (3-7 cm thick) dominated by freshwater mussels of the genus *Unio* and freshwater snails (genus: *Melanopsis*) and containing cultural artifacts including stone tools and carved bone fish hooks.

The shell-rich, artifact-bearing units are interpreted as being deposited nearer to the lake paleoshorelines than the shell-poor, archaeologically sterile units which likely represent deposition in a deeper, less shore-proximal environment. Extensive radiocarbon dating of the site's abundant charcoal has allowed for the creation of a robust age model using Bayesian modeling techniques (OxCal); this model has been used to constrain the timing of water level fluctuations in the basin and we estimate that the Hula Valley experienced dry periods with relatively low water level from 15.2-14.9, 12.8-12.2, 11.7-11.5 and 10.9-10.5 cal ka BP.

Subfossil ostracod remains are present in all samples, with the most abundant species being *Ilyocypris bradyi*, followed by *Candona neglecta* and *Candona angulata*. The habitat preferences of the observed species and their relative abundances are used to reconstruct environmental conditions in paleo-Lake Hula including lake water salinity, turbidity and energy level, while changing precipitation sources and amounts are examined using stable isotopes ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) measured from ostracod valves of the genus *Ilyocypris*. In addition to providing the site with a robust chronological framework, the age model allows the proxy data to be assessed as fluxes, simplifying interpretations of population density and species richness, and for the produced environmental reconstruction to be compared to records from nearby sites. This well-dated, robust multiproxy paleoenvironmental reconstruction of the late Pleistocene/Early Holocene Hula Valley is important both to understand living conditions at the site during periods of human occupation and to contribute to ongoing debates about the nature of water availability during the transition from glacial to interglacial conditions in this part of the Levantine corridor.

O-4204

## Palaeoenvironmental history from New Zealand swamp kauri (*Agathis australis*) tree ring records: Recent progress, sample collection and radiocarbon dating

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### Abstract

Swamp kauri (*Agathis australis*) trees are preserved in bogs across northern New Zealand. The anatomical structure of this buried wood has not been replaced with a mineral precipitate, so they are "subfossil" and can be mined and milled as workable timber. Some excavated swamp kauri have diameters in excess of 2.5m, and many trees attained great ages prior to death (>2000 years of growth). Swamp kauri can be preserved for many millennia in anoxic conditions, and Holocene, late glacial, pre-last glacial maximum, and last interglacial subfossil wood has been recovered. There are associations of the swamp kauri wood with peats, tephra and macrofossils within several types of geomorphic settings.

Recent concerns about swamp kauri extraction rates led us to define how this dendrochronology resource offers globally-unique opportunities for Quaternary science. This presentation will overview the potential of the swamp kauri, and advances made from several contemporary projects, including MIS3 kauri dendrochronology efforts and new sample collections. At present, >6000 years of chronology coverage exists for MIS3. Our expanded radiocarbon results from the last decade of analyses suggest the period 27ka to 60ka may be blanketed by swamp kauri samples. A new project underway as of July 2019 will target the development of supra-long MIS3 kauri chronologies with our collections. Our aim will be to produce higher resolution 14C calibration curves and detailed climate reconstructions to better align global palaeoevidence with ice core data.

O-4205

## Irish Dendrochronology: a review of new approaches in tree-ring dating

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### Abstract

The construction of a continuous Irish oak tree-ring chronology spanning the last 7492 years has led to a better understanding of human, ecological and climatic events. The information obtained from other environment sources can now be evaluated against this and other worldwide, precisely-dated tree-ring sequences. Examination, review and further advances of the long chronologies will provide greater clarity of the timing of past environmental and human activities. We present an overview of new approaches in Irish dendrochronology that enhance the dating and interpretation of tree-ring chronologies in Ireland, including stable and radio-isotopes that facilitate the correlation of problematic samples and floating chronologies from short-lived species. Additionally, pine chronologies provide an opportunity to replicate and extend information obtained from the oak chronologies; in particular, we consider the significance of subfossil bog timbers in the understanding of mid- to Late Holocene environmental change. These new techniques and datasets will produce, new, clear and important environmental and climatic information.

O-4206

## Application and evaluation of a dendroclimatic process-based model (MAIDEN) during the last century in the Northern Hemisphere

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### Abstract

Tree-ring archives are important to reconstruct climate variations of the last millennium with annual resolution. The links between tree-ring proxies and climate have usually been estimated on the basis of statistical approaches, assuming linear and stationary relationships. Both assumptions can be inadequate but this issue can be overcome by ecophysiological modeling based on mechanistic understanding. For example the model MAIDEN (Modeling and Analysis In DENdroecology) simulates tree ring growth starting from temperature and precipitation daily inputs and considering carbon assimilation and allocation in forest stands. Currently, MAIDEN has been applied in the Mediterranean and temperate regions, in the Eastern Canadian taiga and in Argentina. In this study, we test the model sensitivity to the calibration of parameters and to the quality of the climatic inputs. Both are main sources of uncertainties. We especially want to answer the following question: Can we use MAIDEN driven by climate models outputs to reconstruct the climate of the last millennium using data assimilation? We develop a protocol to systematically calibrate the model and apply it to main extratropical tree species, based on the bayesian procedure with Markov Chain Monte Carlo sampling developed by Gennaretti et al. (2017). MAIDEN is applied to selected sites of the Northern Hemisphere, covering a range of environmental conditions and tree species. The performance of the model at those sites is evaluated through a validation step (h-block Jack-knife and cross-validation) and compared with the VS-Lite model (a simple tree-growth process-based model). Pseudoproxy experiments help to evaluate the performance of the MAIDEN model in a flexible and controlled framework.

Gennaretti, F., Gea-Izquierdo, G., Boucher, E., Berninger, F., Arseneault, D. & Guiot, J. (2017). Ecophysiological modeling of the climate imprint on photosynthesis and carbon allocation to the tree stem in the North American boreal forest. *Biogeosciences Discuss.*, 48, 1-26.

O-4207

## Increased variability of Chao Phraya River peak-season flow in Thailand and associated ENSO activity: evidence from tree ring $\delta^{18}\text{O}$

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### Abstract

The Chao Phraya River is central to Thailand's agricultural and economic well being, yet records of annual and seasonal flow regimes are relatively short and incomplete. A long-term record of stream flow variations would therefore be a necessary component for water management plans that take into account the historical impacts from climate variability. Here we present a statistically robust reconstruction of Chao Phraya peak-season (August-November) flow that spans the 257-year period from 1748-2005. Our reconstruction is based on tree-ring cellulose  $\delta^{18}\text{O}$  series from three *Pinus merkusii* site collections from northern and central Thailand and north-central Laos, respectively. The regional  $\delta^{18}\text{O}$  index accounts for 57% of the observed variance of August-November stream flow as measured at the Nakhon Sawan gauging station. Spatial correlation and 21-year running correlation analyses results reveal that Chao Phraya River peak season flow is greatly influenced by precipitation variation driven by the El Niño-Southern Oscillation (ENSO). Periods of enhanced and reduced ENSO activity are associated with strong and weak ENSO-stream flow correlation, respectively. The Pacific decadal oscillation (PDO) also modulates ENSO-streamflow correlations, hence the most extreme flood events along the Chao Phraya occur during periods of increased frequency of La Niña events during extended cold phases of the PDO. Our CPRPF reconstruction should serve as an important tool for future water management planning.

O-4208

## Establishing magnitudes of past debris floods events on an alluvial fan in the Julian Alps (NW Slovenia) using dendrogeomorphological method

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### Abstract

The Planica Valley is a typical post-glacial Alpine valley located in the Julian Alps in NW Slovenia. Structurally it belongs to the Southern Alps. The bedrock mainly belongs to Upper Triassic carbonates. After the post-LGM glacier retreat, the Valley has been filled with various Holocene deposits among which alluvial fans and cones are the most prominent geomorphological features. The Valley has no permanent water streams and thus the sediment, composed of poorly sorted sands, gravels and boulders, is transported onto fans and cones only during (usually autumnal) episodic high precipitation torrential events in a form of debris floods. Debris floods induced by heavy precipitation affect trees by partially burying the stems up to one meter height. Such a combination of sediment transport mechanism, type of vegetation, geomorphological setting as well as the vicinity of a permanent meteorological station makes the Planica Valley a perfect study site for dendrogeomorphological research of past debris floods.

Establishing the magnitudes of past debris flood was a three-step process. In the first step, we sampled 105 trees (*Picea abies*, *Abies alba* and *Larix decidua*) on one of the most active alluvial fan in the Valley. We successfully dated thirteen debris flood events from the year 1903 onward as well as calculated the percentage of affected trees during each event. Debris floods were dated based on sudden growth suppression of buried trees expressed by sequences of narrower tree-rings. In the second step, we correlated flood events with high precipitation potential triggering events by careful analysis of meteorological data. Based on previous research and documented events we choose the minimum threshold of 50 mm of rainfall in a 24-hour period as a potential triggering meteorological event. In the third step, we established the magnitude of each debris flood event by comparing the amount of affected trees with the return period of potential triggering meteorological events. The comparison of the two data sets shows that debris floods, which affected 10 to 20 % of trees, were induced by torrential precipitation events with a 1-2 or 2-5 year return period. Debris floods, which affected 20 to 30 % of trees, were induced by torrential events with a 10- to 25- or 25- to 50-year return period, while debris floods affecting more than 30 % of trees were triggered by torrential events with a 100-year return period. Our dendrogeomorphological research, one of the few done in broader southeastern Alpine region suggests, that magnitude of past debris flood events can be indirectly determined by comparing the amount of affected trees and return period of a triggering rainfall event.

O-4209

## Do tree-ring records from southern Ontario, Canada track local $^{14}\text{C}$ releases from nuclear power plants?

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### Abstract

Trees are natural integrators of changes in the environment. Tree-ring records can provide annually resolved information about a suite of past environmental conditions, including reconstructing past changes in climate and tracking changes in the isotopic composition of the atmosphere. Radiocarbon ( $^{14}\text{C}$ ) is one such component. Naturally,  $^{14}\text{C}$  in the atmosphere varies through time due to cosmic ray flux and ocean-atmosphere dynamics. Anthropogenic activities effect the concentration of  $^{14}\text{C}$  in the atmosphere from global to local scales through burning of fossil fuels, nuclear bomb testing, and the operation of nuclear power plants (NPPs). Tree-ring-based  $^{14}\text{C}$  records are ideal for examining past levels of  $^{14}\text{C}$  because these measurements represent the  $^{14}\text{C}$  concentration in the atmosphere and cross-dated tree-ring samples provide absolute dating control (Reimer et al., 2013). These attributes make tree-ring records an effective tool to track  $^{14}\text{C}$  in the atmosphere from a variety of sources, including NPPs (Matsunaka et al., 2018).

Southern Ontario, Canada is home to 17 operational CANDU reactors (Bruce (8), Darlington (1) and Pickering (6)). The Bruce and Darlington facilities have been undergoing refurbishments since 2016. Monitoring of atmospheric  $^{14}\text{C}$  in Ontario is conducted by the Centre for Atmospheric Research Experiments (44°14'N, 79°47'W), operated by Environment and Climate Change Canada (ECCC). The facility is located in Egbert, Ontario, approximately halfway between the Bruce and Darlington NPPs. Previous studies have found a noticeable influence on atmospheric  $^{14}\text{CO}_2$  levels from 2008-2010 (Vogel et al. 2013) and data collected at the ECCC monitoring station indicate another period of significant increase of  $^{14}\text{C}$  in the atmosphere, well beyond its natural variability, between July-September 2014 and May-July 2015. While the source of these emissions is unknown, refurbishment activities at the NPPs coincide with this time period.

We measured the  $\Delta^{14}\text{C}$  of tree-rings from white spruce (*Picea glauca* [Moench.] Voss) trees sampled across a west-east geographic transect between the NPPs with the aim of better understanding how the atmospheric concentration of  $^{14}\text{C}$  has varied locally in this region, while also attempting to pinpoint the source of the  $^{14}\text{C}$  emissions. Furthermore, atmospheric transport model data was used to assess when the Egbert measurement station (and the tree sites) were downwind of the CANDU facilities. Preliminary results give insight into how the atmospheric samplers and tree-rings record  $^{14}\text{C}$  in the atmosphere. Based on preliminary results, the tree growth period is important and overall the signature of excess  $^{14}\text{C}$  is more diffuse in the tree-rings than in the atmospheric samples.

Matsunaka et al. 2018. *Nuclear Instruments and Methods in Physics Research B*, 439:64–69.

Reimer, P., et al. 2013. *Radiocarbon*, 55(4): 1923–1945.

Vogel, F., et al. 2013. *Radiocarbon*, 55(3):1556-1572.

O-4210

## A new Millennial Length Reconstruction of Summer Precipitation from Stable Oxygen Isotopes in United Kingdom Oaks

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### Abstract

We present a new reconstruction of summer precipitation for the central England region over the past millennium, based upon stable oxygen isotopes ratios ( $\delta^{18}\text{O}$ ) from UK oak tree rings. Western European summers dominated by anti-cyclonic circulation patterns, are characterised by clear skies, warm temperatures, low precipitation totals, low air humidity and more enriched  $\delta^{18}\text{O}$  precipitation. Such conditions usually result in relatively more positive (enriched) oxygen isotope ratios in tree leaf sugars and ultimately in the tree-ring cellulose formed in that year, the converse being true in cooler, wet summers dominated by westerly air flow and cyclonic conditions. In such regions, there should therefore be a strong link between tree-ring  $\delta^{18}\text{O}$  and the amount of summer precipitation. Stable oxygen isotope ratios from the latewood cellulose of oak trees sampled across Great Britain produce a mean  $\delta^{18}\text{O}$  chronology that correlates strongly and significantly with the amount of summer precipitation across the England and Wales region of the United Kingdom. The isotope-based rainfall signal is stronger and much more stable over time than reconstructions based upon oak ring widths.

O-4211

## Enhanced climate instability in the North Atlantic and southern Europe during the Last Interglacial

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### Abstract

The Last Interglacial (LIG; 129-116 thousand years ago [ka]) was characterized in its earlier part by strong positive summer insolation and temperature anomalies at high northern latitudes, amplified by ocean, sea- and land-ice, and vegetation feedbacks. Attendant sea-level rise is estimated to have been ~6-9 m above present, with 0.6-3.5 m derived from Greenland Ice-sheet melting. Despite an abundance of LIG records, considerable ambiguity remains over the extent and nature of climate instability. This arises from the lower signal-to-noise ratio of interglacial variability compared to glacial, and the uneven resolution and poor chronological control of palaeorecords. We address these issues by analysing marine and terrestrial proxies from a deep-sea sediment sequence on the Portuguese Margin and combine results with an intensively dated Italian speleothem record and climate-model experiments. The strongest expression of climate variability occurred during the transitions into and out of the LIG. Our records also document a series of multi-centennial intra-interglacial arid events in southern Europe, coherent with cold water-mass expansions in the North Atlantic. The spatial and temporal fingerprints of these changes indicate a reorganization of ocean surface circulation, consistent with low-intensity disruptions of the Atlantic meridional overturning circulation (AMOC). The amplitude of this LIG variability is greater than that observed in our Holocene records. Episodic Greenland ice-melt and runoff as a result of excess warmth may have contributed to AMOC weakening and increased climate instability throughout the LIG.

Tzedakis, P.C., Drysdale, R.N., Margari, V., Skinner L.C., Menviel, L., R.H. Rhodes, Taschetto, A.S., Hodell, D.A., Crowhurst, S.J., Hellstrom, J.C., Fallick, A.E., Grimalt, J.O., McManus, J.F., Martrat, B., Mokeddem, Z., Parrenin, F., Regattieri, E., K. Roe, & Zanchetta, G. (2018) Enhanced climate instability in the North Atlantic and southern Europe during the Last Interglacial. *Nature Communications*, doi: 10.1038/s41467-018-06683-3.

O-4212

## The diachronic nature of the Saalian - Eemian boundary in Europe

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### Abstract

The Eemian is the term for the terrestrial and coastal marine Last Interglacial in Europe. The Eemian has been extensively studied from paleolandscape, sedimentary, archaeological, molluscan and botanical perspectives and its lower boundary is currently also under evaluation in light of ICS' SQS base Upper Pleistocene Subseries/Stage stratotype definition [1]. Although the duration of the Eemian in north western Europe is well known from lake sediments [2], the absolute age of onset and ending are a matter of correlation and discussion. A critical part is the debate on to what extent the Eemian pollenzone biostratigraphical correlation can be diachronic between subregions of Europe. A second matter is the correlation with the MIS 6-5e transition.

On basis of detection of the Blake paleomagnetic excursion at a site close to the original Eemian type locality in the Netherlands, Sier et al. [3] concluded that the Saalian - Eemian boundary was positioned at ~121 kyr, confirming earlier findings from a site in Germany [4]. Comparison with a marine core offshore Portugal, for which marine isotope stratigraphy, pollen biostratigraphy and paleomagnetic excursion data exists [5,6,7], shows that the onset of Eemian interglacial environmental conditions in north western Europe was delayed by ~6 kyr with respect to southern Europe (~127 kyr). The onset of the Eemian in NW Europe is thus placed well after the MIS 5e benthic  $\delta^{18}\text{O}$  plateau was entered. The striking diachroneity in the onset of interglacial conditions between southern and northern parts of Atlantic Europe, implies that regional climatic conditions over Europe and the North Atlantic in the first part of MIS 5e were very much different from those in equivalent parts of MIS 2 and 1, a feature that is related to known differences between the melting history of the Greenland ice cap following Termination II and Termination I [8,9,10]. It also has implications for reading global fingerprints in the sea-level history of the period [11].

In this presentation we give an overview of the current state of insights in the age of the Saalian - Eemian boundary throughout north western Europe. We perform a cross-correlation including the above and new records, strengthening our earlier findings of diachronic registration of Saalian-Eemian boundaries throughout Europe.

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[2] Müller, H., 1974. *Geol. Jahrb.* A21, 149-169.

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[7] Thouveny et al., 2004. *Earth Planet. Sci. Lett.* 219, 377-396

O-4213

## Compositional turnover and variation in Eemian pollen sequences in Europe

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### Abstract

The Eemian interglacial represents a natural experiment on how past vegetation with negligible human impact responded to amplified temperature changes compared to the Holocene. In Europe, numerous records cover the Eemian or at least parts of it. To understand the spatial patterns of pollen turnover and total variation across Europe we compiled a new dataset of 47 Eemian pollen sequences from 14 different countries. Data were derived from key collaborators around Europe and from open sources such as PANGAEA. Additionally, we scanned and extracted data from publications that represented important geographical voids in our spatial coverage. We selected pollen sequences using a number of criteria that include covering the full Eemian and displaying all phases of an interglacial, namely the protocratic, mesocratic, and oligocratic/telocratic phases. We aimed to explore geographical patterns of i) total compositional turnover and total variation for each sequence and ii) stratigraphical turnover between samples within each sequence. We used detrended canonical correspondence analysis (DCCA), multivariate regression trees, and principal curves. Our results show that turnover and variation are highest in central Europe (47–55°N), low in southern Europe (south of 45°N), and lowest in the north (above 60°N). The DCCA results indicate that there is a distinct temporal pattern of compositional change within each sequence over geographical space. The observed patterns are, in part, site-specific changes, but it is also possible to identify two general patterns in turnover where the DCCA sample values show either a gradually changing linear trend or a unimodal pattern where it reaches a peak and then slowly declines. We provide several hypotheses to explain these observed patterns that encourage further research on the causes of vegetation change during the Eemian and their possible drivers.

O-4214

## Consequences of Saalian ice sheets on early Eemian climate and sea level

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### Abstract

It is now widely accepted that the course of Eemian climate development and sea level rise in the North Polar region after the penultimate glacial maximum (PGM) differed significantly from the Holocene climate pattern which emerged after the LGM. It has been further suggested that the cause for it must be sought in the particular volumes and maximal geographical extensions of the Saalian (pre-Eemian) and Weichselian (pre-Holocene) ice sheets, respectively. While in the mid-latitudes both interglacials show a comparable, insolation-driven climate development after each glacial maximum, this pattern deviates in Arctic and sub-Arctic realms. But, understanding the paleoenvironmental history of that important region is particularly hampered by a scarcity of continuous Eemian records, especially on land. To fill that gap we investigated a 4.5 m thick sequence of Eemian marine beds some 100 km south of Kanin Peninsula (Arctic Russia). The sequence directly overlies Saalian till and allows for a detailed evaluation of past events and their chronology vs. ocean records by using a multiproxy data set. Our record is time-coeval with the collapse of the huge Saalian shelf-based ice sheet which left a glaciostatically overdeepened Barents-Kara Sea shelf region, thereby providing a pathway for rapid inundation of the Eurasian margin during early post-Saalian sea level rise. The oldest marine sediments reflect a period of harsh, fluvially-affected environmental conditions with cold turbid waters and heavy seasonal sea-ice cover. The later occurrence of a typical Arctic shelf and deep-sea microfossil assemblage together with broad-leaved species in pollen spectra is representative of the climatic amelioration in the early Eemian. The final stage of the record is marked by regression due to regional glaciostatic adjustment. Although conditions remained largely humid and warm - these did gradually deteriorate towards the end of the record - there is no direct indication from the microfossil community for enhanced penetration of warm Atlantic waters. The rich malacofauna, however, among them plentiful *Arctica islandica*, reflect conditions akin to the early Holocene in Svalbard's fjords. At face value, U/Th ages of this species indicate that these sediments were deposited shortly after the PGM during early sea level rise.

O-4215

## Last-interglacial sea-level records on New Providence Island, Bahamas: A test of glacial isostatic adjustment models

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### Abstract

With the prospect of rising sea level on a warming Earth, there is considerable interest in high-sea stands of the recent geologic past. One period that has received much attention is the last interglacial (LIG), corresponding to marine isotope stage (MIS) 5.5 or 5e, estimated to be ~130 ka to ~115 ka. Although there is agreement that LIG sea level stood higher than present, geologic records show differences from region to region. Some differences may be due to glacial isostatic adjustment (GIA) processes. Most sea-level GIA models agree that relative sea level during the LIG was highest in regions close to former ice sheets, such as the Laurentide Ice Sheet of North America. One modeled area includes the islands of the Bahamas in the western Atlantic Ocean. Here, LIG sea level is modeled to be as much as 11-12 m higher than present. We tested this using the geologic record of LIG sea level on New Providence Island, Bahamas. Two independent geologic records of LIG sea level are found in the Bahamas, emergent coral reefs and oolitic beach ridges. Both corals and ooids take up uranium from seawater when they are precipitated and therefore both can be dated by uranium-series methods. Coral patch reefs on the north shore of New Providence Island have present elevations between 3 m and 4 m above sea level. Patch reefs are dominated by the corals *Acropora cervicornis*, *Orbicella annularis*, *Siderastrea* sp., and *Diploria* sp., many in growth position. U-series ages of corals that have experienced closed-system conditions range from ~128 ka to ~118 ka. All the coral taxa have optimal growth in waters ranging from -3 m to as much as -10 m to -45 m. Their presence at 3-4 m above sea level implies, therefore, a paleo-sea level of *at least* 6-7 m above present. An independent estimate of paleo-sea level comes from beach ridges that contain oolitic beach foreshore and sub-tidal sediments. The foreshore facies sediments preserve keystone vugs, indicators of paleo-sea level. Although many oolites contain calcite cement, previous studies in the Florida Keys show that U-series analyses of such deposits still yield reliable approximate ages. Ten localities along the southern shore of New Providence Island have beach ridge exposures of vug-bearing oolitic beach sediments that have corrected U-series ages of ~124 ka to ~116 ka (one is ~105 ka), correlating these deposits to the LIG. Elevations of beach ridge vugs range from ~4 m to ~13-14 m and average ~9 m. We conclude from both records that sea level during the LIG stood at least as high as 6-7 m and possibly as high as 13-14 m, which supports GIA models for the LIG in the western Atlantic Ocean.

O-4216

## The last interglacial (MIS-5e) in Alpine speleothems: the Sieben Hengste record (Switzerland)

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### Abstract

The last interglacial (MIS-5e) represents the closest opportunity to characterize ecological adaptation to a warmer climate. In the European Alps, evidence of thermophile vegetation is abundant (Wegmüller, 1992; deBeaulieu and Reille, 1992; Drescher-Schneider, 2000; Pini et al., 2010) but still lacks precise chronological constraints. Meanwhile, speleothems provide accurately dated paleoclimate records which do, however, only indirectly record changes in the local environment.

Here, we present a speleothem record (7H-12) from the Sieben Hengste cave system, Switzerland, encompassing the last interglacial period. The onset into the interglacial is dated at  $129.8 \pm 0.8$  ka, consistent within error with recently published records of Termination II for the European Alps (Häuselmann et al., 2015; Moseley et al., 2015). However, in marked contrast to these speleothem records, 7H-12 shows a rapid increase in  $\delta^{18}\text{O}$ , which reaches a climax at  $128.4 \pm 0.8$  ka and is followed by a gradual depletion until 117.5 ka. This distinct pattern, characterized by low interannual variability, correlates well with the Greenland synthetic record suggesting that 7H-12 was little affected by local processes and, thus, may represent a robust archive for the last interglacial at a regional scale. Pollen extraction from the speleothem calcite reveals maximum concentrations of ca. 20 palynomorphs per gram with assemblages dominated by *Alnus*, *Hedera*, *Corylus* and *Picea*. Several of these species are presently absent from the cave's hydrological catchment area, but are clearly identified in regional pollen assemblage zones of the last interglacial. Although statistically weak, these results support warmer conditions consistent with the stalagmite  $\delta^{18}\text{O}$  record. Overall, our sample offers a unique opportunity to link higher resolved palynological sequences with a precisely dated paleoclimate record.

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O-4217

## Climatic and oceanographic conditions in the Santa Barbara Basin (southern California) during the Last Interglacial (MIS 5e)

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### Abstract

The dinoflagellate cyst record from Ocean Drilling Program (ODP) Hole 893A in Santa Barbara Basin (SBB), southern California, is examined at sub-millennial scale resolution ~150-110 kyr. A qualitative and quantitative (modern analogue technique) approach utilizing dinoflagellate cyst abundance and assemblage composition is used to reconstruct changes in marine primary productivity and sea-surface temperature. Throughout the sequence, dinoflagellate cyst assemblages are dominated by the coastal upwelling related heterotrophic cysts of *Brigantedinium* spp., while changes in the relative abundances and concentrations of thermophilic taxon *Spiniferites mirabilis*, cold water taxon *Selenopemphix undulata*, and oceanic taxa such as *Impagidinium* spp. and *Operculodinium centrocarpum* indicate the development of at least four distinct intervals in the hydrological regime from MIS 6 into MIS 5e and MIS 5d. The overall dinoflagellate cyst assemblage of MIS 5e is notably different from the Holocene and the modern in the SBB, particularly by abundances of *Spiniferites mirabilis* that reach up to ~10% in MIS 5e and the low abundances of *Echinidinium* spp. and *Lingulodinium machaerophorum*. This suggests SST's were higher but the basin did not undergo or record strong seasonal surface stratification.

O-5000

## Quaternary Mars?

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### Abstract

On Earth, the Quaternary period, extending from ~ 2.6 Ma to the present day, is defined by the most recent periods of widespread northern hemisphere glaciation, and its deposits are generally very-well studied. On Mars, the concept of an analogous 'Quaternary' is harder to apply and study, as in situ data from 'fieldwork' is rare: only at a few locations has the local stratigraphy been observed using instrumented, robotic explorers. Thus, much of what we know about Mars chronology has been revealed by remote-sensing surface geomorphology studies, meaning that Mars' geological periods are far simpler, less sub-divided, and have greater uncertainties in their bounds than Earth's.

Mars' main geological periods (the Noachian, >3.7 Ga; the Hesperian, 3–3.7 Ga; and the Amazonian, <3.0 Ga) are defined by impact crater size-frequency statistics and global-scale morphostratigraphic mapping. Amazonian Mars has undergone little geological activity compared to Earth, so many ancient morphologies are preserved. Coupled with mounting evidence that the Noachian environment was more suitable for life than Mars today, the focus of Mars exploration has mainly been on the more ancient landscapes and rocks. Yet the most recent period of Mars' history is fascinating: there is growing geomorphic evidence for recent shifts in environmental conditions, and many questions to answer.

For example, Mars' polar ice caps host numerous layers of ice and dust. What can they tell us about recent climate cycles on Mars? Mars' mid-latitudes host older, debris-covered glaciers. What environmental conditions permitted glaciation of Mars' mid-latitudes, where exposed ice is currently unstable? Huge swathes of the high latitudes are draped in a smooth (at m-scale) ice-rich mantle that appears to be actively degrading. When did mantle modification processes change from deposition to degradation? Very young landforms in the northern latitudes appear to have formed by solifluction or freeze-thaw processes, yet Mars' climate is currently too dry and cold, and the atmosphere too thin, for water-ice to melt or liquid water to be stable at the surface. Do these landforms demonstrate a recent climatic excursion, or extreme micro-environments?

Additionally, 10m-scale aeolian mega-ripples known as Transverse Aeolian Ridges are abundant, appear to have pristine morphologies, yet must be relics of palaeoenvironmental conditions because larger dunes migrate by ~1 m per year under present-day winds, yet TARs remain immobile. Did global mean wind strengths change recently?



Theoretical studies suggest that Mars' obliquity (currently similar to the Earth's at  $\sim 25^\circ$ ) varies cyclically by up to tens of degrees on  $\sim 100$  ka timescales, with orbital eccentricity having similar cycles. Additionally, mean obliquity shifted from  $\sim 35^\circ$  to the present level around 5 Ma.

In this presentation we will describe Mars' 'Quaternary' landscapes, and discuss how they fit into the current understanding of Mars' recent palaeoclimate.

O-5001

## Building high resolution Holocene palaeoenvironmental chronologies: A case study from Lough Cullin, southeast Ireland

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### Abstract

The construction of robust, high resolution chronologies is a critical aspect of palaeoenvironmental study. Accurate interpretation of ecological patterns and processes and the integration of palaeoenvironmental data with the archaeological record requires precise chronologies, with the interpretative value of detailed sub-fossil proxy analyses impacted by poor or flawed chronological control. Radiocarbon is the predominant method for dating organic material such as peat and lake sediments which form the source material for most sub-fossil proxy records of environmental change. However, there are certain problems and issues in terms of 'best practice' approaches to the dating and chronological modelling of palaeoenvironmental records, including optimal sample selection in terms of different organic fractions (macrofossils, humin and humic fractions), the relative density of dates required in terms of individual sequences as well as with reference to particular sections of the radiocarbon calibration curve, and overall strategies in terms of maximising return from investment of effort and financial resources.

In this paper we present a case study of a near complete Holocene sequence from a small lake basin in southeast Ireland, with high-resolution radiocarbon dating, to constrain the environmental reconstruction of the area. The use of a multi-proxy approach, using pollen data, loss on ignition and XRF geochemical signatures constrained by this high-resolution dating reveal a palaeoclimatic history spanning the Holocene for the south-east of Ireland - an area which has been mostly overlooked on the island of Ireland, and where the influence of the Atlantic ocean is not as marked as it is on the west coast, where many of the palaeoclimatic studies have taken place to date. The sequence includes evidence of anthropogenic influences on the lake from early the Mesolithic to early Medieval times. Potential evidence of the 8.2k event affecting the environmental conditions of south-east Ireland is also seen within the sequence.

O-5002

## High-resolution multi-proxy reconstruction of Holocene productivity and lake mixing dynamics, Lake Żabińskie, Poland

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### Abstract

Human impacts to lake ecosystems are well documented, typically driven by land-use changes, increased nutrient loading and warming temperatures. Increased primary production and bottom-water anoxia are globally recognized as significant environmental problems. However, long-term records of eutrophication and meromixis are needed to understand the natural range of variability in lake systems and to be able to detect and quantify anthropogenic disturbances. Additionally, we can better understand the dynamics of lake ecosystems by studying the interactions between forcings such as climate and land-cover change and the response of lake ecosystems over long timescales.

Hyperspectral Imaging (HSI) is a recently developed, rapid, non-destructive, and cost-effective scanning method that measures the spectral signal of the sediments at very high spectral (3 nm) and spatial resolution (60 µm pixel size). Using this technique, the abundance of sedimentary pigments such as chloropigments and Bacteriopheophytin *a* can be quantified<sup>1</sup>. HSI data, in combination with micro X-ray Fluorescence (XRF) data, allow for unprecedented insights into lake ecosystem trajectories at subannual resolution.

In this study, we present Hyperspectral measurements of chloropigments and Bacteriopheophytin *a* to reconstruct lake productivity and meromixis, respectively, in a ca. 11,000 year-long varved sedimentary record from Lake Żabińskie, a small (42 ha) deep (44 m) kettle-hole lake in NE Poland. These data are supported by XRF, Carbon, Nitrogen and Sulphur elemental datasets. The record has been dated using varve counting (most recent 6,500 years), <sup>14</sup>C AMS dating (91 dates), and radionuclides (Pb-210 and Cs-137) to produce a high-quality chronology. Evidence of meromixis is found from ca. 10,600-9,800, 7,500-3,000, 2,600-2,100 and 1,330-330 cal yr BP. During the Holocene, the lake was typically meromictic with strong stratification favored by warm summer temperatures and limited wind fetch on the small lake surrounded by dense forest. Beginning in 1620 CE, forest clearing and increased agriculture lead to major increases in lake productivity and soil erosion rates (Ti counts)<sup>2</sup>. Prolonged meromixis (since 620 CE) was terminated at this time, with holomixis persisting until present. This is evidence of a direct link between anthropogenic land-cover modification and lake biogeochemistry. The causes of earlier shifts in mixing regime are currently under investigation, however there is evidence for erosional events causing the termination of meromixis periods, and periods of denser forest cover are likely associated with meromixis.

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O-5003

## Establishing the 'natural' baseline and anthropogenic perturbation of phosphorus dynamics in the Shropshire Meres

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### Abstract

Excess nutrient loading and the cultural eutrophication of aquatic ecosystems is a global problem. In many catchments mitigation practices to reduce loading and tackle the impact of excess nutrients have been met with varying success. Disentangling nutrient cycle and climate impacts on the lake ecology is challenging, particularly where the legacy phosphorus (P) contained in the sediments critically undermines catchment management practices to remediate impacts of P loading. The longer perspective from sedimentary records can be used to examine whether there is a history of nutrient loading and quantify the 'natural' baseline of a catchment. Palaeo-records provide a methodology for examining these long-term nutrient dynamics, however previous studies have tended to focus on measured element concentrations (or diatom-inferred P) rather than calculating loading.

Here a combination of sediment records and limnological monitoring from Crose Mere (Shropshire, UK) are used to show the benefits of a loading approach. The inclusion of sediment mass accumulation rates enables quantification of the P load from the catchment and allows the anthropogenic impact on the nutrient budget and the present-day lake status to be examined.

Twenty-four months of monitoring at Crose Mere found P levels which exceed EU water quality targets. Elevated P has persisted at the site since at least the 1970s, when the lake was previously monitored, and historical evidence suggests an even longer nutrient rich legacy. To understand the context of the present lake status, a longer-term approach is critical to determine both the onset and explore the causes of eutrophication. Here, sediment accumulation and geochemical records have determined the phosphorus and detrital erosion fluxes for the last ~12,000 years at Crose Mere. A transect of cores across the lake reveals repeatable basin-wide episodes that show increased flux of erosional indicators (soil-derived Ti, K, Zr, Rb) and these are accompanied by in-wash of particulate-bound P. The earliest of these episodes is attributed to Neolithic farming, with the subsequent pattern of loading increasing step-wise towards the present day. Pollen inferred episodes of human impact coincide with these rate increases in particulate and nutrient fluxes, and correspond to the timing of major (pre)historic periods. Fossil pigments record parallel changes in algal communities and show the in-lake ecological responses to changes in nutrient flux. Thus, Crose Mere has experienced a long legacy of human impact from low-level pre-historic perturbation of the landscape, introduction of agriculture and large-scale and permanent woodland clearances. Linking the monitoring of P dynamics with the sedimentary record suggests an initial onset to declining nutrient status ~800 years ago and crossing reconstructed EU thresholds for poor nutrient status ~60 years ago, highlighting the importance of legacy P in the management of lowland farmed catchments.

O-5004

## Impacts of human activities during the past 6500 years on terrestrial and lake ecosystems on the Swiss Plateau

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### Abstract

Humans have changed European ecosystems since the beginning of agriculture in the early Neolithic. Anthropogenic activities around lakes increased soil erosion and changed terrestrial nutrient cycles in the course of agriculture and domestication of animals, causing a release of additional nutrients into lakes and consequently leading to lake eutrophication. The information about human-induced changes in aquatic ecosystems and their surroundings can be extracted from lake sediments. Areas with a long history of human occupation are particularly attractive for studying the effects of early human impacts on lakes, since in these repeated phases of impact and recovery should be expected.

Burgäschisee is a small (21 ha), deep (31 m) and eutrophic lake on the Swiss Plateau with well-studied pile-dwellings and other archaeological findings indicating human presence and activities around the lake since the early Neolithic (ca. 4500 BCE). Burgäschisee is of particular interest because of its annually laminated sediments which allow the development of records with exceptional high temporal resolution and chronological precision. We applied multi-proxy palaeoecological (pollen, diatoms, non-pollen palynomorphs, microcharcoal) analyses to reconstruct human-induced eutrophication in Burgäschisee during the last 6500 years.

Our results show remarkable changes in diatom assemblages along with the first appearance of cultural indicator pollen, such as *Cerealia*-, *Hordeum*- and *Triticum*-type, as well as increased concentrations of microscopic charcoal in the sediments of Burgäschisee (3830-3620 BCE). Rapid increases of *Staurosira construens* and *S. venter* indicate a turbid environment as a result of landscape opening and soil erosion due to agricultural activities. Planktonic *Pantocsekiella pseudocomensis*, *P. costei* and *C. radiosa* are replaced by periphytic diatoms, such as *Gomphonema parvulum* and *Navicula vulpina*, indicating eutrophication due to anthropogenic impact. Additionally, the occurrence of akinetes of cyanobacteria (e.g. *Anabaena*, *Aphanizomenon*) supports our diatom and pollen-based interpretation that local human impact led to significant nutrient enrichment in the lake. The subsequent increase of planktonic diatoms, such as *P. pseudocomensis* and *C. radiosa*, indicate ecosystem recovery. The lake ecosystem recovered from human induced disturbances relatively quickly (probably promoted by the water level rise) but did not return completely to the pre-disturbance state.

According to the diatom data, the second remarkable regime shift occurred along with intensification of agricultural activities around Burgäschisee in the early Medieval period (ca. 700 CE). Small planktonic *Stephanodiscus binatus* indicate increased nutrient concentrations. Increases by *Tabularia flocculosa* and *Centronella reicheltii*, indicators of pH lowering, are more difficult to explain but may be caused by paludification of shores and/or by hemp retting, which had a direct impact on the lake ecosystem.



The obtained information is relevant for the understanding of lake ecosystem response to climatic change and human impact. Our study provides valuable information on the resilience of lake ecosystems to repeated human induced disturbance.

O-5005

## How severe was the impact of human activity on the landscape of Late Holocene Orkney? Evidence from Tuquoy, Westray.

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### Abstract

Since prehistoric times, human activities have played, directly or indirectly, an increasing role in the evolution of terrestrial ecosystems, generating significant changes in biotic communities, soil erosion and atmospheric pollution. In order to ascertain the severity of human impacts on the landscape, it is important to use a variety of different biogeostigraphic proxies to identify and separate the contribution of different causal factors, such as climate, and to assess the importance of each through time. A palaeoenvironmental investigation of sediments from the infilled Loch of Tuquoy, located within 500m of the high-status Norse farmstead and Crosskirk at Tuquoy on Westray, Orkney, provided an opportunity to assess the role of humans in landscape change. Orkney is an important location in the Viking/Norse world, containing a wealth of Norse archaeological remains, but little is known about the impact Norse communities had on the landscape and it is also located on the western seaboard of the North Atlantic so should be sensitive to changes in climate. Pollen, non-pollen palynomorphs, microscopic charcoal, sediment geochemistry and mineral magnetics were performed on a 2.2 metre-deep core to assess the severity of human activity. Two major periods of human activity occurred: the first from c. 900 to 150 cal BC and then between cal AD 700 and 1750, which encompasses the Norse occupation of the farmstead at Tuquoy. Pollen evidence suggests that land was cultivated for barley and oats/wheat and used for pasture during both periods as part of a mixed agrarian economy. While the landscape was largely treeless from 850 cal BC onwards, minor woodland clearance occurred in both periods. A cultural landscape seems to have been created before the Loch of Tuquoy record commenced and development of vegetation thereafter appears largely unchanged by human activity from the Late Bronze Age onwards. The palaeoeconomy of the Norse seems to have been a continuation of earlier practices. Switches in sediment source to the loch and changing intensity of non-pollen palynomorphs indicative of nutrient-poor water appear to be linked to human presence, but the loch shifts back to an earlier state when human activity appears to be less intense.

O-5006

## A late-Holocene proxy record of eutrophication in a small kettle lake (Ontario, Canada): Indigenous settlement or climate change?

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### Abstract

Globally, the period of AD 1000 to present was characterized by three climatic regimes: the Medieval Warm Period (AD 1000- 1300), the Little Ice Age (AD 1450- 1850) and the modern period (AD 1850- present). Many studies have invoked these intervals when interpreting shifts in sedimentary proxy signals during the late-Holocene. Previous research in Ontario (Canada), however, has suggested that bush burning and early agriculture undertaken by Indigenous peoples also influenced the eutrophication of lakes during this period. To understand the relative roles of climate change and Indigenous activities during the late-Holocene, we have analyzed recent sediments from Barry Lake, a kettle lake in southern Ontario which is located near the remnants of an Indigenous village (the Richardson Site), an important portage route (the Percy Portage), and an archaeologically-significant lake (Rice Lake). Interpreting proxies derived from the sediment organic matter allows us to trace the lake's productivity, indicating when cultural eutrophication may have occurred. Moreover, proxies from the inorganic record, such as the oxygen isotope compositions of marl ( $\delta^{18}\text{O}_{\text{marl}}$ ), offer information about historical temperature or hydrologic changes, indicating how climate affected the lake.

Thus, for two ~950-yr sediment core records tightly constrained by radiocarbon and lead-210 dates, we present (i) carbon ( $\delta^{13}\text{C}_{\text{org}}$ ) and nitrogen ( $\delta^{15}\text{N}_{\text{total}}$ ) isotope ratios of sedimentary organic matter; (ii) total organic carbon (TOC), total nitrogen (TN) and C:N ratios; (iii)  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of marl and shelly fauna; (iv) macrofossil analysis; (v) grain size analysis; (vi) mineralogy; and (vii) magnetic susceptibility. Both cores show synchronous changes in organic proxies that are indicative of eutrophication from AD ~1300 to AD ~1600. This period is characterized by increasing TOC, TN and  $\delta^{13}\text{C}_{\text{org}}$  and decreasing or unchanging C:N ratios. Our finding of eutrophication from AD ~1300 to AD ~1600 corresponds with similar trends at Crawford Lake (213 km distant), which were attributed to the population growth of Indigenous peoples. We have also determined, however, that  $\delta^{13}\text{C}_{\text{marl}}$  and  $\delta^{18}\text{O}_{\text{marl}}$  increase rapidly in one core from AD 1247 to AD 1307 (and increase in the other core from AD 1337 to AD 1446) and remain relatively high in both cores until AD ~1600, indicating that the changes in organic proxies may be driven by climatic change rather than (or in addition to) human activity. This research demonstrates that analyzing the isotope compositions of organic and inorganic sedimentary fractions can offer insights into the drivers of eutrophication.

O-5007

## A New Zealand perspective on the Anthropocene: how successive waves of human land use shaped Lake Pounui's current condition

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### Abstract

Despite New Zealand (NZ)'s "clean and green" image, which underlies its strong touristic appeal, 44% of the country's monitored lakes are categorised as eutrophic or worse. If one likens ecosystem health to human health and the ecologist's impact assessment to the physician's exam, the dearth of medical history readily becomes apparent. Most lake monitoring programmes are of too short a duration and only start after a system has already begun deteriorating, so that the ecologist cannot answer those fundamental questions analogous to the physician's "When did you begin feeling ill? How quickly did you become ill? What symptoms prompted you to seek medical attention?". Lake Pounui, located in NZ's lower North Island, is an all-to-common case – throughout its spotty four-decade monitoring history, the lake transitioned from oligotrophic to eutrophic states currently characterised by fortnightly episodes of anoxic bottom water during summer months. Interestingly, Lake Pounui's catchment comprises 90% native bush with marginal pastureland on the northeastern flank, and the lake is one of the few North Island bastions of declining *Isoetes kirkii*, an endemic aquatic macrophyte that indicates good health. In conjunction with the landowners, we developed null and alternative hypotheses directed at Lake Pounui's medical history: phytoplankton blooms have always occurred in Lake Pounui ( $H_0$ ), and the introduction of exotic fish species prompted a trophic cascade, resulting in the contemporary algal proliferations ( $H_1$ ). Results from a 3-kyr, multiproxy sediment record reveal eutrophic diatom abundances as prevalent 3-2 kyr BP as today, supporting  $H_0$ . Māori occupation was detected through an abrupt increase in macro-charcoal fragments concurrent with an opening forest canopy and the appearance of bracken fern. Together, these suggest people used the landscape for food staples roughly 400 yr BP. Whether intentionally or not, these catchment modifications clarified the water column, supported by the first appearance of *I. kirkii* and an increased abundance of epiphytic diatoms. Prokaryotic DNA from the most recent sediments exposes a fascinating sequence: bacteria typical of perch and trout gut contents precede denitrifying bacteria which in turn pre-empt cyanobacteria, a major constituent of the contemporary blooming flora. Collectively, these data suggest the introduction of pest species triggered a chain of events resulting in Lake Pounui's annual algal proliferation and that any restoration plan should consider exotic fish removal. This test case highlights the importance of long-term baselines, which are often only supplied by "paleo" techniques, to create evidence-based recovery programmes.

O-5008

## Northern Hemisphere Holocene land-cover reconstructions from fossil pollen data

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### Abstract

Terrestrial ecosystems play an important role in Earth systems processes, yet we still do not fully understand the feedbacks between these ecosystems and Earth's climate. These ecosystem processes operate at multiple timescales; fast processes occur at sub-annual timescales, and slow processes, driven by changes in forest composition and structure, occur over decadal and longer timescales. Slow processes are rarely directly observed from instrumental data, yet are critical to understanding the stability of the terrestrial biosphere over the coming decades. Networks of paleoecological data, particularly sedimentary pollen data, offer our strongest observational constraint on long-term vegetation dynamics and underlying processes and feedbacks.

We reconstruct land-cover for the Holocene for the Northern Hemisphere. To do this, we use: (i) networks of fossil pollen records - the most reliable paleoecological proxy for land-cover; (ii) estimates of pollen productivity and fall speed, and (iii) a model of pollen-vegetation relationships, REVEALS (Sugita, 2007). For the Northern Hemisphere, we estimate the fraction of summergreen trees, evergreen trees, and open land.

To determine the differences between these pollen-based reconstructions and land-use scenarios that are more commonly used land-use models, we compare the fraction of open land with estimates of deforestation from the anthropogenic land-cover change (ALCC) scenarios generated by KK10 (Kaplan et al., 2009). Identifying cause to these differences provides an opportunity for improvement in ALCCs used to inform both global earth system and dynamic vegetation models.

This work results in improved understanding of the history of Holocene land-use change over a large spatial extent and slow ecosystem processes, the biogeochemical and physical forcings from past anthropogenic land-cover change on climate, and the long-term carbon dioxide budget. It is a contribution to PAGES LandCover6k.

O-5009

## European land-use at 6000 cal BP: from on-site data to the large-scale view

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### Abstract

The PAGES LandCover6K group is concerned with whether prehistoric human impacts on land cover were sufficiently large to have had a major impact on regional and global climates. This is usually done via modelling land cover using different scenarios. However, there are major differences between the current available land-use scenarios, between these scenarios and reconstructions based on pollen analysis. The only way to provide a useful assessment of the potential for land-use changes to affect past climate is to input land-use models with more realistic land cover and land-use changes based on palaeovegetation (land cover) and archaeological evidence (land-use). Here, we present efforts to reconstruct land use for the European continent at 6000 cal BP, using a synthesis of land-use data derived primarily from radiocarbon dates, site based distribution maps, the environmental archaeological record of animals and plants recovered, alongside expert, contextual data.

We discuss some of the methodological challenges of developing generalised land-use categories within a European context and how these reflect the diversity of agricultural and hunter-gatherer land-use at this time; identify regions for which we have good datasets and major gaps in our understanding and how we move from point data to wider understandings of land-use activity. We present a top-level land-use map for Europe at 6000 cal BP and summarise key land-use activities and the variability of land-use for selected regions and potential per capita usage. Finally, we compare these data to preliminary land-use maps for periods before and after 6000 cal BP and to modelled outputs of land-use. We show that large areas of Europe were already occupied by 6000 cal BP and subjected to land-use change, although the intensity of land usage at this time varied significantly between regions, likely the consequence of both gaps in archaeological knowledge and differences in land-use practice. Incorporating this variability in land-use intensity will produce a considerable improvement in existing land-use scenarios.

O-5010

## Holocene quantitative pollen-based vegetation reconstructions in Europe for climate modelling: LandClim II

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### Abstract

Understanding land use and land cover (LULC) change through time is an important aspect when attempting to interpret human-environment interactions through time. Palaeoenvironmental techniques have been crucial in bridging this gap by providing information that has been used to estimate climate change, vegetation change, sea level change etc. through time using a variety of proxies. Producing quantitative land-cover reconstructions has been an aim and a challenge with several methods attempted during the decades. In this project, we use the REVEALS model has been tested and validated in several regions of the world.

We use REVEALS-based quantitative reconstructions of vegetation change to investigate the biogeochemical and biogeophysical forcings of land-cover change on climate. In the first phase of this project, LandClim I, quantitative vegetation reconstructions were produced for Europe (Mediterranean area excluded) focusing on five time windows of the Holocene between 6ka BP and present. The results from a regional climate model showed that the impact of the reconstructed LULC between 6 ka and 0.2 ka BP via biogeophysical forcing varied geographically and seasonally.

We present the REVEALS quantitative pollen-based vegetation reconstruction from the ongoing second phase of the project LandClim II "Quantification of the biogeophysical and biogeochemical forcings from anthropogenic deforestation on regional Holocene climate in Europe". This reconstruction covers entire Europe and is transient over the Holocene with a time resolution of 500 years between 11.2 and 0.7ka BP, and 100 to 300 years from 0.7ka BP to modern time.

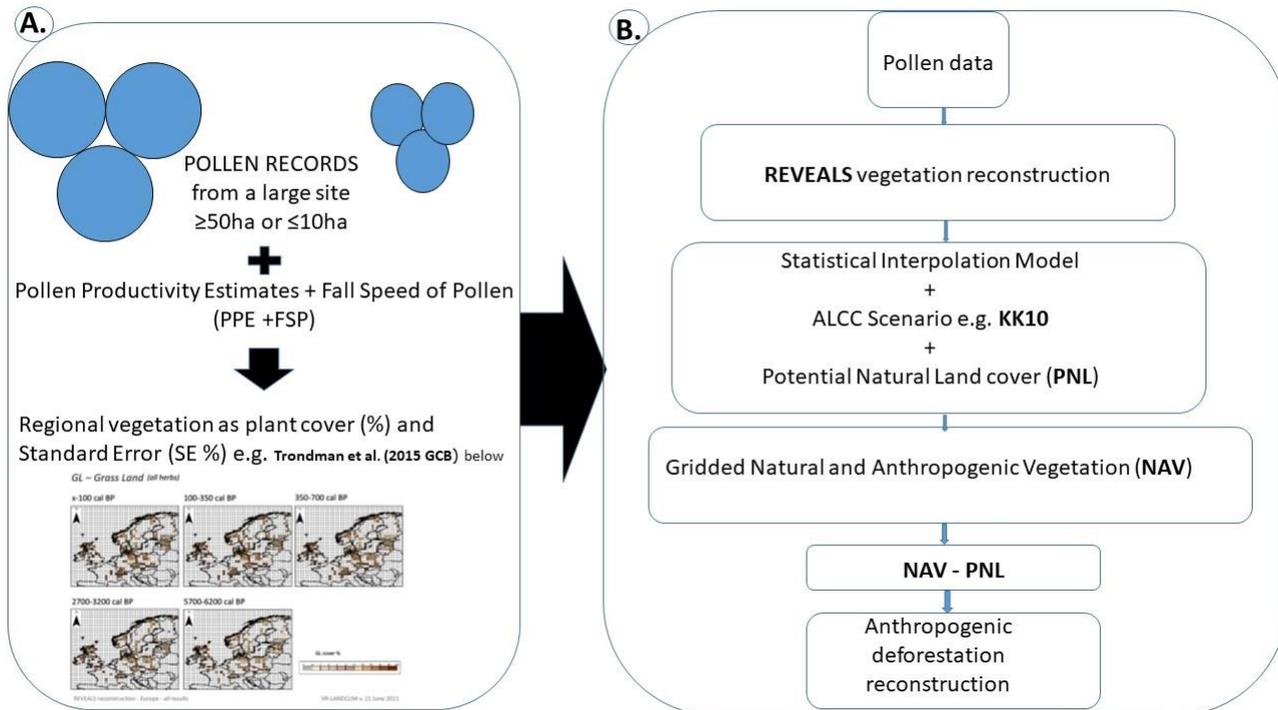


Figure 1: Schematic representation of the quantitative vegetation reconstruction process. **A.** Requirements and results of the REVEALS process while **B.** highlights the steps that we undertake to elucidate the anthropogenic impact from the natural land cover

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O-5011

## Spatiotemporal changes of Holocene cultivated land use in China based on archaeological data

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### Abstract

With the spread of agriculture during the Holocene, human cultivated land use has begun to alter the earth surface for thousands of years, however, the amounts and spatial patterns of land use are unclear due to lack of corresponding records in prehistoric period. PLUM (Prehistoric Land Use Model), which is developed based on the relationship between environmental variables and archaeological sites distributions, has been successfully validated and applied in several typical river valleys in northern China. In recent years, we have established an archaeological sites database across the whole China according to the systematic second national culture survey, and it provides an opportunity to reconstruct the spatiotemporal changes of cultivated land use during the Holocene in China.

The results reveal that the most significant relative and absolute increases of cultivated land use amounts occurred during 7-6 ka BP (about 174%) and 3-2 ka BP (about 136591 km<sup>2</sup>), respectively. The percentage of cultivated land use area to the whole country has increased from about 0.2% to 2.6% during 8-2 ka BP, which indicates that about 20.3% of modern land clearance levels occurred 2000-3000 years ago on average. In spatial sense, the Yellow River valley in northern China has been the most important human activity center until 5 ka BP, but the center has moved southwards and eastwards since then. Around 3 ka BP, the intensities of human activity in northern and southern China have even turned to the similar levels.

In comparison above results with the reconstructed vegetation evolution by pollen records in China, we could conclude that the impact of human activity on vegetation has intensified from regional to country scale during the Holocene, and the decrease of forest cover since 5 ka BP in eastern China is significantly accelerated by the coupled effects of drier climate conditions and spread of human cultivation.

O-5012

## REVEALS -based reconstruction of Holocene vegetation abundance in temperate China: new insights on past human-induced land-cover change for climate modelling

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### Abstract

Quantification of the effects of human-induced vegetation-cover change on past (present and future) climate is still a subject of debate. Our understanding of these effects greatly depends on the availability of empirical reconstructions of past anthropogenic vegetation cover. In this context, China is an important region given that agriculture started already in early Holocene, and expanded rapidly over large areas throughout the eastern part of the country. Quantitative reconstructions of plant cover based on pollen data has long been a challenge. In recent years, approaches were developed to correct biases due to inter-taxonomic differences in pollen productivity, dispersal and deposition, and between-site differences in size and type of accumulation basin (lake or bog). The REVEALS model (Sugita, 2007) is the approach for quantitative reconstruction that has been most tested, validated, and applied over the last years. The model estimates regional vegetation cover using pollen records from large lakes or multiple small sites (lakes and bogs). The spatial scale of REVEALS reconstructions is ca. 10<sup>4</sup> km<sup>2</sup>, which is adequate for climate modelling. Relative pollen productivity (RPP) of plant taxa is a key parameter required for REVEALS applications. RPP estimates are available from earlier studies in temperate China for plant taxa characteristic of steppes, meadows, and woodlands.

In this study, we estimated RPPs for plant taxa of traditional agricultural landscapes in central-eastern China, as a complement to earlier RPP studies (Li et al., 2017). We then established a synthesized RPP dataset by assessing all available RPPs (Li et al., 2018) and used it with pollen records from lakes and bogs to produce REVEALS-based estimates of Holocene regional vegetation-cover change in temperate China. We compared the REVEALS reconstructions with existing data on past climate and human history in order to interpret our results in terms of anthropogenic land-cover change. The study is a contribution to PAGES LandCover6k.

The REVEALS-based estimates of regional plant cover differ significantly from the pollen percentages. Pollen percentages mainly underestimate landscape openness in comparison to REVEALS based estimates of open-land cover, except when *Artemisia* (high RPP) is dominant. Timing and magnitude of change often differ between REVEALS-based plant cover and pollen percentages. There is general agreement between periods of increased REVEALS-based landscape openness and times of human activity as inferred from archaeological data. Human-induced deforestation is highest in eastern China with 3 major phases at ca. 5500, 3000 and 2000 calibrated years before present. The cover of trees was highest during mid Holocene from ca. 8000 BP in some regions, mainly between ca. 7000–5000 BP and until ca. 3000 years BP.

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O-5013

## Relative Pollen Productivity estimates (RPP) of some key pollen taxa in south-east India

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### Abstract

Reconstructing the past vegetation conventionally uses pollen percentages (PPs) or pollen accumulation rates (PARs). Qualitative interpretation of PPs and PARs is based on insights gained from modern analogues of the pollen-vegetation relationship or on the comparative approach that compares past and modern pollen assemblages. Quantifying past vegetation/ land cover using pollen data requires other approaches that can correct the non-linear relationship with vegetation and biases due to inter-taxonomic differences in pollen productivity, dispersion and deposition. Relative Pollen Productivity (RPP) can be estimated using the Extended R-Value (ERV) model (Prentice and Parsons, 1983), provided modern pollen assemblages and distance weighted vegetation abundance (DWPA) around the pollen sampling point are available from actual field measurements (e.g. Li et al., 2017).

We present for the first time RPPs of some of the key pollen taxa retrieved from the fossil pollen sequences located within the broader *Acacia–Albizia* biogeographic zone in the drier parts of south-east India along the Coromandel coast, falling in the rain shadow of the southwest or summer monsoon. To achieve this, surface soil samples for pollen analysis and distance-weighted vegetation data were collected from 14 sites in the current mosaic landscape of this biogeographic zone using the Crackles Vegetation Survey protocol (Bunting *et al.*, 2013). RPPs of 6 key pollen taxa, viz., Poaceae, *Acacia/Albizia*, *Dodonaea*, *Justicia*, Melastomataceae/ Combretaceae, and *Randia* were estimated with the ERV model (sub-model 3) for which the best likelihood function curve was obtained using the Prentice Bog (dispersion) model. Results indicate a Relevant Source Area of Pollen (sensu Sugita, 1994) of 164 m radius for the modern pollen samples. The estimated RPPs relative to Poaceae (RPP set to 1) are highest for *Acacia/Albizia*, *Dodonaea*, and *Justicia* (>10), and are <5 for the three remaining taxa. Ecologically, taxa such as *Acacia/Albizia*, *Dodonaea*, Melastomataceae/ Combretaceae, and *Randia* are considered as markers of the Tropical Dry Evergreen forests of the Coromandel Coast.

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O-5014

## Testing the REVEALS model in South-East India – reconstruction of Holocene regional land-cover change

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### Abstract

Pollen-based quantitative reconstruction of regional land cover is an essential step to infer past landscape dynamics and to produce vegetation descriptions useful in Earth-system modelling. In this study, we test the REVEALS (Regional Estimates of VEgetation Abundance from Large Sites) model (Sugita, 2007a) for the first time tropical south east India to reconstruct Holocene regional land-cover change. We use three fossil pollen records from the Coromandel coast, falling in the rain shadow of the southwest or summer monsoon and characterized by Tropical Dry Evergreen Forests (TDEFs). One of the pollen records is from a site located in the same region as sites used to estimate Relative Pollen Productivity (RPP) needed for the application of the REVEALS model. The two other pollen records are from the same biogeographic zone, ~150 km south of the primary site. The REVEALS reconstructions are achieved for consecutive 500-year time windows up to 0.7 ka BP and time windows of decreasing length up to present following the protocol of PAGES LandCover6k (Gaillard et al. 2018).

In addition to RPPs estimated for six key taxa of SE India, *Poaceae*, *Acacia/Albizia*, *Dodonaea*, *Justicia*, *Melastomataceae/Combretaceae*, and *Randia*, we applied RPPs from China (Li, et al., 2017) for *Aster/Anthemis-t.* (known as Compositae Echinata in India), *Amaranthaceae/Chenopodiaceae*, and *Cyperaceae*, assuming that RPPs in temperate China and SE India are comparable. The REVEALS reconstructions suggest that, except for *Cyperaceae*, all other taxa are over-represented in the pollen record. Fluctuations in the quantitative estimates of key pollen markers of the TDEF vegetation through time indicate that the present mosaic vegetation of the region may have existed for a long time, and that the land cover of SE India was a scrubland with grasses and patches of TDEFs through most of the Holocene.

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O-5015

## Microfacies analysis of Lateglacial Swedish clay varves

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### Abstract

One of the most renowned varve chronologies is the Swedish Timescale (STS). This is generated through the analysis of annual layers deposited in the Baltic Ice Lake (BIL), which was ice-dammed by the Fennoscandian Ice Sheet during the Lateglacial Interstadial and Younger Dryas periods. The STS is based on correlation between numerous clastic varve thickness series, which generates an annually resolved record of Fennoscandian Ice Sheet retreat. However, the total number of varves in the STS is contested with some researchers suggesting there are “missing varves”, in particular 700-900 years are missing during the Younger Dryas - Pre-Boreal period (12.9-11.35 ka BP). These errors may be caused by the practice of linking varve series between sites based on either macroscale varve thickness patterns and/or distinct sedimentological features, observed at the macroscale that are considered to reflect regional processes. However, to date, there have been few studies that have examined the microfacies of the glaciolacustrine varves from this time period and that test whether sedimentological features identified at the macroscale are corroborated by common features at the microscale across sites.

We present the results of microfacies analysis from three Lateglacial/early Holocene varve records from Östergötland. Microfacies analysis has enabled an understanding of the evolution of local proglacial lake processes through the construction of site-specific varve deposition models. Several distinct varve microfacies ranging in thickness, texture and structure were identified at each site. Melt season characteristics vary from complex microfacies that are typically >10 mm thickness with multiple sediment inputs (proximal varves) to simple single-layered melt seasons in the thinner, <1 mm thickness varves (distal and ultra-distal varves). However, whilst there are common microfacies at each site, differences exist and these changes occur over temporal scales. In addition, across all three sites, deformation structures such as faults, folds and inverted varves were identified, but the frequency and complexity of deformation zones is site-specific. We suggest that the observed differences in varve microfacies and frequency of deformation zones likely reflect a combination of a) local lake processes and b) differences in local slope instability; verified by basin topographical surveys.

These results have implications for the robustness of the existing Lateglacial STS and potentially the timing of deglaciation in Sweden. We conclude by making a series of recommendations for correlating regional varve thickness chronologies and to test existing correlations.

O-5016

## Wijdefjorden and Femmilsjøen – an integrated fjord-lake study in northern Spitsbergen

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### Abstract

Recent research in Svalbard has provided compelling evidence for early Holocene glacier advances during a time when marine bivalves indicate that the surrounding seas were warm. The overall aim of this project is to reconstruct the Holocene climate and glacial history of northeast Spitsbergen, using a holistic approach that includes collection and integration of marine, terrestrial and lacustrine data. The area of main interest is the 8 km long lake Femmilsjøen in NE Spitsbergen, one of the largest and deepest lakes in Svalbard, its surroundings, as well as the adjacent, outer parts of the fjord Wijdefjorden. The surge-type glacier Longstaffbreen terminates in the eastern end of the lake.

Marine sediment cores, swath bathymetry data, as well as sub-bottom profiler data were collected just off Femmilsjøen in the summer of 2017. Lacustrine sediment cores, sub-bottom profiles and swath-bathymetry from the lake were collected in 2018. The surrounding area of Femmilsjøen, between the coast of Wijdefjorden and Longstaffbreen/Midtgarsbreen, were mapped during the field campaign in 2018, and ridges with shells deposited by re-advances during Late glacial - early Holocene were identified. The acoustic data reveal numerous transverse ridges across the lake floor. Acoustically stratified deposits fill the depressions between these ridges.

On-going analyses of the sediment cores from the two archives are: lithostratigraphic logging, organo-geochemical analyses, biomarker and granulometric analyses, as well as XRF core scanning. The multiproxy approach enables inter-archive comparison.

This study will help to clarify the timing of glacier advances in the region in relation to the timing of incursion of warm marine waters in the early Holocene. On our poster, we present preliminary results of the on-going analyses of the data set and we discuss potential and draw first implications about the development of the environmental conditions during the Holocene on northeast Svalbard based on our terrestrial-marine records.

**O-5017**

## **Formation and deformation of an ice-contact sub-lacustrine fan, Blessington, Ireland**

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### **Abstract**

A Late Midlandian/Devensian ice-contact delta with foresets >60 m high developed during ice retreat from its LGM position against the Wicklow Mountains. The delta complex includes a zone of sub-lacustrine fan sediments <200 m wide, which built up a ridge >20 m high, and leeside bottomset sands extending several hundred metres further. Successive faces in an active gravel pit, cut perpendicular to ice movement towards the SE, revealed the geometry and sedimentary architecture of the fan.

The following features are present: 1) an early fan ridge with common flat thrusts; 2) a thin diamict drape over this ridge; 3) backsets <15 m high including gravel cross-beds prograding up slope; 4) local W-dipping erosion/non-deposition surfaces on the ice side of the fan ridge, time-equivalent to highly asymmetrical growth of foresets on the lee side; 5) rare larger-scale W-dipping erosion surfaces truncating <15 m of section; immediately below these surfaces are localized gravel fans <8 m thick, indicating that these are effectively ice-contact surfaces; 6) diamict "intrusions" <6 m high penetrating and deforming adjacent fan sediments; 7) occasional W-dipping thrust sheets >5 m thick with diamict at base, overlain by bedded sediment; some emerged on lake floor, to be partially eroded before burial; 8) back-slope collapse features on various scales, including coherent rotated blocks of sand and gravel >5 m thick; 9) steep gravity-faulted back-slope surfaces displaced by subsequent low-angle thrusts; 10) a free-standing vertical cliff >5 m high cut through undisturbed horizontal sediments; 11) sand and silt diapirs on various scales, some due to sediment loading, some probably responding to ice push.

The faces show a complex history of ice retreat and re-advance on a local scale, during overall retreat prior to growth of the delta itself. Distance between the ice and the fan ridge varied: when close, erosion surfaces and asymmetrical leeside foresets developed, or cross-bedded sediments prograded up the backslope; with ice retreat the backslope often collapsed, sometimes to be followed by re-advance and thrusting of the remaining ridge. Prolonged melting of buried ice blocks was responsible for some deformation.

O-5018

## Environmental reconstruction based on lake sediments: implications for proglacial lakes distribution in central Russian Plain during the last glaciation

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### Abstract

Lake Galich (58°24'N, 42°17'E, 101 m above sea level) is one of the largest natural lakes in the middle part of the Volga River basin. Although it is situated outside the area of the Late Valdai/Weichselian ice-sheet, it is believed that during the Last Glacial Maximum (LGM) it was a part of the vast Kostroma proglacial lake connected with other similar lakes. According to this hypothesis, during the LGM the shoreline of the Kostroma proglacial lake was at about 145 m a.s.l., and the present-day Lake Galich formed a narrow bay over 60 m deep. According to the age model based on radiocarbon dating, 69 m of Lake Galich sediments penetrated by coring accumulated for almost 60 thousand years. This sediment thickness provides a continuous archive of the Valdai Glaciation environment and climate history, from the end of the Marine Isotope Stage (MIS) 4 to the beginning of the Holocene, which is unique for the region. The studies of Lake Galich sediments are of great importance for resolving the question of the existence of large proglacial lakes in the central part of the Russian Plain during the LGM. Palynological data indicate that during the Early and Middle Valdai (MIS 4 and 3) the vegetation in the area was of a periglacial forest-steppe type, with open woodlands of spruce, pine and birch. Grain-size analyses of lake sediments indicate very stable sedimentation conditions during MIS 3, with particle size gradually increasing from clay to medium loam and an average accumulation rate of 1.4 mm per year. At the boundary of MIS 3 and 2 the sediment accumulation rate did not change, but the fraction of coarse silt, the main component of loess deposits, reached its maximum content (60%). At the LGM, the periglacial-steppe communities with *Artemisia* prevailed in the area due to increasing aridity of climate. Development of erosion on the slopes poorly protected by sparse vegetation is marked by presence of spores reworked from the Jurassic and Early Cretaceous deposits. After the LGM, the mean accumulation rate of lake sediments decreased to 0.8 mm per year, in spite of the considerable increase in particle size. Therefore, the studies of bottom sediments of Lake Galich showed no traces of a manifold increase in the depth of the lake during the proposed damming up to 145 m a.s.l. at the LGM, which casts doubt on the very possibility of such proglacial lakes existence in the region at the time.

The research was carried out with support of the Russian Science Foundation project 17-17-01289 «Runoff rerouting and migration of the Main Divide of the Russian Plain during the last glaciation».

O-5019

## The Last Glacial and Holocene deposits of Lake Bolshoye Shchuchye, Polar Ural, Arctic Russia

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### Abstract

Seismostratigraphic studies of the 11.8 km<sup>2</sup> and ~140 m deep Lake Bolshoye Shchuchye, Polar Urals, reveal that the lake basin contains up to 160 m thick acoustically laminated sediments. The spatial and temporal distribution of the lake sediments have been mapped with the aid of 100 seismic profiles and 2 well-dated long sediment cores retrieved from the lake basin. Time slice maps constructed from the seismic reflection data allows the sediment volume and sediment flux to be quantified through four periods. Hemipelagic processes dominated the sedimentation in Lake Bolshoye Shchuchye during at least the last 24 cal. ka BP, with only local variations from delta progradation and slope gravity processes. The sedimentation rate during Last Glacial Maximum was high and characterized by varved deposits. A major shift in the sediment accumulation, dated to c. 18.7 cal. ka BP, is interpreted to mark the end of the local glacial maximum and the initiation of glacial retreat in the area. At this time the sedimentation flux was greatly reduced, indicating fast retreat and possible disappearance of the glaciers. The shift at the Younger Dryas - Holocene boundary is very pronounced in the seismic signature, marked by a further reduction in sedimentation rate. The denudation rate in the accumulation area during the Holocene is only a eighth of the LGM denudation rate. The age of the oldest stratified sediments in Lake Bolshoye Shchuchye is not well constrained, but estimated to c. 50-60 ka.

O-5020

## The development of proglacial lake within the Izborsk-Malskaya paleovalley (Pskov region, Russia) in the Late glacial time.

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### Abstract

Some fingerprints of lacustrine conditions (varves and ancient shorelines) were found into the Izborsk-Malskaya paleovalley (Pskov region, Russia). It gave us a possibility to suggest the existence of unknown earlier proglacial lake which was forming during the deglaciation of paleovalley. The semi-buried erosion form (Izborsk-Malskaya paleovalley) is located at the base of the eastern slopes of the Haanja Upland. The paleo-incision is narrow, straight and deep (the modern depth is 40-50 m, while the depth of paleovalley - about 100 m). The thickness of the Late Pleistocene glacial deposits filling the paleovalley reaches 50 m.

During the fieldwork in the southern part of paleovalley were found varves. The depth of their top varies from 6,40 to 8,20 m (probably more). There is a decrease in depth of varves towards modern lakes located at the bottom of paleovalley. Near the northern shoreline of Lake Malskoye was observed hummock moraines and other landforms originated under a condition of melting dead ice which could dam the runoff from the proglacial lake. The position of the former ice-dam and structure of terraces of the valley right side helps us to reconstruct sizes of the proglacial lake. AMS 14C dates combined with results of pollen analysis support that the proglacial lake was existing during the Allerød. The proglacial lake was rapidly drained at the end of the Allerød. This event reflects in the sediment sequence. Grain size and microstructure analysis of varves obtained to suggest that the key borehole penetrated into proximal and distal varves formed in different ways of sedimentation.

Investigations of geomorphology and sediments filling the paleovalley allow us to reconstruct the proglacial lake development within the Izborsk-Malskaya paleovalley and also deglaciation features of the paleo-incision.

The reported study was funded by RFBR according to the research project № 18-35-00700.

O-5021

## Palaeoenvironmental history of proglacial lakes in eastern Siberia.

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### Abstract

Sedimentary records from glacial lakes of eastern Siberia provide insight into palaeoenvironmental changes over the late Quaternary. One key site represents the Bol'shoe Toko lake system in southeastern Yakutia, Russia (56°15'N, 130°30'E). It is situated at 903 m a.s.l. at the northern foot of the Stanovoi Mountains. Surrounded by three sets of moraine arcs and an ancient lake terrace, the hydrologically open fresh-water lake basin is 83 km<sup>2</sup> large and extends over 15 km in length and 7 km in width, with a maximum water depth of 80 m. The central part of the lake includes a subaquatic ridge. Isolated smaller kettle-like lakes cover the surrounding moraines and terrace. The geomorphological features point to a former proglacial setting, though the mountainous catchment (up to 2200 m a.s.l.) today is unglaciated. The area is occupied by taiga vegetation and situated within the continental temperate climate zone.

The lake system represents a natural laboratory of hydrology and palaeolimnological changes in the past, unaffected by direct anthropogenic influence. Modern hydrochemistry (ions and stable isotopes) displays differences between the open and closed water bodies, which tend to higher and heavier element concentrations. These lake systems also differ with oligotrophic conditions in the large and deep lake and mesotrophic conditions in the smaller and shallower lakes. This contrast is also reflected in limnoecology by bioindicators of preserved modern remains of diatoms and chironomids and the composition of organic matter in modern lake-bottom sediments. Water depth is another important habitat factor for limnoecology. Mineralogy and grain size of the minerogenic sediment fraction helps to unravel sediment supply from the mountain river versus shore erosion.

Modern depositional environments support the interpretation of sediment cores, spanning the last 30 kyr, according to radiocarbon dating. A glacial advance during the last glacial maximum, did not affect the whole lake, as former glaciations did. Postglacial development was characterized by a lake-level lowering of around six metres around 4.5 ka BP after the early to mid-Holocene climate optimum, demonstrated by the deflooding and isolation of a small lake on the lower lake terrace. Diatom remains in short sediment cores, dated by Cs and Lead activity, point to ecological changes during the last century, possibly related to the onset of global warming.

Restricted glaciation during the last glacial maximum compared to former glacial advances is consistent with geomorphological and limnogeological findings from the central Verkhoyansk Mountains some 1000 km farther to the north. The sequence of mountain glaciation thus is out of phase with the global ice-volume pattern, possibly because of complex atmospheric moisture routing effects, which so far are poorly understood for eastern Siberia. The postglacial lake history matches the northern-hemispheric pattern of Holocene climate history.

O-5022

## Defining the 'generalist specialist': Exploring the ecological and cultural plasticity of Middle and Late Pleistocene *Homo sapiens*

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### Abstract

Attempts to define our species as unique amongst all other hominins have tended to focus on differences in capacity for symbolism, language, social networking, technological competence, and cognitive development. More recently, however, a series of researchers, drawing on previous discussions of 'variability selection', have highlighted the unique *ecological* characteristics of *Homo sapiens*. Here, we critically review the current archaeological, palaeoecological, and palaeoenvironmental datasets associated with the Middle to Late Pleistocene (300-12 ka) evolution and dispersal of our species within and beyond Africa. We argue that evidence for the occupation of diverse 'extreme' environments, including deserts, high altitude environments, the palaeoarctic, and tropical forests characterize our species as a 'generalist specialist'. Not only could *H. sapiens* occupy and use a variety of environments, but local human populations could also develop specialized, culturally mediated adaptations in particular environments over the course of millennia. Testing and evaluating this ecological niche represents a framework for discussing what it means to be human, and reveals new priorities in archaeological and palaeoanthropological research. It also represents a potential point of intersection for discussions of human neurological, cultural, and ecological 'plasticity'.

O-5023

## Evidence for Aterian occupation of a humid Sahara shows that archaic *Homo sapiens* could occupy a diverse array of environments

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### Abstract

The Aterian is crucial to understanding the dispersal of early modern *Homo sapiens* and the development of behavioral complexity in North Africa. A currently unresolved question relates to the environments and climates that these early *Homo sapiens* occupied. Here we report a new Aterian site in Southern Tunisia that shows occupation of a humid Sahara. It is found within shoreline deposits of a megalake which developed within the Chott el Djerid basin during past humid periods. The geomorphology, sedimentology, molluscan/fish/ostracod assemblage and OSL ages indicates a fresh water lake existed between 80 and 90 ka. The Aterian lithics recovered from the site occur in association with an extensive assemblage of vertebrate remains consisting of 25 different taxa that indicates an open savanna environment. Analysis of the fauna suggests a natural death assemblage, yet some faunal remains bear witness to human butchery, indicating active scavenging of carcasses by Aterian populations. This evidence of Aterian occupation of a humid Sahara contrasts with evidence from other sites for occupation of arid and coastal environments, thus indicating that these archaic *Homo sapiens* could occupy a diverse array of environments, from the benign to the extreme.

O-5024

## Coping methods – how Western Mediterranean hunter-gatherers dealt with climate change

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### Abstract

Throughout the Late Glacial in the Western Mediterranean, there are multiple evidences of rapid climate change that likely affected the hunter-gatherer inhabitants of the region. A particularly significant example was Heinrich Event 1, a short-term climate event 18 to 15 thousand years ago. Paleoclimate models (Ludwig et al. 2018) show an increase in arid areas throughout the Southern parts of the Western Mediterranean, which are expected to have significantly influenced human settlement dynamics. To this day, however, the exact impact and nature of such changes is poorly understood.

Working with a comprehensive archaeological database, this contribution analyzes the influence such rapid climate changes had on the hunter-gatherer societies of the Western Mediterranean. With a rich research history and a detailed archaeological and climatological dataset to work with, the prehistoric societies inhabiting Late Glacial Northwest Africa and Iberia are an ideal test case to examine human–climate interactions. Focusing on the Late Pleistocene societies of Morocco and comparing them to contemporaneous groups on the Southern Iberian Peninsula, we drafted a multi-proxy approach to characterize and compare different land use strategies. We applied a number of spatial analytical methods to our dataset of Iberomaurusian and Magdalenian sites of Heinrich 1 and Greenland Interstadial 1 (18-13ka). With this approach, we aimed not only to examine direct reactions to the environmental changes of Heinrich 1, but also the aftermath during the subsequent phase of climate amelioration.

We were able to identify different land use strategies employed by both societies during as well as after Heinrich 1. These we interpret as different coping strategies used to deal with phases of increased aridity, leaving unique, detectible marks on the archaeological record. Importantly, we also show that the reactions to short-term climate events have long-term impacts on societies, these remaining in place even after the climate event itself has passed. These observations not only expand our knowledge of Western Mediterranean prehistory, but also hint at the wide range of methods prehistoric communities employed to cope with extreme environments.

### References:

Ludwig, P. et al, 2018, *The Last Glacial Maximum and Heinrich event I on the Iberian Peninsula: A regional climate modelling study for understanding human settlement patterns. Global and Planetary Change* 170, 34-47.

O-5025

## The Middle Stone Age open-air dynamics in semidesertic areas of Eastern Morocco

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### Abstract

The *Homo sapiens*-related Middle Stone Age occupation of Eastern Morocco is well-known from cave or rockshelter long sequences (ie. Station Météo, Rhafas, Ifri N'ammur, Taforalt). Notwithstanding, little or nothing is known about open-air dynamics, where the only information so far came from disperse and unstratified lithic scatters.

For the last ten years, we have undertaken systematics surveys and excavations in the Aïn Beni Mathar – Guéfaït basin, Jerada province, which has allowed the discovery of different stratified open-air locations and provide new data about the *Homo sapiens* management of wider environments. The paleoecological reconstructions show open semidesert environments with vegetation concentrations related to water points and lakes, very similar to the actual landscape. The sites documented are mostly located on slopes and exposed surfaces of riverbanks, around springs, and appear to be associated with areas rich in both biotic and abiotic resources, namely lithic raw materials outcrops. Technologically these sites are characterized by homogeneous sets of flake assemblages with important Levallois components (preferential and recurrent) but also discoidal and opportunistic strategies. Retouched tools are abundant, mainly denticulates and scrapers, and at some locations “Aterian” assemblages with tanged pieces and bifacial foliates have been documented.

In this paper we present data about different surface locations discovered in the Sahb el Gahr – Swiwina plain, including the systematic excavations at SBG1-1 & SBG2-1 and Oued Charef sites. Our interdisciplinary results will provide an overview of this MSA dynamics open air contexts in a semidesertic area, focusing on the subsistence strategies and comparing them with the information provided by cave and rockshelter occupations.

This work will contribute to providing a broader perspective of the *Homo sapiens* technological evolution and adapting during the North African Middle Stone Age.

O-5026

## Living in the lake: Stone Age habitats and hydrological change in the Kalahari Desert, southern Africa

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### Abstract

The interior Kalahari of southern Africa is an archaeological enigma: a desert that is not quite a desert; lacking surface water yet with evidence of multiple Lake highstands during the last 250ka; and long regarded as an archaeological backwater. It is home to the world-renowned MSA sites at Tsodilo Hills but despite the wider landscape being noted 70 years ago for its rich lithic legacy, systematic archaeological analyses have been few and far between, especially in the context of extensive open-air sites. This huge region remains a significant knowledge gap in African Stone Age archaeology.

From 2016-19 a major landscape archaeology project has been conducting the first systematic analysis of the extensive Stone Age archaeology of the Kalahari's 90,000km<sup>2</sup> Makgadikgadi basin, framed around the question of how Late Quaternary hydrological changes, relating to mega-lake waxing and waning, affected human mobility, resource use and the distribution of archaeological sites in the landscape.

We have mapped 38 archaeological sites and 44 scatters/minor sites (mainly MSA, also LSA and Pastoralist) on the floor and perimeter of Makgadikgadi; excavated six sites using *décapage* methodology; conducted sedimentological and landform including sampling for chronometric (OSL, <sup>14</sup>C), geochemical and bio-proxy analyses; and mapped and sampled >300 silcrete outcrops for geochemical provenancing of lithic source areas. Together, these methods provide an unprecedented approach to reconstructing MSA interactions with, and movement in, a hydrologically dynamic environment, with implications for wider theories of early human interactions with changing environments.

Preliminary findings indicate extensive MSA use of Makgadikgadi during lowstands or at seasonally dry times. Basin floor occupation sites have been preserved through burial during lake highstands and subsequent deflation exposure. Raw materials are dominated by black silcrete that arrived from a range of source areas, often many tens of km distant, in different stages of preparation. While the degree of post-depositional artefact disturbance varies from site to site, *chaîne opératoire* analyses show that some sites are surprisingly well preserved. In these cases flakes and tools have been refitted to cores over distances of a few metres, allowing documentation of technological approaches and knapping sequences, with further reconstruction of site specific behaviour patterns. Excavated sites fall in the 90-70ka age range. Overall, the Makgadikgadi MSA has greater affinities to areas to the north and east rather than South Africa, suggesting that hydrological networks connecting the basin to more tropical source regions have played a key role in Late Quaternary societal dynamics.

O-5027

## Social network mapping in southern African highlands and drylands using strontium isotope geochemistry

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### Abstract

Today's social media platforms are the outermost branches of an evolutionary tree whose roots run deep. At some point in the Pleistocene, hunter-gatherers began exchanging non-utilitarian artifacts like beads and other ornaments over hundreds, and sometimes thousands of kilometers. Among ethnographically documented foragers these networks symbolically link distant groups, acting as social adhesives that enhance fallback opportunities, information availability, and reproductive potential, among other benefits. Charting the evolution of long-distance social networks can thus help determine when, why and how our species began harnessing material culture to mitigate risk, particularly when strategizing life in extreme environments. This paper presents the results of strontium isotope analyses of ostrich eggshell beads recovered from late Pleistocene and Holocene contexts in two contrasting habitats of southern Africa: the Namaqualand Desert (South Africa) and Maloti-Drakensberg Mountains (Lesotho). Our data demonstrate the existence and persistence of highland and dryland exchange networks, and hold implications for tracing the development of social strategies for long-term survival in the southern African interior.



Figure 1. A 30,000 year-old Middle Stone Age ostrich eggshell bead from Sehonghong Rockshelter, Lesotho

O-5028

## Assessing variations in the habitability of deserts during humid episodes: defining extreme.

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### Abstract

Hyper-arid deserts are some of the most hostile environments on the planet for humans. Nonetheless, archaeological evidence demonstrates repeated occupations of the Sahara and Arabia during the Pleistocene and Early Holocene, correlating temporally with orbitally mediated periods when these areas were relatively wetter and greener. During such 'greening' episodes, however, environmental amelioration would have been spatiotemporally variable, dependent upon diverse geomorphological, hydrological, and topographic conditions and the interaction of these local variables with large-scale climatic conditions, such as the movement of the ITCZ and monsoon belt. It thus cannot be assumed that amelioration of these deserts was uniform, and a spectrum of environments likely existed, some more extreme than others. However, this dynamism and its expression at different spatial scales remain relatively poorly understood. Understanding the spatiotemporal patterns of habitability within these deserts is crucial both for understanding the observed distribution of archaeological sites, and for assessing the important roles these areas may have played in relation to key events in human history through the removal, or reinstatement of barriers created by hyper-aridity and absence of surface water.

Here we discuss how syntheses of palaeohydrological mapping and palaeoenvironmental proxy data can elucidate where seasonally or permanently activated drainage, lakes, and wetlands may have recurrently formed in these deserts during different humid periods, and where the density and distribution of these water sources may have produced relatively contiguous 'corridors' of surface water. We discuss high spatial resolution (90m) data we have now produced for the Saharan and Arabian deserts. These data allow more nuanced discussion of when and where relatively more hospitable and inhospitable environments persisted during humid episodes, permitting hypotheses to be proposed regarding where different regions within deserts lay upon an 'extremity spectrum'. At a larger scale, the patterns of when and where habitable environs connected at different times are providing new insights into potential environmental controls upon routes for hominin dispersals and population interactions, in particular, new data regarding likely routes for early expansions of our own species within Africa and across southwest Asia.

O-5029

## Holocene hydroclimatic change in south-central Alaska inferred from $\delta^{18}\text{O}_{\text{diatom}}$ at Sunken Island Lake, Kenai Peninsula lowlands

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### Abstract

Reconstructing the Holocene hydroclimate of southern Alaska is important for understanding the evolution of North Pacific ocean-atmosphere circulation. Previous research suggests a shift in the climate of the Northeast Pacific continental margin occurred at  $\sim 4$  ka. This shift is characterized in part by a strengthened Aleutian Low (AL) associated with mean conditions resembling a positive phase of the Pacific Decadal Oscillation (PDO). Oxygen isotope data from endogenic materials formed in lakes and subsequently stored in sediments can be used to infer the isotope composition of lake water ( $\delta^{18}\text{O}_{\text{lake}}$ ), which is sensitive to hydroclimatic variables such as the  $\delta^{18}\text{O}$  of meteoric water and precipitation-evaporation balance (P-E). While the  $\delta^{18}\text{O}$  of calcites is most often analyzed, in Alaska carbonate-bearing lakes are relatively rare; in such cases, the  $\delta^{18}\text{O}$  of diatoms can be studied alongside diatom flora analysis to further elucidate paleoenvironmental change. We present a new Holocene  $\delta^{18}\text{O}_{\text{diatom}}$  and diatom flora record from Sunken Island Lake, a hydrologically-closed kettle lake in the Kenai Peninsula lowlands, where the local evaporation line indicates  $\delta^{18}\text{O}_{\text{lake}}$  is influenced by changes in P-E.

The  $\delta^{18}\text{O}_{\text{diatom}}$  data show a Holocene range of 5.7‰ (+26.5 to +32.2‰ VSMOW,  $n = 98$ ). Mean  $\delta^{18}\text{O}_{\text{diatom}}$  prior to 4 ka was +29.5‰ ( $n = 49$ ), which increased to a mean of +30.5‰ ( $n = 20$ ) between 4 and 1 ka, then decreased to a mean of +28.4‰ ( $n = 29$ ) over the past 1 ka. Increased  $\delta^{18}\text{O}_{\text{lake}}$  at Sunken Island might reflect either drier conditions (decreased P-E) or increased  $\delta^{18}\text{O}_{\text{precipitation}}$ . Increased  $\delta^{18}\text{O}_{\text{precipitation}}$  in this region implies positive PDO-like conditions and a strengthened AL, which promote moisture transport from the relatively  $^{18}\text{O}$ -enriched North Pacific Ocean through the Gulf of Alaska to the Kenai Peninsula. Shifts in  $\delta^{18}\text{O}_{\text{diatom}}$  during the instrumental period are broadly consistent with changes in annual precipitation at Kenai airport as well as with shifts in the PDO and AL. This suggests that  $\delta^{18}\text{O}_{\text{diatom}}$  reflects both changes in source water and P-E, which are opposing influences on  $\delta^{18}\text{O}_{\text{lake}}$ . Although higher values from 4 to 1 ka might indicate decreased P-E, a regional study of lake-level fluctuations suggests water levels rose progressively following their lowest levels in the early Holocene. Therefore, our observed shift to higher  $\delta^{18}\text{O}_{\text{diatom}}$  at 4 ka suggests a change in meteoric source water, which dominated the  $\delta^{18}\text{O}_{\text{lake}}$  signal rather than decreased P-E. This increase in  $\delta^{18}\text{O}_{\text{diatom}}$  at 4 ka adds to evidence for an ocean-basin-scale shift involving the PDO and AL. The origin of the decrease in  $\delta^{18}\text{O}_{\text{diatom}}$  at 1 ka is uncertain. In absence of regional evidence for a change in moisture source, we ascribe it to local factors that increased P-E at this site. Major shifts in diatom flora will be used to further contextualize these changes in  $\delta^{18}\text{O}_{\text{diatom}}$ .

O-5030

## Palaeohydrological changes in Yellowstone Lake (Wyoming, USA) for the last 11 000 years inferred from oxygen isotopes in diatoms

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### Abstract

The hydrothermal system of Yellowstone is located on one of the World's most active volcanic plateaus (Wyoming, 2357 m a.s.l.) and comprises more than 10,000 thermal features, which influence geochemical cycling through fluid-rock exchanges (Cl, Si, Li, Na) and gas formation. Springs host unique groups of microorganisms living in extreme environmental conditions and using diverse inorganic sources for their development.

Several large hydrothermal explosions (creating craters of more than 1 km in diameter) occurred during the Holocene, raising the question of how climate and associated changes in lake level and hydrostatic pressure have affected the hydrothermal system and the lake ecosystem at a multi-millennial timescale. For this purpose, sediment cores (c. 12 m-long) were taken in the northern part of Yellowstone Lake in 2016 as part of the "Hydrothermal Dynamics of Yellowstone Lake (HD-YLake)" research program. The lake sediments are highly rich in diatom fossils, enabling hydrological changes to be inferred using oxygen isotope ratios ( $\delta^{18}\text{O}$ ) of the biogenic silica.  $\delta^{18}\text{O}$  reflects the isotopic composition of the lake water during diatom growth. The ratio varies according to changes in lake water temperature, lake water balance, and precipitations sources. The current functioning of Yellowstone Lake and its influence on  $\delta^{18}\text{O}$  in the lake waters were investigated using modern water samples from the lake and its main tributaries. To avoid possible influences of vital effects, we extracted only one diatom species, *Stephanodiscus yellowstonensis*.

A major hydrothermal explosion about 8000 years ago was identified from geochemical and sedimentological evidence near the base of the sediment core, lying just below a tephra layer, dated ca. 7700 years ago, from the explosion of the Mount Mazama. A long-term decrease in  $\delta^{18}\text{O}_{\text{diatom}}$  (samples becoming depleted in heavy isotopes) through the record is interpreted as a gradual change in lake surface area and lake water evaporation. Short-term variations and an abrupt decrease in  $\delta^{18}\text{O}_{\text{diatom}}$  3000 years ago reflect periods of rapid change in the lake water balance. These isotopic results will be compared with lake-level changes inferred from terraces and diatom assemblages to study the response of the lake ecosystem to hydrological changes. Comparison with regional paleoclimatic records and shoreline and stratigraphic evidence of hydrothermal explosions will allow an examination of the potential influence of climate on the hydrothermal system.

O-5031

## Biogeochemical cycling in the North Pacific Ocean through the Mid Pleistocene Transition

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### Abstract

The subarctic North Pacific Ocean has been a relatively understudied region in terms of palaeoclimate, limiting our understanding of how the region has both driven and responded to palaeoenvironmental events. Today, the subarctic North Pacific Ocean is marked by a year round stratified water column with a halocline at c. 300 m water depth. Previous studies at ODP Site 882 in the Northwest Pacific (Fig. 1) have suggested this system developed at the onset of major Northern Hemisphere Glaciation (2.73 Ma). In addition to limiting the upwelling of carbon rich deep waters and associated ventilation of CO<sub>2</sub> to the atmosphere, the shift to a stratified state fundamentally altered oceanographic conditions and biogeochemical cycling across the region. Key questions remain over whether the region remained permanently stratified for all of the Quaternary, or whether the changes in stratification/biogeochemical cycling altered over major climatic transitions such as the Mid Pleistocene Transition (MPT), a process that would alter regional ocean-atmospheric carbon exchanges.

Diatom isotope records from IODP Site U1341 at Bowers Ridge in the Bering Sea (Fig. 1) indicate that the development of the stratified system at ODP Site 882 in the subarctic Pacific led to a nutrient leakage from the deep North Pacific Ocean through the Kamchatka Strait and into the Bering Sea, fuelling an opal bloom at IODP Site U1341 and indicating a strong linkage between the two regions that may have impacted regional carbon cycling. It is not known whether this nutrient leakage and the link between the two regions continued after 2.5 Ma and whether these changes alter over the evolution of the MPT or are concordant with changes in south Bering Sea productivity. This has important implications for assessing whether changes in biogeochemical cycling and associated impacts on the Bering Sea carbon cycle could have contributed towards lowering atmospheric CO<sub>2</sub> and the climate transitions at the MPT.

We present here silicon isotope data from diatoms ( $\delta^{30}\text{Si}_{\text{diatom}}$ ) from both sites, constrained using records of opal biogenic silica in order to test the mechanisms of biogeochemical cycling and the hypothesis of nutrient leakage from the subarctic North Pacific Ocean to the Bering Sea between 2.52 Ma and 0.5 Ma encompassing the MPT. This has enabled us to reconstruct temporal changes in photic zone nutrient utilisation and silicic acid supply in the northwest subarctic Pacific Ocean and south Bering Sea through the progressive intensification of glacial-interglacials through the early Quaternary and over the MPT. We will use these data to identify whether changes in biogeochemical cycling and oceanographic conditions (stratification) at ODP Site 882 are concurrent with biogeochemical cycling in the south Bering Sea, advocating potential linkages between the two sites.



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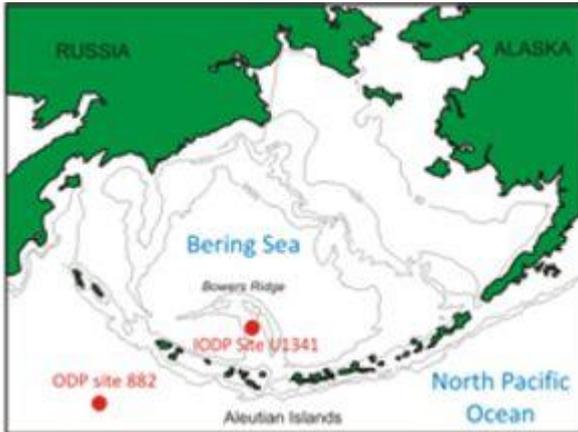


Figure 1: Map showing the location of the cores

O-5032

## Subtropical Australian climate and environmental change over the past 80,000 years from Welsby Lagoon, North Stradbroke Island

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### Abstract

Records of terrestrial environmental and climatic variability that extend beyond the Last Glacial Maximum (LGM) in Australia are rare. This paucity of terrestrial archives is further hampered by poor age constraints and low sample resolution. Such records are critical to debates about the relative roles of people, climate and the extinction of megafauna in shaping Australia's environment. Here we present a high-resolution, well-dated, multi-proxy record of climate, vegetation and fire history covering the past ca. 80,000 years from Welsby Lagoon, North Stradbroke Island, subtropical eastern Australia. The Welsby Lagoon chronology has been developed from 21 OSL ages and 20 <sup>14</sup>C dates and spans the regionally significant periods of Marine Isotope Stage (MIS) 4, MIS3 and the LGM.

To reconstruct the evolution of the wetland and document environmental and hydrological change we utilise a variety of proxies reflecting within-wetland change (plant macrofossils,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ,  $\delta^{18}\text{O}$ , aquatic pollen, plant lignin, photosynthetic pigments). Since its formation, Welsby Lagoon has undergone an ecosystem state shift from an open-water lacustrine system to a macrophyte-dominated palustrine swamp after ca. 40 ka. A thorough understanding of the development of this site permits robust interpretations of aquatic, terrestrial and climatic changes. For example, the  $\delta^{13}\text{C}$  composition of the Welsby Lagoon sediments during MIS4 and MIS3 reflect variations in lacustrine primary productivity, corresponding to multi-millennial scale changes in nutrient input and insolation. Hydroclimate variability, inferred from  $\delta^{18}\text{O}$  of aquatic cellulose, drives centennial scale lacustrine and terrestrial environmental changes.  $\delta^{13}\text{C}$ -inferred lake productivity declines during wet periods, while terrestrial pollen composition displays greatest response to rapid drying events. This high-resolution, independently dated record extending to the beginning of MIS4 has the potential to advance our understanding of millennial to centennial scale climate and ecological variability during significant time periods in subtropical Australia.

O-5033

## Monsoonal-driven terrestrial subsidies controls lake-atmosphere carbon exchange since the LGM

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### Abstract

Secondary production in lakes and associated emission of CO<sub>2</sub> are heavily subsidized by terrestrial carbon but the role of climate forcing remains unclear. The carbon stable isotope composition of zooplankton in a sediment core from a sub-tropical alpine lake in SW China tracked atmospheric CO<sub>2</sub> and δ<sup>18</sup>O records of monsoonal strength over the last ~26 ky. Both terrestrial and aquatic ecosystems were carbon limited during the Last Glacial Maximum when C<sub>4</sub> vegetation dominated the catchment. Zooplankton production and lake CO<sub>2</sub> (inferred from *Bosmina* δ<sup>13</sup>C) increased from 10 k y B.P. with strengthening of the SW Asian monsoon and forest expansion, indicating a strong but indirect climatic control on lake-carbon dynamics. These results highlight the importance of land-cover and hydrology in controlling terrestrial organic matter subsidies of secondary aquatic production and greenhouse gas emission at 10<sup>2</sup>-10<sup>3</sup> years timescales.

O-5034

## Nitrogen isotopes in lake sediments of Tiefer See (NE Germany) from monitoring to the sedimentary record

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### Abstract

Nitrogen is an important element reflecting nutrient input and recycling in lake sediments. Lacustrine paleorecords of nitrogen and their isotope composition  $\delta^{15}\text{N}$  may reveal human impact by extensive land use, manure, fertilizer, and atmospheric pollution and can be used to reconstruct the eutrophication history under consideration of lake setting, surrounding catchment and internal processes.

To understand the  $\delta^{15}\text{N}$  signature of paleorecords and to distinguish the natural variability and anthropogenic forcing from nitrogen cycle and lake productivity, we compared the recent input and productivity, monthly monitored in sediment traps since 2012, with annually laminated lake sediments from NE Germany. The studied lake Tiefer See is located on the southern rim of the Pomeranian terminal moraine at the border of temperate oceanic to continental climate. The region is sparsely populated and used for agriculture and affected by manure and synthetic fertilizer.

Today the trapped material in lake Tiefer See is mainly autochthonous produced and signed by significant high  $\delta^{15}\text{N}$  values ranging between +7 and +14‰, reflecting seasonal variations with lower values during the spring and higher values during the autumn and winter time. High  $\delta^{15}\text{N}_{\text{NO}_3^-}$  and low  $\delta^{18}\text{O}_{\text{NO}_3^-}$  in lake water clearly indicate influence of manure (Kendall et al. 2007). Comparing the mean  $\delta^{15}\text{N}$  values of the trapped material to the isotope composition of the recent annual layers, a good accordance were found with  $\delta^{15}\text{N}$  values of around +9‰. Our results allow the transmission into the past and the high resolution seasonally reconstruction of nutrient input and eutrophication. The  $\delta^{15}\text{N}$  record testify the anthropogenic nitrogen input over the past 2000 years with largest changes since the last 200 years. With the agricultural reform at the beginning of the 19<sup>th</sup> century,  $\delta^{15}\text{N}$  start to rise from around 3‰ to recent 9‰ due to intensified land use and fertilization and with this nutrient input and enhanced lake productivity and eutrophication.

Kendall, C., E. M. Elliott, and S. D. T. Wankel, 2007, Tracing anthropogenic inputs of nitrogen to ecosystems, in R. H. M. a. K. Lajtha, ed., *Stable Isotopes in Ecology and Environmental Science*, Blackwell Publishing, p. 375-449.

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O-5035

## Comparison of paleotemperature reconstructions based on the assemblage composition and oxygen isotope ratios of sedimentary diatoms

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### Abstract

Sedimentary diatoms have been successfully used to quantitatively reconstruct diverse limnological variables, including temperature, at various timescales. Even though temperature is often less of a key driver of diatom ecology than other environmental parameters (such as water chemistry), inference models based on diatom assemblage composition have been shown to be reliable in deriving past air and lake water temperature trends. The oxygen isotope composition ( $\delta^{18}\text{O}$ ) preserved in the biogenic silica of sedimentary diatoms have also demonstrated the potential to reliably reflect water temperature at the time of frustule formation.

This study aims to compare the two approaches in identical samples from one sediment core (Ni2-B) and to explore if and how the results differ, and how their combination can contribute to more reliable paleotemperature inferences. We used as our case study a large Arctic lake (Nettilling Lake, Baffin Island, Canada) from a region where paleoenvironmental reconstructions remain sparse. Results revealed a rather weak correlation ( $r^2=0.4$ ,  $p < 0.1$ ) between inferences from the two approaches, with significant differences in the inferred values. These discrepancies could in part be due to the complex hydrology of the study system which is also recorded in the  $\delta^{18}\text{O}$  signal.

Despite these results, we believe that this combination of proxies has the potential to provide new and exciting insights for paleotemperature reconstructions and future studies of postglacial environmental change in well-mixed lakes. To our knowledge, this is the first study to simultaneously present temperature inferences from both lacustrine sedimentary diatom assemblage composition and the isotopic signal extracted from their siliceous structure.

O-5036

## SEQS-DATESTRA a Geographic Database of terrestrial Quaternary stratigraphical sites of Europe (IFG 1620F-SACCOM)

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### Abstract

INQUA-SEQS during the 2016-2019 Intercongress period aimed to build a Database of Quaternary Terrestrial European Stratigraphic Sites (DATESTRA). DATESTRA follows the need for stratigraphic Quaternary correlations across Europe and a concise, informative and easy to use system to share as many information as possible about the most important Quaternary sites. Across Europe stratigraphical schemes were developed in the past using complex litho-, chrono-, and bio-stratigraphical criteria due to the fragmentary nature of the records and to the problems related to reliable dating techniques covering the full range of Quaternary time. The terminology used for defining the chronostratigraphical setting is often based on local or old-fashioned schemes and the need for a common language/terminology/methodology is strongly necessary in order to share among European Quaternary scientists basic geoscientific information. The main goal of SEQS-DATESTRA is therefore to create a Database that summarize the litho-, bio-, pedo-, morpho and chrono-stratigraphical data from the main Quaternary sites of Europe and therefore provide a tool for cross-border correlations of the main Quaternary subdivisions, combining existing knowledge and expertise of regional specialists. The main outcome is a shared Database available to all the Quaternary audience on open GIS based Web platforms to give to the wider audience as possible, also at informative level, the chance to have an overview of the European Terrestrial Quaternary setting. The Database principles are that it must be: a) concise, containing very basic information as starting point for further refined search; b) easy to compile, allowing with few and clear rules its compilation from people with different scientific backgrounds; c) easy to query, this is the crucial point for consultation and correlation across Europe. The Database should serve to the end-user as a starting point for further and more detailed information. At first, DATESTRA should contain only key sites, such as historically known sites or the better stratigraphically significant and constrained sites from every country of Europe. The structure of the Database is therefore conceived considering these objectives. Each point (site) holds values of domains that provide the knowledge applicable to the Database and each site has a number of attributes (and related domains) and each attribute has a limited number of values, in order to make the Database as simpler as possible.

O-5037

## Signatures of the pre-Eemian interglacial in northern Russia

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### Abstract

This issue has been discussed since 1940-s when two different marine formations were described in the sub-till position. In the 1960-s geologists firmly believed in two interglacial invasions of Atlantic saline water into the Russian Arctic. The first such transgression named Kazantsevo and related to the late Quaternary by V. Sachs imported boreal fauna including extinct *Cyrtodaria jenseae*=*C. angusta* as far east as the Taimyr Peninsula. Later investigators related *Cyrtodaria* strata to much older events and therefore adopted for the late Quaternary only one interglacial transgression correlated with the Eemian (Larsen et al., 2006). However, in the thickest Quaternary of West Siberia and the Pechora Basin *Cyrtodaria* strata are separated from the uppermost boreal marine formation only by one glacial complex. This complex, covered by Eemian sediments and commonly related to the final Middle Pleistocene, extends far beyond the limit of the last Early Weichselian ice sheet (Svendsen et al., 2004).

The late middle Pleistocene age of the marine formation with *Cyrtodaria* shells and arboreal pollen commonly inferred from its second from the surface stratigraphic position has lately been confirmed by ESR ages from 200 to 290 ka. The dates are obtained in VSEGEI on a *Cyrtodaria* sequence on river Yangarei in present tundra, 68°44'N. The sequence is overlain by marine sands with OSL dates 115 and 122 ka.

The warm marine incursion of the late Middle Pleistocene into the Arctic seems strange considering the cool interglacial of MIS 7 elsewhere in northern Europe. However, there is independent evidence of very warm conditions provided by peat layers in the Pechora Basin which occur between two thick diamict formations conventionally mapped as youngest Middle Pleistocene tills. The Seyda peat in tundra at 67.5°N has yielded pollen spectra of southern taiga and the age ca 200 by 10 OSL measurements and by uranium-series dating (Astakhov, 2004; Murray et al., 2008). The Rodionovo peat 3.5 m thick yielded U/Th dates ca 250 ka at its stratotype on 65.5°N (Arslanov et al., 2006). These results confirm a MIS 7 age for the penultimate interglaciation identified as 'the Rodionovo thermochron' in northeastern European Russia.

The data obtained so far in northern Russia suggests a MIS 7 interglacial at least as warm as the Eemian. If corroborated the described interglacial formations would provide an important stratigraphic landmark for the Eurasian Quaternary.

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O-5038

## Weichselian ice dynamics in the SW sector of the Baltic Sea

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### Abstract

Dating of Weichselian sediments in the south-western sector of the Scandinavian Ice Sheet (SIS) in Sweden, Denmark and Germany, mainly by luminescence dating of glaciofluvial and glaciolacustrine sediments, and cosmogenic nuclide exposure dating of boulders give new insights into the timing of various glacial, glaciofluvial and glaciallimnic processes (Hughes et al., 2016). In Germany, the traditional names of ice advances like Brandenburg, Frankfurt and Pomeranian advance pretend a synchronous formation of ice marginal positions over some distance. The existing data are reviewed and a revised model of Weichselian ice dynamics in the SW sector of the SIS is presented.

During the early MIS3, the lithostratigraphically documented Ellund-Warnow advance marks the first expansion of glaciers during the Weichselian into the SW Baltic Sea area. Related tills were found in western Mecklenburg and in parts of Schleswig-Holstein.

During late MIS 3, the ice attained the maximum extent within the Oder lobe (Brandenburg advance) and reached into Denmark (Klintholm advance) (Hardt et al., 2016). Nevertheless, there is no evidence that Bornholm, the Rønne Bank as well as Rügen were overridden by ice at that time; instead, glaciofluvial and glaciolacustrine sediments were deposited. The area shaped by the maximum ice advance of the Oder lobe, dated to 32-28 ka, is mainly characterized by meltwater sediments and erosional channels, which are in accordance with the assumption of a fast flowing ice of an outlet glacier. Distinct terminal moraines are missing. Thus, various sedimentary environments existed in close neighborhood in the southwestern Baltic Sea basin and the surrounding areas.

The ice advance in correspondence with the global LGM at about 22-20ka, named Pomeranian advance in NE Germany, (Lüthgens & Böse 2011, Lüthgens et al. 2011), was likely characterized by slower moving ice, forming boulder-rich, distinct end moraines in northern Brandenburg, Mecklenburg-Vorpommern and in Schleswig-Holstein. Isochronic ice cover is also documented in the Baltic Sea basin and Denmark.

The configuration and dynamics of the SIS in its southwestern part was therefore very different during the MIS 3 and MIS 2 ice advances, influenced by climatic parameters, and the topography of the Baltic Sea basin and adjacent areas.

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O-5039

## Molluscs from the Singil deposits (late Middle Pleistocene) of the Lower Volga region, Russia: a new stratigraphical approach

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### Abstract

According to the traditional point of view, the Singil deposits were located between the Baku and Khazar Horizons and were correlated with the Likhvin Horizon of the Quaternary Stratigraphical scale of Russia, or with the Holsteinian (MIS 11). The Upper part of the Singil deposits is visible at the basis of the riverside cliffs, and their lower part goes below the level of the Volga River water and can be opened only by boreholes. Researchers usually analyzed only the surface part of the Singil clays.

New core materials indicate the occurrence of the Singil deposits between the Lower and Upper Khazar, which suggests that the Singil is much younger (the end of the Middle Pleistocene, Late Saalian, MIS 7-6) than previously stated. New data changes the history of the Caspian region geological development.

We have studied two mollusc complexes from Singil deposits – from the lower dark gray clay and from the upper yellowish-gray clay. Malacomplexes of these parts differ from each other.

The first mollusc complex is represented by 2856 shells of bivalves and gastropods from the sediments of Borehole 2 Kosika and six localities in the riverside cliffs – Zaimiszhe, Tsagan-Aman, Vostok, Kosika, Kopanovka, Vladimirovka. In total, 28 taxa, 15 genera, 11 families were identified. Freshwater molluscs include *Lymnaea*, *Bithynia*, *Valvata*, *Lithoglyphus*, *Viviparus*, *Sphaerium* and *Corbicula* genera. Brackish-water molluscs include *Pyrgula*, *Adacna*, *Monodacna* and *Hypanis*, which are able to tolerate significant desalination. Representatives of the genus *Dreissena* could inhabit both fresh and brackish-water bodies. Thus, freshwater species, Caspian gastropods and cardiids were encountered in the complex, which is probably due to the proximity of the seashore. The presence of a *Corbicula* indicates a relatively warm climate. The association of molluscs from the Zaimiszhe locality differs from other by the presence of *Didacna*, which indicates a more seaward conditions of sedimentation.

The second mollusc complex is represented by 574 specimens of bivalves and gastropods from the same localities. In total, 19 taxa, 11 genera, 8 families were identified. The difference in the species composition of this complex from the first molluscs complex is in a smaller number of specimens and species diversity, the presence of few *Didacna* and molluscs living in rivers (*Unio*), which indicates the development of a regressive stage.

The studied material showed that the conditions of the Singil sediments accumulation were not homogeneous – there were freshwater reservoirs with periodic flooding by seawater. Up section, the depletion of the malacological complex indicates the regressive stage of development. Our results were compared with findings on mammals, amphibians, reptiles, palaeocarpological and palynological analyzes. The main conclusion of the research is that the formation of the Singil sediments took place at the final regressive stage of development of the Early Khazar basin

O-5040

## EQUATE – Building a European Quaternary Aminostratigraphic Timescale

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### Abstract

Timing is everything: accurate dating of the archaeological record is essential to an understanding of the history of the human species, but beyond the limit of radiocarbon dating (~60 ka), sites become more difficult to date. Amino acid geochronology, which uses the time-dependent breakdown of proteins in biominerals, has the potential to date the whole of the Quaternary. Recent analyses of the intra-crystalline fraction of calcitic biominerals (*Bithynia opercula*) has enabled the development of an aminostratigraphic framework for Britain for the Pleistocene. The intra-crystalline protein decomposition (IcPD) within the opercula provides a framework for understanding the regional geological and archaeological record, and has revealed a temporal structure within the British Palaeolithic.

Correlation of Quaternary sequences, even in adjacent regions, can often be problematic, but the development of regional aminostratigraphies promises to provide robust chronologies, enabling more confident correlation. The calcitic opercula of bithyniid (or similar) gastropods occur commonly in many Quaternary sequences, offering potential for development and correlation of regional aminostratigraphies around the world.

Extending the British framework to continental Europe (and beyond) is the next step, and we present the results from analyses of a series of key archaeological and palaeontological sites from across Europe from France to Russia. In order to build the most comprehensive framework possible, we are targeting type localities for interglacial stages, sites with independent geochronology, horizons that can be related to glacial sediments, river terrace sequences, biostratigraphy and archaeology. A critical region for study is the Black Sea, since this region harbours the oldest evidence of human presence in Eurasia and is the type area for the Pleistocene small mammal biozonation applicable across Europe. These dating schemes will shed light on our human story, providing temporal context for episodes of human occupation across Europe, framed within their palaeoenvironments.

O-5041

## Multi-proxy analysis for reconstructing the late Quaternary sedimentary evolution and stratigraphy of a south-Alpine alluvial basin (Venetian Plain, Italy)

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### Abstract

The research investigates the sedimentary evolution of the Venetian Plain (NE Italy) with a focus on the Middle and lower Upper Pleistocene climatic and environmental changes. This period is still poorly known in the area, due to the few available cores reaching the relative sediments, generally found at a depth higher than 30 meters.

The Venetian Plain constitutes part of the foreland basin of the southern Eastern Alps, the Northern Apennines and the External Dinarides. Its particular position, characterized by the proximity of both the orogenic belts and the Adriatic Sea, has influenced its sedimentary evolution during the glacial-interglacial cycles occurred since the Middle Pleistocene. General aim of the research is to enhance the comprehension of the stratigraphy and prograding mechanisms of the alluvial systems (megafans) of the plain in relation to climatic fluctuations, sea - level change and active tectonics. This will allow to extrapolate the depositional history and the drainage pattern of the plain, to define the paleoenvironmental evolution and to improve the climatic proxy dataset on the southern side of the Alps needed for bio - chronostratigraphic subdivision and correlation with neighboring Mediterranean, north-Alpine and eastern European regions.

We are focusing on a 130 m deep core ("GER1") drilled in Padua, in the distal part of the megafan of the Brenta River, analyzing different environmental and sedimentological proxies and testing stratigraphic and bio - chronological correlation with others deep cores in the area.

Basing on lithofacies assemblages, the presence of paleosoils, and the micropaleontological content, we divided "GER1" into 8 depositional units, mainly constituted by fluvial sediments but with evidence of marine intercalations. In one of these units we find foraminifera such as *Ammonia beccarii tepida* and *Elphidium granosum* suggesting a shallow-marginal marine environment during an interglacial phase. Sediment provenance analysis (gross composition of both sand and gravel levels and transparent heavy mineral associations) allows us to distinguish the different supply of fluvial sediments in the area (Brenta, Adige, Bacchiglione and Piave rivers) and to infer the variation in the drainage pattern during the Middle - Upper Pleistocene.

Fundamental environmental and biostratigraphic information derive from pollen and NPP analysis, in particular for sediments older than the radiocarbon dating limit.

Along the core we identified two principal components of tree pollen types: a group of broadleaf taxa including *Quercus robur – pubescens* type and a group of conifers (*Pinus* undiff., *Larix*, *Juniperus*) with *Betula*. In the deeper part of the core we find ancient taxa such as *Zelkova*, *Buxus*, *Carya* and *Keteleeria/Abies* in association with temperate forest types. Thanks to the finding of the last two, we can hypothesize the MIS correspondence of the proximal marine unit and suppose that we are in an ecological refuge area.

O-5042

## Late Wolstonian Substage (c. MIS 6) glaciation in the British Isles

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### Abstract

Glaciation during Marine Isotope Stage (MIS) 6 is widely recognised around the world, with significant ice extension across continental Europe during the Saalian Stage (c. MIS 10–6). In the British Isles, understanding of the age and extent of the equivalent glaciation has been debated. The Wolstonian Stage (c. MIS 10–6) stratotype is based on a series of glacial sediments exposed at Wolston, West Midlands. Here direct evidence that the glacial sediments are underlain or overlain by Hoxnian (c. MIS 11) or Ipswichian (c. MIS 5e) interglacial stage sediments is limited. This age is further complicated since these sediments overlie fluvial deposits (Baginton-Lillington Formation Gravel) that have been attributed by some researchers to deposition in the headwaters of a pre-Anglian Stage (c. MIS 16–14) ‘Bytham River’. This attribution is based on the suggested correlation of similar lithological characteristics of the Baginton-Lillington Gravel to the Bytham Gravel in the East Midlands, and the Ingham Formation Gravels, in East Anglia, both of which are thought to be overlain by Anglian Stage (c. MIS 12) glacial sediments. Research presented here challenges this interpretation of the age the Midlands glacial sequence, since younger Middle Pleistocene glacial sequences occur in both the English Midlands and East Anglia. Glaciofluvial sediments associated with the ‘younger’ advance of the lowland late Middle Pleistocene glaciation have been sampled for optically-stimulated luminescence (OSL) and post-infra-red stimulated luminescence (pIRSL) dating. The ages obtained demonstrate that glacial ice advanced into the West Midlands as far as Moreton-in-Marsh at c.180 ka, within the Late Wolstonian Substage (correlated to MIS 6 globally). Additional work in East Anglia confirms significant glacial advance during c.170 ka at Tottenhill. Moreover, important Hoxnian Stage interglacial sequences in the West Midlands are overlain by deposits of this younger glaciation, the latter being directly correlated to that of the Wolstonian Stage sequence in the type area. These findings unequivocally date the MIS 6 ice limit for the British Isles to the Late Wolstonian Substage, allowing correlation with the equivalent Late Saalian Substage across continental Europe.

**O-5043**

## **Glacial landsystems and their applications: retrospect and prospect**

David Evans

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### **Abstract**

Glacial landsystems are holistic evaluations of sediment–landform associations and their genetic relationships to the processes involved in terrain development. As such they are encoded with a wealth of information on former glaciation style as dictated by physiography and ice dynamics and hence can facilitate a preliminary prediction of expected subsurface conditions using depositional surface morphology and the wider landscape setting. Since their introduction to engineering geology in the 1970s, glacial landsystems have become more sophisticated and bespoke to a wider range of glaciated terrain types. Moreover, the compilation of modern landsystem exemplars has ensured the development of an increasingly firm foundation in the understanding of process-form regimes in glacial systems. In particular, the landform-sediment assemblages that are evolving rapidly in recently deglaciated terrains provide invaluable modern analogues for paleoglaciological reconstruction. Consequently we have become more adept at deciphering the highly variable depositional record of former glaciers, ice caps, and ice fields in terms of the interrelationships between glacier type, thermal regime, climate, and topography, but because the thermal regime plays a critical role in the entrainment, transport, and final deposition of glacial debris, it is emphasized here in terms of its controls over landform and sediment genesis. The role of the basal thermal regime in the formation of moraines and subglacial tills is presented as a spatial and temporal continuum in a conceptual process-form model, which identifies active temperate and cold polythermal glacier snouts as end members and a range of polythermal scenarios inbetween. The spatial and temporal continuums inherent within this model help us to recognise and acknowledge superimposition and change in glacial landsystem evolution and signatures. A range of examples are used to demonstrate spatio-temporal change in glacial landsystems, in both modern and ancient contexts, emphasizing the role of thermal regime variability. As this variability is driven by the climate of the environment in which a glacier snout is located, we can begin to develop greater confidence in employing glacial geomorphology (i.e. landsystem imprints) as archives of temporal climate change.

**O-5044**

## **Periglacial landsystems: retrospect and prospect**

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### **Abstract**

Periglacial landsystems provide a conceptual framework to interpret the imprint of periglacial processes on the landscape, and to predict the engineering properties of the ground. In the UK, landsystems have been distinguished according to topography, relief and the presence or absence of a sediment mantle. Four landsystems characterise both lowland and upland periglacial terrains in the UK: *plateau* landsystems, *sediment-mantled hillslope* landsystems, *rock slope* landsystems, and *slope-foot* landsystems. Two additional landsystems are also identified in lowland terrains, where thick sequences of periglacial deposits are common: *valley* landsystems and *buried* landsystems. Finally, submerged landsystems, which may contain more than one of the above, exist on the continental shelf offshore of Great Britain. Individual landsystems contain a rich variety of periglacial and permafrost landforms, sediments and sedimentary structures. Key periglacial lowland landsystems are summarised using ground models for limestone plateau-clay-vale terrain and caprock-mudstone valley terrain, and upland periglacial landsystems are synthesised through ground models of relict and active periglacial landforms, supplemented by maps of upland periglacial features developed on bedrock of different lithology. The landsystem concept can be extended to modern permafrost and periglacial regions. An example is presented of thermokarst landsystems in regions of ice-rich permafrost in Canada, Siberia and Alaska.

**O-5045**

## **Quaternary Geological Ground Models for the Reduction of Engineering Risk**

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### **Abstract**

The geology of the Quaternary Period is often under-appreciated in construction yet its legacy is highly significant for ground engineering. All ground projects will encounter relict Quaternary terrains, deposits and landforms and their correct identification and interpretation is key to the success of any such engineering projects. The development of Quaternary ground models will help to communicate and understand the vertical and lateral variability of these environments, defining geological hazards that may be present and understanding the risks that they potentially pose.

This presentation will highlight the report developed by the Geological Society of London Engineering Group Working Party on the Engineering Geology and Geomorphology of Glaciated and Periglaciated Terrains within a UK context. Case study examples will be presented to illustrate the hazards potentially encountered in these terrains and the diagnostic characteristics that the geoscientist should be aware of during the site investigation process in order to manage the uncertainty presented by these highly variable ground conditions. The tools and building blocks necessary for the development of Conceptual Ground Models will be addressed.

**O-5046**

## **A Landsystems Approach to Glacier-Permafrost Interactions**

Richard Waller

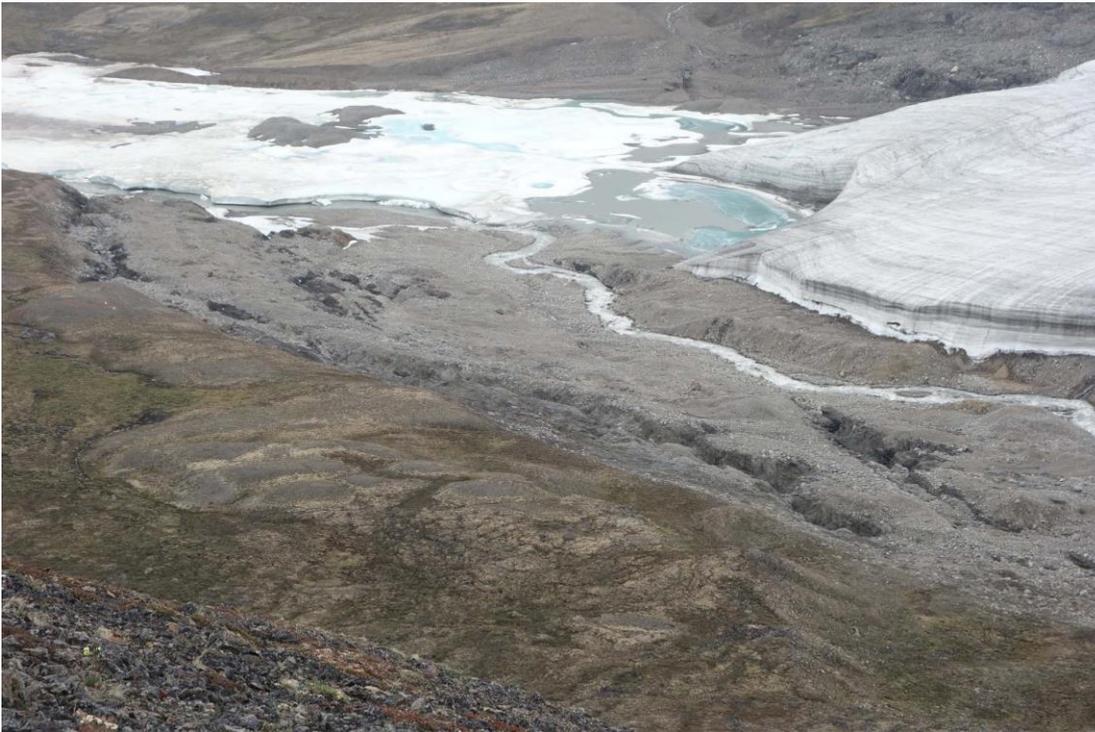
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### **Abstract**

Whilst glaciers and permafrost comprise the two key components of the global cryosphere, the nature, extent and wider implications of glacier-permafrost interactions have until recently received surprisingly little attention. Traditional views have assumed that such interactions are spatially restricted and that where they do occur, the cold-based and polythermal glaciers underlain by permafrost are slow moving, geomorphologically inactive and therefore of limited research interest. Recent research in both modern and ancient glacial environments has however challenged these traditional conceptions and illustrated the ability of glaciers and permafrost to actively couple and interact over larger areas and over longer timescales than previously assumed. These interactions have in turn been associated with the operation of distinctive basal and ice-marginal processes and geomorphic impacts that are diverse, complex and commonly very different to those typically associated with glaciers and ice sheets.

The adoption and utilisation of the landsystems concept by glacial geomorphologists has promoted the development of increasingly robust genetic associations between glacial processes and forms that have revealed both the diversity of glacial landsystems and the glaciological and environmental controls responsible for their formation. Previous research examining the diverse landsystems associated with Pleistocene Ice Sheets in North America, Europe and Siberia has provided an insight into the distinctive landforms and landform assemblages associated with glacier-permafrost interactions. In addition to preserving pre-glacial features, the influence of subglacial and ice-marginal permafrost has for example been attributed to the formation of thrust-block moraines and extensive tracts of hummocky moraine. It has also been connected to the development of extensive lateral meltwater channels that are commonly used to reconstruct the retreat behaviour of cold ice in high latitude settings (figure 1).

This presentation will address recent developments in landsystems research concerning the diagnostic signatures and wider implications of glacier-permafrost interactions in both ancient and modern landsystem settings. In addition to considering the remarkable ability of cold-based glaciers to preserve pre-existing land surfaces, the presentation will consider the operation of distinctive processes such as bedrock fracture, debris entrainment and the detachment of bedrock rafts and well as the associated landsystem products. It will also highlight the role of permafrost in preserving buried ice and delaying specific processes of paraglacial adjustment in polar environments. Finally, the potential implications for engineering projects in landsystems affected by glacier-permafrost interactions will also be considered.



**Figure 1:** Ice margin and foreland of Fountain Glacier, Bylot Island. This illustrates the boulder-dominated surfaces, incised lateral meltwater channels and large proglacial icing commonly associated with polythermal glaciers terminating in areas of continuous permafrost.

O-5047

## Significance of glacial landsystems and process-form regimes in permafrost terrain: the Smoking Hills region of northwestern Arctic Canada

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### Abstract

In northern Canada, considerations of natural resource potential include not simply identification of a resource itself, but also an understanding of aspects of engineering geology of surficial and shallow bedrock materials within formerly glaciated terrain, particularly in areas of ice-rich permafrost. Hence, understanding the landscape is not simply a surficial geology mapping exercise, but more an integrated consideration of the evolution of the landsystem and the inherent process-form regimes. As part of the Geological Survey of Canada's GEM2 research program, this study examined the Smoking Hills region of northwestern Arctic Canada (~69°N; 127°W). While parts of this area were previously reported as unglaciated during the last (Late Wisconsinan) glaciation, new glaciological models and field studies argue that the entire region was glaciated, and that the study area was situated south of the westward-flowing Amundsen Gulf Ice Stream. A unique older glacial stratigraphy (3-5 separate glaciations) is preserved in the region, for which an improved chronology based on cosmogenic nuclide burial dating and a stratigraphic reinterpretation is being undertaken.

Regionally exposed bedrock and complex Quaternary stratigraphies located in incised valleys document a range of past glacial processes, and in particular extensive glaciotectonic deformation and entrainment of poor to weakly-consolidated Cretaceous sedimentary bedrock. Glaciotectonic features include deformed intraclasts of coherent bedrock ranging from thin (<1 cm) stringers and blocks to large metre-scale boudins, cohesive bedrock rafts (metres to 10s of metres thick) and acute to overturned fold structures ≤100 m in vertical height. Extensive preglacial bedrock slumping along valleys likely contributed much of the entrained bedrock material, however, sections of deformed bedrock in valley walls also clearly demonstrate regional-scale, thin-skinned glaciotectonic deformation. Southward directed, arcuate, *en echelon* ridges on either side of the Horton River valley in an area of thin (0-2 m), discontinuous till cover expose massive ice and ice-rich debris that is interpreted as glacial thrusting of proglacial sediments, possibly buried glacial ice, and underlying bedrock. Elsewhere thick (up to 12 m) layers of buried glacial ice in valley bottoms suggests the potential for long-term preservation and re-incorporation by subsequent glaciations. The ice-thrust ridges are amongst the only regional-scale surface landforms recognized in the area (i.e. no extensive fluting or drumlin fields), suggesting that while the presence of patchy till cover indicates warm-based conditions, the thin-skinned tectonics and buried glacier ice, reflect localised basal freeze-on. Thicker tills within the complex stratigraphies of the buried valleys yield clast macrofabrics indicative of long term ice flow from the east or northeast. The evolution of this landsystem signature likely requires transitory changes in glacier basal thermal regimes possibly in association with advance and retreat of the adjacent westward-flowing Amundsen Gulf Ice Stream.

**O-5048**

## **Intensification of thaw slump activity in the Keele and Redstone River watersheds, Northwest Territories, Canada**

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### **Abstract**

Retrogressive thaw slumps are a dynamic climate-driven geomorphic process in ice-rich terrains that can rapidly degrade thick accumulations of permafrost into surrounding aquatic systems. We identify over 200 prominent thaw slumps largely absent from earlier inventories in the Keele and Redstone River watersheds (~ 5000 km<sup>2</sup>) west of the Mackenzie River in the western Northwest Territories, Canada. These slumps represent the southernmost concentration of widespread thermokarst disturbance in the western Canadian subarctic. High-resolution satellite imagery (2002-present) and air photography (pre-2002) show the majority of these features have initiated in the last 10-15 years. Increases in disturbance size and growth rate are consistent with regional increases in temperature and rainfall. The headwalls of several thaw slumps that we visited consist of diamicts from the late Wisconsinan Laurentide Ice Sheet that include massive, and sometimes deformed ice at their base. The largest retrogressive thaw slump documented could be termed a 'mega-slump' with a headwall height of > 35 m and total disturbance area of ~ 25 ha, displacing large amounts of thawed sediment into the river below. A thick (~ 5 m) massive to glaciotectonized ice lens at the base of this slump is driving the degradation upslope, similar to mega-slumps documented in the Peele Plateau further north. Using remotely sensed mapping techniques, in conjunction with field and lab-based permafrost characterization, we aim to provide a basis for evaluating climate-driven trajectories of ice-rich terrain in northwestern Canada.

**O-5049**

## **Using boreholes to identify and classify buried palaeovalleys in Scotland**

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### **Abstract**

Buried palaeo-valleys have significant (and often unexpected) implications for groundwater, hydrocarbon and geothermal resources and may provide detailed archives of palaeoenvironmental and landscape change.

They have been identified widely beneath lowland parts of the UK including eastern England, central England, south Wales and the North Sea. Although it is unclear whether the features onshore were created by: (i) subaerial fluvial incision; (ii) glacial erosion forming over-deepened U-shaped valleys, which can then become partly submerged and filled by younger sediment; or (iii) incision of tunnel valleys (or tunnel channels) by subglacial meltwater beneath glaciers and ice sheets.

In the Midland Valley of Scotland palaeo-valleys have been identified yet the age and genesis of these enigmatic features remain poorly understood. This study utilized a digital data set of over 100 000 boreholes that penetrate the full thickness of Quaternary deposits in the Midland Valley of Scotland. It identified 18 buried palaeo-valleys, which range from 4 to 36 km in length and 24 to 162 m in depth.

Geometric analysis using the borehole dataset has revealed four distinct valley morphologies, which were formed by different subglacial and subaerial processes. Some palaeo-valleys cross-cut each other with the deepest features aligning east–west. These east–west features align with the reconstructed ice-flow direction under maximum ice sheet conditions. The shallower features appear more aligned to ice-flow direction during ice-sheet retreat, and were therefore probably incised under more restricted ice-sheet configurations.

The bedrock lithology influences and enhances the position and depth of palaeo-valleys in this lowland glacial terrain. Faults have juxtaposed Palaeozoic sedimentary and igneous rocks and the deepest palaeo-valleys occur immediately down-ice of knick-points in the more resistant igneous bedrock. The features are regularly reused and the fills are dominated by glaciofluvial and glaciomarine deposits. This suggests that the majority of infilling of the features happened during deglaciation and was unrelated to the processes that cut them.

O-5050

## Temperature effects on carbon isotope composition in plants and soil and their relevance to paleoclimate reconstruction

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### Abstract

Understanding of the relations between climatic factors and carbon isotope composition ( $\delta^{13}\text{C}$ ) in modern plants and soil is the premise of applying the  $\delta^{13}\text{C}$  derived from sediments to paleoclimate reconstruction. Temperature and precipitation are two of the most important climatic indicators that palaeoclimatologists pay close attention to, and they are also two of the most important influencing factors of  $\delta^{13}\text{C}$  in plants and soil. With respect to the precipitation effects, one consistent conclusion has been obtained. However, the temperature effects remain unresolved due to the interaction between temperature and precipitation. To evaluate the temperature influences on  $\delta^{13}\text{C}$  in plants and soil more effectively, we sampled a large number of plants and soil across a temperature gradient along 400 mm isoline in China to minimize the effect of precipitation changes on  $\delta^{13}\text{C}$ . We measured the carbon isotope composition of bulk leaf tissues ( $\delta^{13}\text{C}_{\text{bulk}}$ ) and soil total organic matter ( $\delta^{13}\text{C}_{\text{som}}$ ). Considering that sediments contain organic matter from a variety of sources, such as plant sources, microbial sources and so on, to further facilitate paleotemperature reconstruction, we also evaluate the effects of temperature on leaf wax n-alkane traits and carbon isotope composition. This study shows that  $\delta^{13}\text{C}_{\text{bulk}}$  of C3 plants increases with temperature with a slope of  $0.11\text{‰}/^{\circ}\text{C}$  ( $R^2 = 0.35$ ,  $p < 0.001$ ) whereas C4 plants have no change in  $\delta^{13}\text{C}_{\text{bulk}}$  across the temperature gradient. Leaf wax n-alkanes distribute from n-C<sub>21</sub> to n-C<sub>35</sub> with n-C<sub>31</sub>, n-C<sub>29</sub> and n-27 as their dominant components. Total n-alkane concentration ( $\Sigma\text{alk}$ ) decreases whereas average chain length (ACL) increases temperature, especially for summer temperature. For the common plants grown along the gradient, *Artemisia* species, consisting of three species, *A. argyi*, *A. capillaris* and *A. scoparia*,  $\delta^{13}\text{C}_{29}$ ,  $\delta^{13}\text{C}_{31}$  and  $\delta^{13}\text{C}_{27}$  are very similar in each species. There are positive relations between  $\delta^{13}\text{C}_{\text{bulk}}$  and  $\delta^{13}\text{C}_{29}$ ,  $\delta^{13}\text{C}_{31}$  and  $\delta^{13}\text{C}_{27}$  for each plants. Increasing trends in both  $\delta^{13}\text{C}_{\text{bulk}}$  and  $\delta^{13}\text{C}_{29}$  are found with temperature. However, correlation of  $\delta^{13}\text{C}_{\text{bulk}}$  with temperature ( $R^2 = 0.18$ ) is much weaker than that of  $\delta^{13}\text{C}_{29}$  with temperature ( $R^2 = 0.6$ ) for the pooled *Artemisia* species. This suggests that  $\delta^{13}\text{C}_{29}$  is a better proxy of paleotemperature than  $\delta^{13}\text{C}_{\text{bulk}}$ . In addition, this study also observes that there is no relationship between  $\delta^{13}\text{C}_{\text{som}}$  and temperature. One of the main reasons for this observed pattern is that soil contains other sources of organic matter in addition to terrestrial high plant sources. Therefore,  $\delta^{13}\text{C}$  of total organic matter in sediments does not appear to be used for paleotemperature reconstruction. The future work should address the impact of temperature on carbon isotope composition of n-alkanes with long-chain in soil organic matter.

O-5051

## Physical processes of cooling and megadrought in 4.2 ka BP event: results from TraCE-21ka simulations

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### Abstract

It is widely believed that multidecadal to centennial cooling and drought occurred from 4500 BP to 3900 BP, known as the 4.2 ka BP event that triggered the collapse of several cultures. However, whether this event is a global event or a regional event and what causes this event along with the physical processes remain unclear due to the limitations of the previous reconstruction and simulation works. In this study, we investigated the spatiotemporal characteristics, the possible causes and the related physical processes of the event using a set of long-term climate simulations, including one all-forcing experiment and four single-forcing experiments. The results derived from the all-forcing experiment show that the cool and dry conditions related in this event occur over most parts of the Northern Hemisphere (NH), indicating that this event could have been a hemispheric event. The Southern Hemisphere (SH) experiences relatively warmer and wetter conditions. The simulated megadrought over the Mediterranean, Oman, inner North America and the wet South America are consistent with the reconstructions. The wetter SH indicates southward shift of the Intertropical Convergence Zone (ITCZ), which is also consistent with the reconstructions. The cooler NH and warmer SH illustrate that this event could be related to the slowdown of the Atlantic Meridional Overturning Circulation (AMOC). The comparison between the all-forcing experiment and the single-forcing experiments indicates that this event might be caused by the internal variability, while external forcings such as the orbital and greenhouse gases might have modulation effects. A positive North Atlantic Oscillation (NAO)-like pattern in the atmosphere (low troposphere) triggers a negative Atlantic Multidecadal Oscillation (AMO)-like pattern in the ocean, which then triggers a Circumglobal Teleconnection (CGT)-like wave train pattern in the atmosphere (high troposphere). The positive NAO-like pattern and the CGT-like pattern are the direct physical processes that lead to the NH cooling and megadrought. The AMO-like pattern plays a “bridge” role in maintaining this barotropic structure in the atmosphere at a multidecadal-centennial time scale. Our work provides a global image and dynamic background of the event. Whereas more model-data and inter-model comparisons are required to better understand the 4.2 ka BP event.

O-5052

## South Pacific Subtropical High since the late Holocene to the end of 21st century

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### Abstract

The South Pacific Subtropical High (SPSH) is a predominant feature of South American climate. It influences the rainfall intensity, the alongshore (meridional) wind strength and the upwelling events over most of the southwestern margin of South America (SA). In recent decades a strengthening and expansion of the SPSH have been observed leading an intensification of southerly winds along the coast of northern to central Chile and a decrease in precipitation from central to southern Chile. These changes have been recorded during the last centuries by several paleoclimate records of southern South America.

In order to broaden our understanding about the regional impacts of global warming in this part of Southern Hemisphere, we analyze the behavior of the SPSH during the late Holocene, particularly for the Current Warm Period (CWP; 1970-2005), by quantitatively comparing information from four CMIP5/PMIP3 simulation models for the historical period and reanalysis data. This information was contrasted with different paleoclimate records of the region to assess the level of agreement between simulation and climate proxies. Finally, we analyze the SPSH anthropogenically forced climate response for the 21st century under RCP8.5 scenario to evaluate the SPSH possible future behavior.

Our results indicate that climate model results are very consistent with most of climate records for the late Holocene. On the other hand, climate projections show that the strengthening and expansion trend observed during the late Holocene will continue throughout the 21st century, highlighting the need to establish adequate mitigation strategies to prevent its impacts.

**O-5053**

**Hydrologic and isotopic modelling of lakes: towards a mechanistic understanding of proxy data.**

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**Abstract**

Lakes sediments are an excellent source of terrestrial hydroclimate records, particularly via reconstructions of lake depth, lake water salinity and the stable oxygen isotope composition of palaeo-lake waters. However, lakes are complex systems, and the hydrological and geochemical response of lakes to climate is often non-linear, multifactorial and variable between sites. This complexity limits attempts to translate lake sediment records into quantifiable climate estimates, such as the amount of regional precipitation or evaporation. Coupled hydrologic-isotopic models - a type of 'proxy system model' - provide one means of addressing this complexity to constrain the interpretation of palaeoclimate proxies. Furthermore, such models facilitate a deeper understanding of the interaction between lakes, meteorology, and catchment/subsurface hydrology with value for addressing how lake ecosystems behave under past and future climate regimes.

A general lake model – CHIMBLE – coupling lake hydrology, groundwater, stratification (energy balance), isotopes, water chemistry and meteorology is being developed to try and resolve these challenges. CHIMBLE has been applied to the maar lakes Bullen Merri and Gnotuk in the Newer Volcanic Province (Victoria). These lakes (and 10 other lakes across the Newer Volcanic Province) have been monitored for the last 3 years for depth, chemistry and stable isotopes. Modelling and monitoring results demonstrate that for many lakes a simple lake model is insufficient and that there is a requirement to couple the lake hydrology to the surrounding catchment and subsurface flows.

**O-5054**

## **An assesment of the spatial coherence of drought reconstructions through regional paleoclimatic simulations**

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### **Abstract**

Climate reconstructions from proxy data are fundamental to better understand climate variability at long time scales. However these reconstructions are subjected to an important uncertainty.

In the case of reconstructions from historical archives, the noise caused by non-climate causes (epidemics, plagues, wars, speculation, etc.) produces drawbacks to establish unambiguous relationships, and therefore the different temporal evolutions obtained should be understood under the uncertainties associated.

In this work we present a description of the spatiotemporal patterns of droughts in the Mediterranean basin of the Iberian Peninsula by using monthly series of droughts covering the last four centuries. Correlations among the reconstructed series from historical archives show some temporal correlation that in most cases (not always) depends on the distance between the locations.

On the other hand, Regional paleoclimate numerical experiments can serve to evaluate the procedures for reconstructing series as well as the physical consistency of a set of reconstructions. In this work we use a set of runs performed with a Regional Climate Model with a spatial resolution of 30km over the Iberian Peninsula for the last millennium.

We analyse the spatial coherence between the reconstructed droughts by using the pseudo reality of the model. This permits us to impose a upper limit of the coherence/correlation that could be found in the reconstructed series. In addition, the stationarity of the relations between the different areas is also investigated. We found that spatial patterns slightly change along the studied period. Finally the relationship between the intensity of the dry episode and its spatial extension is analyzed. We obtain that high intensities are related with large extensions. although it appear some interesting exceptions.

O-5055

## Towards high-resolution climate reconstruction using an off-line data assimilation method and the COSMO-CLM Regional Climate Model

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### Abstract

Data assimilation (DA) methods have been recently used to constrain the paleo-climate model simulations by paleo-proxy records. In this work, we design a computationally affordable offline DA method to assimilate yearly pseudo-observations and real observations into an ensemble of COSMO-CLM high-resolution Regional Climate Model (RCM) simulations. As a testbed for the evaluation of the proposed method we consider the mid-to-late Holocene summer temperature evolution over Europe. This has been the subject of a long-standing debate among different members of the proxy community and between them and climate modelers. The pollen-based summer temperature reconstructions of Mauri et al. 2015 are used for the assimilation. Results suggest that interpretations of european summer temperatures evolution during the mid-to-late Holocene based on single proxy-sources or on climate models are not satisfactory. More efforts should be put in bringing together experts of different disciplines and the results of their analyses: Data Assimilation could be the way to go.

O-5057

## The role of subglacial meltwater in ice-sheet retreat through Marguerite Bay, Antarctica

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<sup>3</sup>Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Japan

### Abstract

Geomorphology of the continental shelf reveals Marguerite Bay was once occupied by an ice stream that was underlain by extensive networks of meltwater channels and basins. This study examines the relationship of meltwater activity with grounding-line retreat since the Last Glacial Maximum as determined from sedimentologic and radiocarbon analysis of sediment cores and modifies previously published reconstructions of ice retreat. Existing geomorphic data suggest an embayment formed during initial retreat from the continental shelf edge, but the timing of initial retreat is not well-constrained. Whereas previous records of grounded ice retreat through Marguerite Bay were based only on minimum ages, we have produced more definitive grounding-line retreat ages by using an updated sediment facies model to guide us in selecting intervals for radiocarbon dating. Grounding line retreat occurred sometime well prior to 14 cal ka BP, with the ice shelf retreating to the middle continental shelf by 13 cal ka BP. The grounding line then continued to form embayments through the deep portions of Marguerite Bay as the grounding line and ice shelf gradually retreated through 11 cal ka BP. Marine radiocarbon ages indicate that by 10 cal ka BP, inner Marguerite Bay was nearly ice-free, corresponding to a 9.6 cal ka BP drawdown of nearby terrestrial ice. Meltwater deposits are found only within the basins of the rugged bedrock and are not found in cores on the shallower outer continental shelf, suggesting sediment was expelled within plumes at high enough velocities or sediment concentrations to prevent plumes from becoming hypopycnal. Meltwater deposition occurred throughout the gradual deglaciation beginning at 13 cal ka BP until just prior to the major 10 cal ka BP ice retreat. Marguerite Bay may be a useful model for estimating the future of the unstable Pine Island/Thwaites Glacier system, which is also underlain by an active hydrological system that produces sediment-laden meltwater plumes today.

O-5058

## Evidence for, and implications of, grounded, marine terminating ice sheets in the Central North Sea in the Early Pleistocene.

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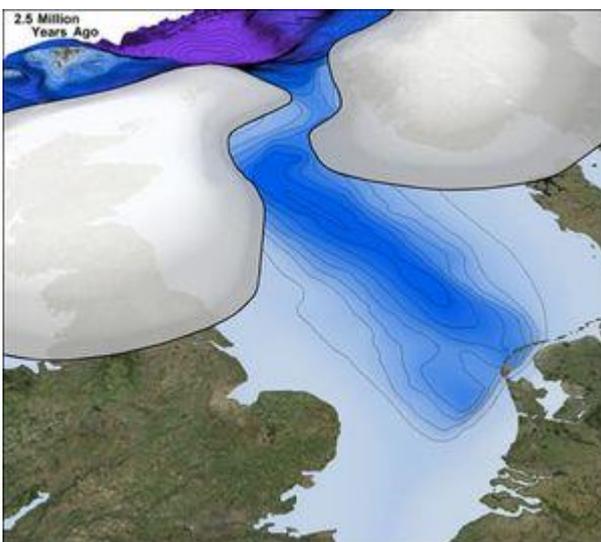
<sup>1</sup>University of Aberdeen, Aberdeen, United Kingdom. <sup>2</sup>Queens University Belfast, Belfast, United Kingdom.

<sup>3</sup>University of Manchester, Manchester, United Kingdom. <sup>4</sup>University of Sheffield, Sheffield, United Kingdom.

<sup>5</sup>Apache North Sea, Aberdeen, United Kingdom. <sup>6</sup>RPS Ichron, Northwich, United Kingdom. <sup>7</sup>Total E&P Danmark, Copenhagen, Denmark. <sup>8</sup>Lloyd's Register, Aberdeen, United Kingdom

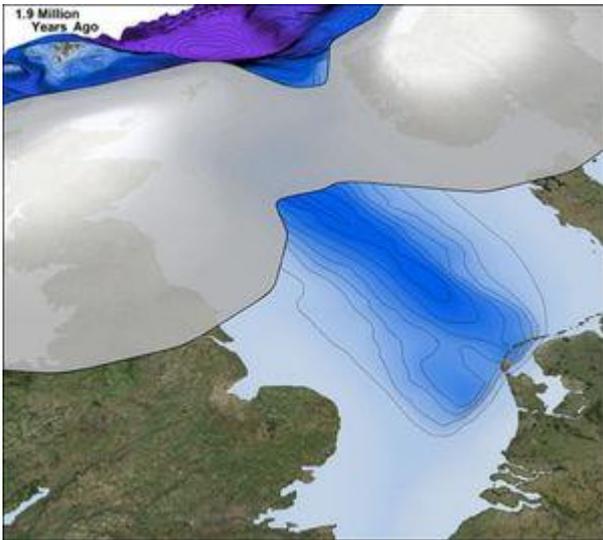
### Abstract

The main depo-centre in the North Sea, along the Central Graben and Viking Graben contains a rich sedimentary archive approaching, in places, 1000 m thick. Here we present a suite of evidence including detailed mapping from 3D seismic reflection data, borehole logs, chronostratigraphy, sedimentology and iceberg trajectory modelling. These data provide the opportunity to constrain the geometries of ice sheets around, and in, the North Sea Basin from the beginning of the Pleistocene. As early as 2.53 Ma a large marine terminating ice sheet/s repeatedly entered the North Sea basin, south of approximately 60°N, grounded in water depths up to ~250 m. By 1.87 Ma there is evidence for grounded ice across the entire basin, suggesting coalescence between British and Scandinavian ice masses and ice sheet geometries equivalent to those of the Late Pleistocene. Establishing the geometries of the early ice sheets is important for a number of reasons. The marine  $d^{18}O$  record is interpreted to show that during full-glacial global ice volumes were less in the Early Pleistocene. Once large enough mid-latitude ice sheets, are known to reconfigure large scale atmospheric circulation, having implications for the interpretation of other environmental proxies. The rapid evolution from fluvial to glacial landscapes, concomitant stripping of regolith and erosion of bedrock have implications for weathering derived  $CO_2$  drawdown and ice sheet dynamics.





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O-5059

## Retreat dynamics of marine-based ice sheets: perspectives from diverse glaciated continental margins

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### Abstract

While the grounding lines of marine-based ice sheets are considered to be broadly governed by regional topography, sea level and ice flux, processes occurring at the interface between the ice base and the substrate on which it rests are a key control on ice flow behaviour. The specific and local-scale processes responsible for the style of flow and rate of retreat can be highly variable across diverse marine settings and, therefore, their wider significance remains poorly understood. The exposed beds of palaeo-ice sheets on formerly glaciated continental shelves are an accessible means of studying past marine-based ice flow and ice sheet margin behaviour. We use a large dataset of glacial landforms from a variety of marine-based ice sheets in both hemispheres to systematically characterise the style of ice flow and retreat from its documented landform products. We interpret these glacial modes - encompassing ice flow, thermal regime, and retreat style - within the context of the local landscape type (trough, bank, basin, and fjord) and bed properties (e.g., slope, aspect, substrate geology). This allows us to test whether certain glacial modes and, importantly, variability in glacial modes are prevalent in certain topographic and substrate settings.

At a first order, we find that basins exhibit the most diverse and, therefore, least predictable behaviour. Both troughs and banks house high variability of glacial flow/retreat mode; we do not find that either favours a 'typical' mode of ice flow or retreat. Surprisingly, substrate geology appears to have little influence on the occurrence of ice streams or whether grounding line retreat proceeds steadily or inconsistently. We explore here the degree to which and the scales over which modes of marine-based ice flow and retreat are sensitive to topographic parameters and substrate properties, and whether any such overarching controls manifest as or are modulated by sub-system-scale processes such as meltwater drainage, subglacial sediment flux and landform creation.

By analysing ice sheet dynamics without the confines of a geographically limited dataset, we aim to provide analogues to contemporary marine-based systems and offer hindsight perspective on potential retreat behaviour into the future.

O-5060

## The advance and retreat of the Irish Sea Ice Stream in the Celtic Sea and its influence on shelf evolution

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### Abstract

The reconstruction of the largest ice stream to drain the British-Irish Ice Sheet at the Last Glacial Maximum (LGM) can provide essential palaeoglacial observations required for constraining numerical ice sheet models. The Irish Sea Ice Stream (ISIS) was long considered to have terminated on the mid-shelf of the Celtic Sea, based on sediment cores and seismic data collected in the 1970s. Here we summarise findings from sediment cores and geophysical data acquired since 2009, and multi-beam bathymetric data acquired since 2001, which permit an updated evolution and palaeoglacial reconstruction of the Irish and UK sectors of the Celtic Sea shelf. In near-shore areas, multi-beam data reveal over 2000 glacial features, including moraine ridges, streamlined bedrock and meltwater channels, recording the southwest advance of the ISIS towards the shelf-edge and its subsequent retreat. The mid- to outer-shelf is characterised by the largest known linear shelf sediment ridges. These vary from long and linear features, the megaridges, in the northwest to sinuous and shorter ridges in the southeast. This ridge field was initially interpreted as tidal in origin, but glacial sediments have been recovered from the flanks of the megaridges. Correlating decimetric-resolution geophysical data to sediment cores, the megaridges comprise three main units. 1) A superficial fining-upward drape above an unconformity, inferred to record decreasing ocean energy during marine transgression. Underlying this drape is 2), the Melville Formation (MFm), which comprises the upper bulk of the megaridges, displaying dipping internal acoustic reflections and consisting of medium to coarse sand and gravel, characteristics that could be consistent with either a tidal or glacial origin. The MFm unconformably overlies 3), the Upper Little Sole Formation (ULSFm), previously proposed to be of late Pliocene to early Pleistocene age, but is here shown to contain glacial sediments dated to the LGM. This stratigraphy constrains the age of the MFm to between 24-14 ka BP, coeval with deglaciation and a modelled period of megatidal conditions during transgression. Stratigraphically and sedimentologically these megaridges could represent glacial features eroded during the post-glacial marine transgression. However, it is argued that they comprise a partially-eroded glacial topography (ULSFm) mantled by post-glacial tidal deposits (MFm), both subsequently eroded by a proposed mechanism of enhanced wave energy during decreasing tidal energy in the later stages of transgression. Regardless of the origin of the ridges, the evidence shows that the ISIS extended to the shelf-edge of the Irish and UK sectors during the LGM.

O-5061

## Retreat of the NE Greenland Ice Stream since the Last Glacial Maximum recorded in marine archives.

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### Abstract

The NE Greenland Ice Stream (NEGIS), the largest ice stream draining the Greenland Ice Sheet (GrIS), is stabilised by two floating ice-shelves of 79N and Zachariae Isstrom. Since 2010, Zachariae Isstrom has experienced an accelerated rate of grounding line retreat (~4 km) and significant ice-shelf loss. This suggests that this sector of the GrIS is now responding to changes in oceanic and/or climatic conditions. However, the adjacent 70 km long ice shelf of 79N has shown comparatively little change with some model outputs predicting this ice shelf will remain stable in the future, despite evidence that it previously collapsed during the Holocene Thermal Maximum. To place these observations into a longer-term context a better understanding of the response of NEGIS to past oceanic and temperature change beyond instrumental records is necessary.

The project 'NEGIS', led by Durham University and in collaboration with AWI and the GRIFF project, aims to reconstruct the history of the NEGIS since the Last Glacial Maximum (LGM) to better understand past ice stream response to a warming climate. Here we present results and interpretations from an offshore dataset collected on the RV Polarstern, cruise PS100, in 2016. Gravity cores, up to 11 m long, supplemented by swath bathymetric and sub-bottom profiler data were acquired. Analyses on the cores include x-radiographs, physical properties, foraminiferal fauna, and radiocarbon dating.

Based on the sediment stratigraphy preserved in cores collected across the shelf, a four-stage process relating to ice stream/shelf retreat has been identified. A basal diamicton, that is barren of foraminifera, is interpreted as a subglacial till and is evidence of grounded ice. Laminated clay and silts containing very low abundance of glaciomarine foraminifera and no ice rafted debris (IRD) directly overlie this diamicton. We interpret this sedimentological unit as indicating glaciomarine conditions most likely deposited in a sub-ice shelf environment. On the outer-shelf, the oldest age from this unit is 19.3 ka BP, and on the inner-shelf it is 10 ka BP. Towards the top of this laminated unit foraminifera abundance increases and the species *Cassidulina neoteretis*, an Atlantic water indicator, becomes dominant. The lack of IRD implies this is still a sub-ice shelf setting. A sharp transition to massive mud containing gravel to pebbly sized clast, rich in foraminifera and dominated by *Cassidulina neoteretis*, captures the timing of ice-shelf break up and is constrained to ~15.7 ka BP on the outer-shelf and 7.9 ka BP on the inner-shelf. This data provides the first constraint of grounding line and ice shelf retreat since the LGM across the NE Greenland shelf. Furthermore, the data suggests that Atlantic waters were present prior to ice-shelf break up and therefore oceanic forcing likely played a significant role in ice-shelf instability.

O-5062

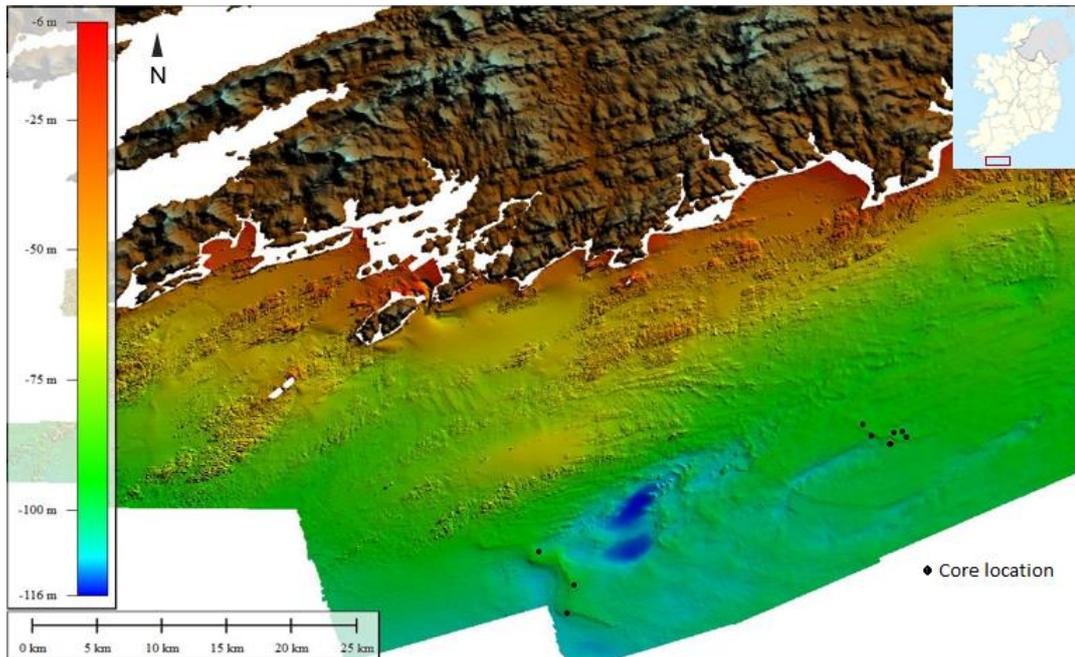
## A comparative study on the last deglaciation of Ireland and Newfoundland using marine geophysical data and sediment cores

Cristiana Giglio<sup>1</sup>, Sara Benetti<sup>1</sup>, Paul Dunlop<sup>1</sup>, Ruth Plets<sup>1</sup>, Colm Ó Cofaigh<sup>2</sup>, Fabio Sacchetti<sup>3</sup>, John Shaw<sup>4</sup>, Jennifer Organ<sup>5</sup>, Trevor Bell<sup>6</sup>

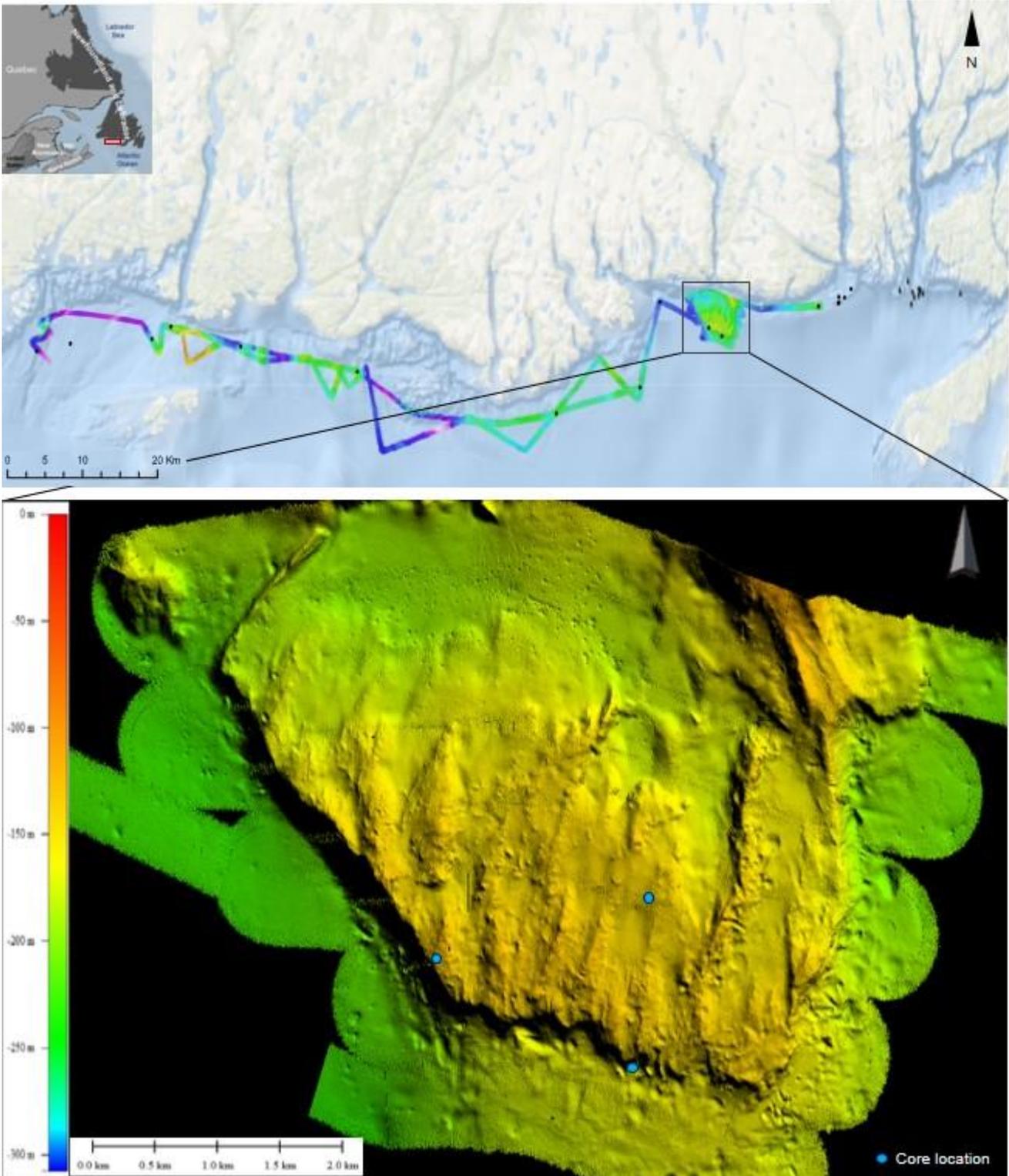
<sup>1</sup>Ulster University, Coleraine, United Kingdom. <sup>2</sup>Durham University, Durham, United Kingdom. <sup>3</sup>Marine Institute, Rinville Oranmore, Ireland. <sup>4</sup>Geological Survey of Canada, Dartmouth, Canada. <sup>5</sup>Geological Survey of Newfoundland and Labrador, St. John's, Canada. <sup>6</sup>Memorial University of Newfoundland, St. John's, Canada

### Abstract

Reconstructing the configuration and behaviour of palaeo-ice sheets is an important scientific goal as it provides new insights into how ice sheets respond to both internal and external drivers over a range of time-scales. During the last glaciation, the British-Irish Ice Sheet (BIIS) and the Newfoundland Ice Sheet (NIS) were situated on opposite sides of the Atlantic Ocean but at similar latitudes. Their position on the edge of the continent and the fact that they terminated in a marine environment make them key sites for examining ice sheet-ocean-climate interactions. The glacial history of the southern marine sectors of both ice sheets is still poorly understood. This project will shed new light on the extension and retreat of these ice sheets during the last glacial period, using high-resolution marine geophysical and sedimentary data collected on the SW Irish and southern Newfoundland shelves. Preliminary analysis of multi-beam bathymetric data from both sites show a series of linear to lobate and arcuate submarine ridges in both regions. Based on their geomorphology, these bedforms are provisionally interpreted as moraines in Ireland and fjord-mouth moraines in Newfoundland. They provide clear evidence of grounded ice and an opportunity to date ice sheets retreat across the continental shelves. Thirty-four sediment cores were acquired on and around these features, in both regions. Initial analysis of the cores has been focused on the interpretation of depositional processes. They include a diamicton facies assumed to be a subglacial till based on lithology, fabric and shear vane measurements, and glacio-marine muds displaying laminations and IRD in the X-radiographs. This presentation will include all of the results to date with the aim of testing the character and (a)synchronicity of the (de)glacial history of two ice sheets across the Northern Atlantic Ocean in order to assess the main drivers for ice sheet decay in the Late Quaternary.



**Figure 1.** Study area SW of Ireland, inshore of the Celtic Sea continental shelf. At the seafloor, ca 100 mbsl, a series of corrugate to linear and arcuate ridges are observed. Nine sediment cores has been collected on and around these glacial moraines.



**Figure 2.** Study area, South of Newfoundland. A series of linear to lobate and arcuate ridges are located at the fjord mouths, thus interpreted as fjord-mouth moraines. Twenty-six cores were acquired in connection with the fjord-systems.

O-5063

## Deglaciation of the last British-Irish Ice Sheet on the Atlantic shelf west of Ireland

Colm Ó Cofaigh<sup>1</sup>, S. Louise Callard<sup>1</sup>, Richard C. Chiverrell<sup>2</sup>, Dave H. Roberts<sup>1</sup>, Colin J. Ballantyne<sup>3</sup>, Margot Saher<sup>4</sup>, Katrien Van Landeghem<sup>4</sup>, Sara Benetti<sup>5</sup>, Stephen J. Livingstone<sup>6</sup>, Steven G. Moreton<sup>7</sup>, Chris D. Clark<sup>6</sup>, Derek Fabel<sup>8</sup>  
<sup>1</sup>Durham University, Durham, United Kingdom. <sup>2</sup>University of Liverpool, Liverpool, United Kingdom. <sup>3</sup>University of St. Andrews, St. Andrews, United Kingdom. <sup>4</sup>Bangor University, Bangor, United Kingdom. <sup>5</sup>Ulster University, Coleraine, United Kingdom. <sup>6</sup>University of Sheffield, Sheffield, United Kingdom. <sup>7</sup>NERC Radicarbon Facility, East Kilbride, United Kingdom. <sup>8</sup>SUERC, University of Glasgow, East Kilbride, United Kingdom

### Abstract

Understanding the pace and drivers of marine-based ice sheet retreat relies upon the integration of numerical ice sheet models with observations from contemporary polar ice sheets and well-constrained palaeo-glaciological reconstructions. This presentation reconstructs the retreat of the last British-Irish Ice Sheet (BIIS) from the Atlantic shelf west of Ireland at, and following, the LGM. It utilises marine-geophysical data and sediment cores that are dated by radiocarbon, combined with terrestrial cosmogenic nuclide (TCN) and optically-stimulated luminescence dating of onshore ice-marginal landforms, to reconstruct the timing and rate of ice sheet retreat from the continental shelf and across the adjoining coastline of Ireland. Moraines and grounding-zone wedges on the continental shelf record an extensive, shelf-edge terminating ice sheet west of Ireland at the LGM, and this is supported by the presence of dated subglacial tills in sediment cores from across the Porcupine Bank, a westwards extension of the Irish continental shelf. Dates on benthic glaciomarine foraminifera from deglacial sediments indicate that initial retreat from the shelf edge was underway before 25.9 ka cal BP. However, dated tills in sediment cores from the Porcupine Bank indicate that the ice sheet remained grounded on the outer shelf until c. 24.4 ka cal BP, and thereafter retreated to the mid-shelf where it formed a grounding-zone wedge at c. 23 ka cal BP. Lithofacies and benthic foraminifera indicate that retreat occurred in a glaciomarine environment. Subsequent recession is constrained by TCN dates on erratic boulders on the Aran Islands on the inner shelf. These sites were ice free by c. 19.5 ka BP. TCN dates from coastal sites along the Connemara mainland to the north indicate the ice sheet had become terrestrially based by 17.4-17.1 ka BP. This suggests that the Aran Islands acted to stabilise and slow overall ice sheet retreat once the BIIS margin had reached the inner shelf. Our results constrain the timing of initial retreat of the BIIS from the shelf edge west of Ireland to the period of minimum global eustatic sea level. Early BIIS retreat is consistent with recent offshore studies on BIIS history from further to the north along the Irish margin. Initial retreat offshore of western Ireland was driven, at least in part, by high relative sea level but our retreat chronology implies that this was more likely to have been a product of local glacio-isostatic depression rather than eustatic sea level rise. A picture emerges of a shelf-edge grounded BIIS during the LGM on the Atlantic shelf west of Ireland which contributed to its own demise by glacio-isostatic depression and associated sea level rise.

O-5064

## Where is the Toba eruption in the Vostok ice core? Clues from the O and S isotopes

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### Abstract

The ca. 74 ka BP “super-eruption” of Toba volcano in Sumatra is the largest known Quaternary eruption. It expelled an estimated of 2800 km<sup>3</sup> of dense rock equivalent, creating a caldera of 100 x 30 km. The eruption is estimated to have been 3500 greater than the Tambora eruption that created the “year without summer” in 1816 in Europe (Oppenheimer, 2002). However, the consequences of this “mega-eruption” on the climate and human evolution that could be expected for such eruption are still debated and uncertain. There is no evidence that this eruption has triggered any catastrophic climate change such as a “nuclear winter”. One of such lack of evidence lies in the ice.

In the ice core community, this eruption still remains a mystery. Indeed, the estimated size of the eruption should have left a gigantic mark in the ice, at least in the form of a huge sulfuric acid layer but none of the ice records covering this period show any such singularity. The sulfate record seems so common that it is in fact difficult to allocate a specific sulfate peak to this event.

In an effort to synchronize the Vostok ice core and the EPICA Dome C core, (Parrenin et al., 2012) have identified three possible sulfuric acid layers for the Toba eruption in the Vostok ice core. In order to see if one of such event could have been the Toba eruption, we have performed the sulfur isotope (and oxygen but still pending at the time of writing) analysis of these three sulfuric acid layers in the hope that it could reveal some particularity. The sulfur results show that 1- all these three events have injected their products in the stratosphere, 2- the sulfur isotopic compositions of these three events share a common array, array that is in lines with other stratospheric eruptions. Well, the mystery remains to why such huge event did not leave any remarkable imprint in the ice unless, as recently been speculated, the Toba eruption did not inject more sulfur in the atmosphere than the Tambora (Yost et al., 2018) or that the eruption was in fact not a single eruption but a series of few, spread over few hundred years.

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**O-5065**

## **Human reactions and escaping from an eruptive Santorini (Thera), Greece**

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### **Abstract**

The Late Bronze Age eruption (*ca.* 1650 B.C.) of Thera (Santorini) was one of the largest known in history, burying and destroying a thriving Cycladic culture that occupied the island. The consequent thick tephra sequence provides detailed information on the eruptive sequence and mechanics – it also buried remnants of Cycladic towns and farmsteads, the most prominent being at Akrotiri on the south coast of the island. Here relationships between the tephra stratigraphy and archaeological excavations clearly indicate the eruption was signaled by a major seismic event and a minor eruption. This precursory sequence instigated an evacuation of the island, but a hiatus between the two eruptive events allowed inhabitants to return for pairs of seismic damage...until the first major phase of the eruption instigated rapid and complete evacuation, as documented by the lack of victims found at Akrotiri attributable to the eruption. Yet few archaeological sites on surrounding islands record an influx of Cycladians with Thera-type crafts, the exception being Crete: where did the evacuees go, or did they perish at sea? We propose that the latter is likely 0 that given the slow speeds of rowed/paddled boats characteristic of Bronze Age boats, evacuees were killed at sea while just offshore of Thera by pyroclastic flows and surges crossing the sea surface. That flows can move across the ocean surface is well documented by modern and past eruptions. That some Cycladians successfully arrive on Crete implies these flows issued through newly collapsed rifts that directed flows to the west and north rather than to the south.

O-5066

## Volcanic impacts on the Nile watershed. Historical implications

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### Abstract

We report here on our ongoing collaborative work that seeks to understand the societal impacts of explosive volcanism on the Nile watershed. The key insight from which our project got its start is the observation that explosive volcanic eruptions can be linked (“teleconnected”) to the reduction in global precipitation. This is particularly dramatic in the case of the African monsoon that drove the annual flood of the Nile. By exploring the many new techniques that integrate climate proxy with historical data to understand a new dimension of historical dynamics, our aim is to establish a new historical ontology for pre-industrial Egypt by describing, for the first time, a detailed example of a coupled natural-human system. This also has wider implications for the entire pre-industrial world. We will provide a few examples from our working this presentation focusing on the second century BCE.

**O-5067**

## **Volcanic Pairs and Climate Modulations of the Last Millennium**

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### **Abstract**

Paired volcanic events are associated with some of the largest climate anomalies of the last millennium; of the three largest volcanic events, two were part of a pair. The Kuwae event (pair) in the mid-15th century has come to be regraded as part of a pair. Likewise, the Tambora eruption 1815 event was the second of a pair of events with the first occurring in 1809.

Here we use GISS-E2.1 and GISS-E3 with the MATRIX aerosol microphysics module to investigate paired volcanic events. We find that the initial event has a meaningful impact on stratospheric chemistry for several years. We investigate how this pre-conditioning modulates the climatic response.

O-5068

## Local impacts of the 1783-84 Lakagígar eruption in Iceland

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### Abstract

In early June 1783 a volcanic eruption began in the vicinity of Mount Laki in southern Iceland. It is often referred to in the non-Icelandic literature as the "Laki" eruption. This is a misnomer as the eruption did not occur on Mount Laki but on either side of it. In Icelandic it is called the *Lakagígar* eruption meaning the "Laki fissure" eruption. It is also referred to as Skaftáreldar, the "Skaftá fires" from the river Skaftá in southeast Iceland which dried up as a result of the eruption. The eruption lasted until February 1784 and was one of the most noteworthy and largest fissure eruptions in historical times. The Lakagígar eruption had a catastrophic effect in Iceland, not because the eruption caused direct loss of life, but because of the indirect effects as a result of the emission of volcanic gases and ashes distributed by wind. The grass, the basic food supply for the grazing livestock, became polluted and flourine poisoned. Within a year of the eruption, 53% of the cattle, 80% of the sheep and 77% of the horses died. The eruption was the primary cause of the ensuing famine which came to be known as *Móðuharðindin* or the "Famine of the Mist". However, the severe weather of the years 1782-84 also played a part in negatively impacting the human as well as the livestock population. It is estimated that the total death toll of *Móðuharðindin* represented 19 to 22% of the Icelandic population or approximately 10,000 people. The eruption occurred at a time when the full effects of the Enlightenment movement were being felt in Iceland. In consequence, there was a great general interest at this time in the observation of nature and natural events. In the year following the beginning of the eruption, six major contemporary descriptions of the event were published in Iceland. Other, unpublished records, such as reports by local officials to the Danish government, also give detailed accounts of the eruption. This presentation will focus on published and unpublished sources to analyse and describe the consequences of the Lakagígar eruption, in particular in northern Iceland, in the Mývatn district and the county of Eyjafjarðarsýsla. It will draw new and unused evidence into the discussion and analyse the effects of the catastrophe on a local level, relating this evidence to better known sources. It will also evaluate the effects of the catastrophe in these areas in relation to the general picture. The catastrophe did not hit every area with equal force, and the difference within and between regions will be discussed and analysed in search of explanations for these differences.

**O-5070**

## **How do the volcanic eruptions influence the decadal megadrought over the eastern China?**

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### **Abstract**

The influences and mechanisms of volcanic eruptions on decadal megadroughts over eastern China during the last millennium were investigated using a control (CTRL) and 5 volcanic eruption sensitivity experiments (VOLC) from the Community Earth System Model (CESM) Last Millennium Ensemble (LME) archive. The CTRL and VOLC experiments have similar decadal megadrought frequencies, which are all included in the 95% confidence intervals based on a 2000-member Monte Carlo simulation. The decadal megadroughts were associated with failures of the East Asia summer monsoon (EASM) resulted from a pattern of meridional tripolar sea surface temperature anomalies (SSTA) in the western Pacific stretching from the equator to high latitude, representing an internal mode in decadal-scale based on empirical orthogonal function (EOF). Composite analyses showed that, on inter-annual scale, within the decade after the eruptions, the volcanic eruptions firstly exacerbate the megadroughts, but then relieve the megadroughts due to the swift shifts from El Niño states to La Niña states on the third year after volcanic eruptions, with another damping process with smaller magnitudes. The impacts of volcanic eruptions on the megadrought magnitudes are linearly superposed on the internal variability. While, on decadal scale, the volcanic eruptions show little influences on megadrought magnitudes and lengths due to the smoothing on inter-annual influences.

O-5071

## Millennial-scale land-use changes and their effect on a small lake in southern Sweden based on pollen and lignin phenols

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### Abstract

In this study, a sediment sequence from Lake Skottenesjön, southern Sweden was investigated to reconstruct the effect of forestry and land-use on erosion rates and delivery of organic and mineral matter to the lake. Catchment-scale vegetation changes during the last 1000 years were reconstructed quantitatively using pollen analysis and the Landscape Reconstruction Algorithm (LRA). Organic matter in the lake sediments was analyzed using lignin phenols and bulk carbon stable isotopes. Changes in the delivery of mineral matter were analyzed using X-ray fluorescence scanning.

Variations in pollen assemblages, lignin phenol concentration and other geochemical proxies show that deforestation, agricultural activities and other human impacts on the lake catchment modified the organic and inorganic matter deposition in the lake. Between ca. AD 1000 and ca. AD 1350, the local land-use was characterized by small-scale agricultural activities associated with the medieval expansion. During this period, the woodland cover was dominated by deciduous trees, as revealed by both pollen composition and high values in the ratio between syringyl and vanillyl phenols (S/V). Increased deposition of terrestrial organic matter was indicated by the high concentration of lignin phenols. Around AD 1350, much of the farmland was abandoned and coniferous woodland cover increased as revealed by the pollen composition. A progressive decline in the lignin phenol concentration after ca. AD 1350 reflects a reduction of terrestrial organic matter input to the lake, probably as a direct effect of increased forestation of the catchment. After ca. AD 1650, both cultivated crops and pasture & meadows expanded in the catchment as seen in pollen assemblages. The increased land-use indicated by the pollen data is in agreement with the population increase documented in the study area between ca. AD 1700 and ca. AD 1850, but locally the human impact remained high for some time after the regional peak in population. Substantial increases in lithogenic elements (K, Ti, Rb) together with lower TOC content and higher C/N ratios indicate enhanced soil erosion from ca. AD 1650 to ca. AD 1950. Elevated  $\delta^{13}\text{C}$  values during this period reflect an increase in lake productivity that can be attributed to higher nutrient input associated with intensive soil erosion. S/V ratios increased in concert with an increase in deciduous trees and a distinct drop in coniferous woodland cover due to timber exploitation. Cinnamyl to vanillyl phenol ratios (C/V) increased together with an increase in grassland cover. The flux of lignin phenols increased drastically reflecting a substantial elevation of terrestrial organic matter input as a consequence of intensive human activities. This study illustrates that the combination of pollen and lignin phenols is useful for investigating past changes in the delivery of organic matter in response to the anthropogenic impact on lake catchments.

O-5072

## Distinguishing between natural and anthropogenic drivers of recent environmental change in Arctic Russia to inform Bewick's Swan conservation

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### Abstract

Arctic environments are highly sensitive to global climatic and environmental changes due to a number of feedback mechanisms. Responses to multiple stressors are already being observed with significant implications for the biota that rely on their ecosystems. The migratory Bewick's Swan is one such species whose population has declined since the 1990s, however significant uncertainties remain regarding the main driver(s) of its demise.

Applying a landscape-scale approach, using a combination of top-bottom core analyses and the more detailed investigation of 210Pb dated cores we reconstruct terrestrial and aquatic ecosystems over the last century in the Pechora Delta, northeast European Russia, one of the main breeding and summer feeding areas for the Bewick's Swan. Multi-proxy analyses, including cladocera, macrofossil, pollen, diatoms and geochemical analyses (XRF, ICP, C and N isotope) are employed to investigate ecological responses to pressures in the region and explore the ultimate impacts on breeding and moulting populations of the Bewick's Swan.

Since the late 20th century, there is clear evidence of community restructuring at the landscape scale across both aquatic and terrestrial ecosystems. The most prominent transformation within aquatic communities involves the replacement of large-bodied cladocera, primarily *Daphnia pulex*, by the smaller-bodied species, *Daphnia longispina*. Concurrently, major shifts in water level are inferred from declines in less moisture-tolerant mosses (*Dicranium fuscescens* and *Polytrichum* spp.) and littoral macrophytes (*Juncus* spp. and *E. hydropiper*), increased abundances of submerged macrophytes, and shifts from benthic (mainly *Fragilaria sensu lato*) to planktonic diatom species with evidence for increased primary production. There is a similar timing of ecosystem change in the terrestrial landscape with typical tundra heath communities being replaced by increasingly dominant boreal components, including *Betula nana*, *Alnus*, *Betula tortuosa* and *Salix* spp. The agreement between macrofossil and pollen records in the timing of community shifts corroborates a universal driver of ecosystem changes in the region. Although there is some evidence of atmospheric pollution, climatic variables appear to be most effective in explaining the trends observed with terrestrial vegetation potentially responding to increased air temperatures and enhanced moisture regimes, while changes in aquatic ecosystems may relate to enhanced hydrological connectivity promoted by increased river discharge and rising sea levels. Changes in vegetation and habitat indicated by the palaeolimnological evidence have significant implications for arctic species such as the Bewick's swan.

O-5073

## Early river deviations in the Swiss Alps and their effects on the lake system of Lake Thun

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### Abstract

Lake Thun was affected by two river corrections during the past millennium. The younger and well-documented deviation of the Kander River into the lake in 1714 AD heavily modified the lake system by increasing the water inflow by 40% and the sediment input by 85%. This work has been considered to be the first major river correction in Switzerland and a pioneer engineering project. The older river correction is less well constrained and documented. In the course of the past millennium the Lütschine River was stepwise deviated away from Lake Thun to upstream Lake Brienz, thus reducing the sediment input to Lake Thun and peak water inflows during floods. Previous studies using a geomorphological and sedimentological approach (paleochannels on the fan delta) combined with historic documents showed that the works on the Lütschine River were probably completed by a final river detour between 1750 and 1797 AD.

In this current project, we aim at (i) exploring the changes in the lake's system caused by these river corrections and at (ii) better constraining the chronology of the Lütschine River deviation. Essential for these investigations are new long Kullenberg-type sediment cores retrieved in 2018.

Sediment cores passing at several locations through the stratigraphic level of the Kander River deviation allow us to document tremendous changes in the sedimentation processes induced by this engineering work. The three most evident effects are a strong increase in authigenic calcite precipitation due to the dissolved load of the Kander River from limestone-rich subcatchments, frequent sublacustrine mass movements due to a fast growing delta, and a better mixing and thus aeration of the lake waters.

The approach for better constraining the past periods or relatively short events (e.g. large flood events) of the Lütschine River inflow is based on the geochemistry and mineral composition of the lake sediments, as well as on Lütschine flood layers. Two approaches are applied: (i) tracking the crystalline signature of the Lütschine sediment load that contrasts with the other tributaries located in catchments purely composed of sedimentary rocks, and (ii) correlating discrete flood layers with historically documented floods. Applied methods are <sup>137</sup>Cs and <sup>14</sup>C dating, XRF core scanning, and mineralogical analyses. Hence, our studies of the Lake Thun sediments support and refine the chronology of the gradual Lütschine River deviation. By clearly pre-dating the Kander River deviation these measures are an example of early human impact on river systems in the Alps that have not yet been well described.

O-5074

## Determining the contributions of atmospheric deposition and climate change to the browning of boreal lakes in Canada

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<sup>3</sup>Cooperative Freshwater Ecology Unit, Vale Living with Lakes Centre, Laurentian University, Sudbury, Canada

### Abstract

Over the past decades, organic carbon (OC) levels have increased in many lakes (i.e., “lake browning/brownification”) across Europe and NE North America. Identified drivers for this increase include reduced acid deposition, land-use/cover changes, and climate change, yet the specific contributions of these drivers are still debated. Recent paleolimnological studies have shown that it is possible to reconstruct past lake-water OC levels from sediment records using visible-near infrared (VNIR) spectroscopy models, thus providing key data about pre-human impact levels and natural long-term OC variability.

To determine the specific influence of acid deposition and climate change on lake-water OC concentrations, we inferred long-term OC trends from lake sediment records in low to high acid deposition regions over the past ~200 years. In contrast to their different acid deposition histories, our study regions in Canada have experienced a similar warming trend (1.3–1.6°C) since the early 1900s. OC reconstructions are based on a partial least square regression between VNIR spectra of surface sediments and corresponding lake-water OC measurements from 345 Arctic, boreal and northern temperate lakes (0–41 mg OC L<sup>-1</sup>, R<sup>2</sup><sub>CV</sub> = 0.57, RMSE<sub>CV</sub> = 4.4 mg OC L<sup>-1</sup>). For lakes near Sudbury in northeastern Ontario – an area that has been heavily affected by acid deposition during the 20th century – we also estimated OC burial rates to identify the implications of changing lake-water OC levels for long-term OC storage in sediments.

Inferred lake-water OC trends show a strong response to changes in atmospheric deposition across the landscape in acid-sensitive as well as well-buffered lake systems. For example, in lakes located in the high acid deposition region around Sudbury, OC concentrations declined by ~50% compared to pre-industrial levels. After SO<sub>2</sub> emission reductions in the 1970s, OC concentrations started to slowly recover, but still remained ~30% below pre-industrial values by the 2000s. In contrast, in lakes of the low deposition Experimental Lakes Area of northwestern Ontario, OC values declined by only ~10% during the early 20th century and exceeded pre-industrial values by the 1970s (~10% relative increase by the 2000s), likely in response to climate change. Our findings confirm the widespread “re-browning” of lakes in former high acid deposition regions, but also suggest that OC levels will potentially exceed pre-industrial values with complete recovery from acidification in response to ongoing climate change. In contrast to lake-water OC dynamics, OC burial trends in Sudbury lakes are more complex, and appear to be primarily driven by local (e.g., land-use/cover change, eutrophication) rather than regional changes.

O-5075

## Long-term effects of contamination from arsenic-rich mine tailings and natural variability on lake ecosystems in Northeastern Ontario, Canada.

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### Abstract

A silver mining boom in the early twentieth century near the Town of Cobalt in northeastern Ontario, Canada, has left a legacy of arsenic-rich mine tailings spread across the landscape, including contamination of many lakes and rivers. Mining and the dumping of mine tailings ended in Cobalt around the early-1930s but these tailings remain largely unmanaged and continue to move around the environment contaminating lake ecosystems with arsenic and other metals. The objectives of this research were to investigate the impact, if any, of arsenic-rich mine tailings on lake ecosystems, define ecological baseline conditions, and assess natural variability and recovery in these ecosystems, if any has occurred since mining activity ceased in the 1930s. Mine tailings were clearly visible in the sediment record (<sup>210</sup>Pb dated to ~1930) as a band of gray clay to silt material with elevated metal concentrations including arsenic levels of up to ~11,000 mg/kg. In fact, surface water concentrations of arsenic continue to be highly elevated at approximately 1,100 µg/L in some lakes. In the paleolimnological records, significant shifts in diatom assemblages occurred in response to the tailing contamination driven by an increase in the relative abundance of *Fragilaria construens*. *construens* to nearly 60% of the diatom assemblage, the loss of benthic diatom diversity, and a reduction in planktonic diatom abundance with no evidence of recovery in the diatom community nearly a century after mining activity has ceased. Surprisingly, at the landscape-scale, arsenic contamination is a poor-predictor of changes in surface sediment diatom, cladoceran, and chironomid assemblages, as well as open water zooplankton abundance and community, and phytoplankton concentration (measured as chl<sub>a</sub>). These results suggest that, within a single lake, mining contamination resulted in pronounced changes to the ecosystem with little to no ecological recovery. At the landscape scale, however, site specific limnological characteristics (e.g. mean depth, nutrients, colour, pH) are more important in structuring the biological community than regional mining related contamination.

O-5076

## Palaeolimnological evidence of tropical environmental change in three freshwater lakes in Tropical East Asia

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### Abstract

Regime shifts in ecology are characterised by major, often abrupt changes in ecosystem structure and functioning in response to one or more driving variables, or pressures. These responses can be due to natural or anthropogenically-driven changes. However, natural and anthropogenic drivers can produce similar responses in lake systems and thus, present a challenge in distinguishing natural from anthropogenic change in lake sediment archives. Despite the current combination of rapidly increasing pressures on what are often highly important socio-ecological systems, the resilience of lakes in the warm tropics to human perturbation is far less well understood than those at higher latitudes. Less work has been done disentangling human disturbance responses from other signals found in tropical lake sediment archives, such as climatic warming. Distinguishing the past effects of human drivers of ecological change is becoming increasingly important to anticipating how tropical lake systems will function in future. This paper focuses on evidence of environmental change from a cluster of three deep, freshwater, volcanic crater lakes (Yambo, Mohicap and Sampaloc) at low altitude on the island of Luzon, Philippines. The lakes support different intensities of aquaculture and shoreline development, allowing anthropogenic signals associated with human activity to be disentangled from regional climatic signals. Measured and monitored climate and water quality data, in addition to sedimentary evidence from sediment cores collected from the three study lakes, were used to determine the magnitude and trajectory of changes in lake water quality in the surrounding catchment. Sediment cores were radiometrically dated and analysed for organic matter, spheroidal carbonaceous particles (SCPs), diatoms, chironomids, pollen and charcoal. Despite differences in human pressures, a common trajectory and timing of aquatic ecological changes is apparent at all three study sites. This potential regime shift is characterised by a replacement of benthic with planktonic diatoms and an increase in diatom accumulation rates from the early to mid-1980s, is evident, and attests a low threshold for disturbance effects. A predominantly planktonic diatom flora has persisted even after recent improvements in environmental quality. The timing of these changes coincide with shifts in chironomid taxa that support the idea of a regime shift. The potential new regime may be less resilient and more susceptible to harmful algal blooms, abrupt expansions of anoxic conditions, and periodic mass fish kills when compared with its former state. Changes in the local pollen taxa and charcoal abundance also reflect shifts in vegetation cover and the timing and magnitude of local human disturbance. The results of the multi-proxy analysis provide new insights into possible anthropogenic regime shifts taking place in this region. The research further highlights the sensitivity of freshwater ecosystems in the warm tropics to disturbance pressures, and the risks to livelihoods, ecosystem services and sustainable development.

**O-5077**

## **Lake sediments and natural capital**

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### **Abstract**

Lakes are important components of our landscape and provide a range of important ecosystem services and natural capital. Additionally lake sediments contain signals of their physical, chemical and biological ontogeny reflecting natural system dynamics as well as anthropogenic activity. A summary of the available lake data is vital to help shape research efforts to determine catchment and lake system contributions to biogeochemical processes, for example, carbon burial. This is particularly important in the context of global climate change. This presentation will summarise the publicly available spatial data on Ireland's lake population. Although small in area, lakes play a critical role in biogeochemical cycling by storing organic carbon produced by the catchment/lake and by releasing CO<sub>2</sub> and CH<sub>4</sub> to the atmosphere. While Ireland has considerable peat and lake rich landscapes, quantitative data on carbon sequestration/burial in lake sediments are largely lacking. A synthesis of the lake sediment geochronologies that have been established for Irish lacustrine systems will be outlined and sediment accumulation rates quantified to-date will be used to establish key patterns and trends in relation to lake type. This in turn will provide invaluable context in terms lake sediment studies and interpretations of Anthropocene change in this north-west Atlantic coastal region.

O-5078

## Mediterranean vegetation change, landscape dynamics and human population trends through the Holocene

Jessie Woodbridge<sup>1,2</sup>, Ralph Fyfe<sup>1</sup>, Alessio Palmisano<sup>3</sup>, Neil Roberts<sup>1</sup>, Andy Bevan<sup>3</sup>, Stephen Shennan<sup>3</sup>

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### Abstract

The Mediterranean landscape has undergone significant changes throughout the Holocene. This research utilises large databases of modern pollen (Davis *et al.*, 2013) and fossil pollen from sediment cores (Leydet *et al.*, 2007-2018) as a proxy for vegetation change. Radiocarbon-led archaeological population proxies (Shennan & Edinborough, 2007) and settlement surveys are used to compare vegetation change with demographic trends. Cluster analysis and community classification of pollen datasets have revealed numerous closed forest/wooded vegetation types (e.g. evergreen and deciduous oak woods) and several open or scrub vegetation types (e.g. sclerophyllous scrub, steppe, grassland, parkland) (Fyfe *et al.*, 2018; Woodbridge *et al.*, 2018). Pollen-inferred landscape change indicates both short and long-term variability, which reflects temporal variations in climate and human land use. The pollen-inferred vegetation patterns and archaeological-inferred demographic trends are compared with fire history and palaeoclimate datasets in order to explore the drivers of disturbance in time and space within Mediterranean ecosystems. The initial decline in forest cover overlapped in time with the adoption of Neolithic farming, which spread from southwest Asia across most parts of the Mediterranean between ~9000 and ~7500 BP. Similarly, the gradual opening of Mediterranean landscapes between 7500 and 3000 Cal yr BP coincided with demographic rise and the emergence of complex, socially-stratified societies between the late Neolithic and the Iron Age. Thus, both human impact and climate change seem likely to have been responsible for land-cover changes during the mid-Holocene. However, the increase in open landscapes after 3000 Cal yr BP is consistent with anthropogenic causation (Roberts *et al.*, *in press: Holocene*). Analyses from six case study regions spanning the Mediterranean indicate that this has been a dynamic landscape throughout the Holocene with frequent changes in land-cover and persistence of disturbance and drought-adapted plant assemblages within an extensively human-modified environment.

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O-5079

## How does Holocene land use impact on land cover change at the national scale?

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### Abstract

It is widely accepted that European vegetation and biodiversity patterns have been shaped by humans over long time-scales, with deforestation, agriculture, grazing, fire and settlement having significant impacts. The complexities of these relationships remain poorly understood, particularly the relationship between land use practice and land cover change. It is important in managing future change to know how long these activities have been impacting upon natural systems and how they have shaped landscape dynamics. Exploring environmental change within the context of the Holocene (the last ~11,700 years) allows comparison of ecosystem states across a wide range of land use strategies, from hunter-gathering to complex patterns of land use in later prehistoric and historical periods. This contribution presents a new major effort to characterise land use from archaeological datasets, using the British Isles as a case study region, and compare spatial and temporal patterns of land use with contemporary land cover and land cover change. Whilst previous research across Europe has started to relate patterns of forest cover to past population expansion and contraction (e.g. Woodbridge et al. 2014), what people were actually doing (their land-use strategies), and the impacts of these land use strategies had on biodiversity lacks detail and remains unclear at national or regional scales.

This Leverhulme Trust-funded project is collating and synthesising archaeobotanical datasets derived from on-site excavations, and synthesising these to develop information on regional-scale land use and land use change, analysing these data within a palaeoinformatics approach (cf. Brewer et al. 2012). Initial synthesis of palynological and palaeoentomological data has revealed clear relationships between palaeo-demographic changes (from Bevan et al. 2017), vegetation cover and insect assemblages (from Smith et al., 2018) related to major patterns of subsistence change at the national level.

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O-5080

## Speeding up global landcover reconstructions with ROPES

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### Abstract

Over the past two decades, a better understanding of the pollen-vegetation relationship has triggered the development of quantitative methods in palynology, which enable pollen based reconstructions of past landcover. The methods are now increasingly applied in studies around the globe, initiated e.g. by the PAGES Landcover 6k project. However, in many parts of the world, application is still hampered by the fact that the methods available require pollen productivity as a key parameter. Calibration studies to calculate pollen productivity are laborious and time consuming; they so far focus on Europe and China with only single studies in other regions.

As an alternative method we present ROPES, which enables reconstructions from single pollen records alone, i.e. without predefined pollen productivity estimates. ROPES reconstructs regional cover of plant taxa using high resolution pollen profiles from large basins, which provide pollen accumulation rates (PAR). Unlike pollen percentage values, a change in the PAR of a taxon is linearly related to a change in its regional abundance. If, for example, the PAR of pine doubles at some point in time, this change is expected to represent a doubling in the mean regional cover of pine. To arrive at actual abundances, ROPES combines PAR data with count based reconstruction methods like REVEALS, in an iterative approach. REVEALS requires pollen productivity estimates, which are, as mentioned above, widespread unavailable. ROPES hence starts with random productivity estimates, which are then adjusted through optimization until the reconstructed cover of each taxon indeed shows similar changes along the profile as the respective PAR values (e.g. the doubling in pine). If successful, the approach thus arrives at past mean regional abundance *and* pollen productivity estimates for all relevant taxa in a data set. In other words: with ROPES pollen productivity is an observable or result rather than a pre-defined parameter.

To illustrate the potential of ROPES we first show applications for a number of sites across Central Europe, which demonstrate changes of pollen productivity in space and time. Changes in space, e.g. along climate gradient, have been postulated but could not yet be demonstrated with modern calibration studies. Calibration studies are moreover unable to detect variations of pollen productivity in time, e.g. in response to changes in climate or land management. ROPES can detect such changes and provide means for interpreting them.

Secondly, we show example applications for pollen records from all continents to illustrate the flexibility of ROPES.

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Theuerkauf M and Couwenberg J (2018) ROPES Reveals Past Land Cover and PPEs From Single Pollen Records. *Frontiers in Earth Science* 6. doi:10.3389/feart.2018.00014.

O-5081

## Mid to late Holocene reconstructions of forest composition in the northeastern and midwestern United States

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### Abstract

Reconstructions of pre-historic forest composition provide the means to establish natural baselines, variability, and trajectories of forest composition, both prior to and during the emergence of extensive anthropogenic land use. Pollen-vegetation models (PVMs), are used to reconstruct forest composition from sediment pollen data, typically by characterizing the processes of taxon-specific pollen production and dispersal.

Here we reconstruct changes in forest composition for the last 8,000 years at 300-year intervals for both the northeastern (NE) and upper midwestern (UMW) United States using the Bayesian hierarchical spatio-temporal PVM STEPPS and networks of fossil pollen records from the Neotoma Paleoecology Database. The quantitative, spatially explicit reconstructions of forest composition can be analyzed to test for significant changes over time, thereby advancing towards a long-standing challenge in palynology: distinguishing ecological signal from observational noise.

STEPPS is calibrated and validated using sediment pollen and land survey vegetation data from the early Euro-American settlement era (NE: 1700 – 1800 CE, UMW: 1800 – 1850 CE). For the calibration era, pollen-based reconstructions of forest composition compare favorably to observed vegetation, with accurate representation of both the main vegetational zones and ecotones.

In both spatial domains, we are able to reconstruct the spatial and temporal extent of the mid-Holocene hemlock decline (ca. 5400 cal BP). The hemlock decline is among the most prominent rapid vegetation changes seen in both regions; it results in the highest vegetation dissimilarities between consecutive time slices prior to large scale human influence. Hemlock begins to recover regionally after about 1500 years. In the NE, the relative abundance of hemlock does not reach the level prior to the decline, but in the UMW, hemlock returns to pre-decline levels.

In the NE, beech abundances increase during and after the hemlock decline, reaching maximum abundances at 4000 cal BP. Over the last 2000 years, beech decreases in central New England and spruce increases in northern New England. In the southwestern part of the NE, chestnut expands during the last 2000 years.

In the UMW, the single largest change over the last 2000 years is the in-filling of hemlock within its range, despite a largely stable range limit. Ash, elm, and other hardwoods expand in the Big Woods region. These changes took place against a regional backdrop of vegetation changes that were small in magnitude or insignificant, suggesting high complexity in the spatiotemporal patterns of past forest dynamics and the controlling environmental factors.



Overall, these reconstructions show how large networks of fossil pollen records, in concert with Bayesian hierarchical approaches like STEPPS, can detect the complex spatiotemporal patterns in past forest composition. A next critical step is to assess the possible influences of past variations in temperature and moisture availability upon these regional-scale vegetation change.

O-5082

## New methods of estimating Relative Pollen Productivity, a key parameter for reconstruction of past land cover from pollen records

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### Abstract

Mathematic models illustrating pollen-vegetation relationships provides new insights into reconstructing past land cover from pollen data, and also have the potential to translate the many thousands of pollen records produced over the last century into formats relevant to ecologists, archaeologists and climate scientists. However, the reliability of these land cover reconstructions depend on the availability of model parameters. A key parameter, Relative Pollen Productivity (RPP), is usually estimated from empirical data using “Extended R Value analysis” (ERV analysis, Parsons & Prentice, 1981; Prentice & Parsons, 1983). Collecting sufficient field data for successful ERV analysis is time-consuming, and acts as a major barrier to wider use of reconstruction models. Lack of RPP estimates for many regions is currently a major limitation on reconstructing global land cover.

We present two alternatives to ERV analysis, the Modified Davis method and an Iteration method, which use the same underlying model of the relationship between pollen and vegetation to estimate RPP from empirical data, but with different assumptions. These models are shown in simulation to perform at least as well as ERV analysis with both small and large datasets, and have the potential to increase the speed and geographic range of RPP estimation. We will present examples of their application to modern datasets including an example from southeast sub-tropical China which is not suitable for standard ERV analysis, and show how they can be used to obtain useful RPP estimates from problematic data.

Adding these two methods to the “toolkit” for land cover reconstruction from pollen records opens up the possibility to extend RPPs to wilder areas with available datasets such as existing Tauber trap data across Europe from Pollen Monitoring Programme (PMP). This can both speed up the inclusion of more of the globe in past land cover mapping exercises such as the PAGES Landcover6k working group and improve our understanding of how this parameter varies within a single taxon across geographic areas and the factors control that variation.

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O-5083

## Estimates of relative pollen productivity and application of the Landscape Reconstruction Algorithm on Holocene pollen records in Cameroon

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### Abstract

Questions related to conservation biology (e.g. biodiversity) and climate change often require a long-term historical perspective in which quantitative reconstructions of past vegetation abundance/land cover at local and regional spatial scales play an important role. The Landscape Reconstruction Algorithm (LRA; Sugita 2007 a, b) estimates vegetation abundance/plant cover at the regional scale (100 km x 100 km) and local scale (area of ca. 1-5 km radius) using the models REVEALS and LOVE, respectively. The LRA is the most widely tested, validated, and applied pollen-based quantitative reconstruction approach to date. However, the method has been used primarily in the northern hemisphere. Duffin and Bunting (2008) published estimates of relative pollen productivity (RPP), a parameter needed in LRA applications, for five plant taxa of southern Africa. Within the French research project C3A "Causes and consequences of the last great environmental crisis 3000 years ago in forests of Atlantic Equatorial Africa", we test the LRA in the mountain woodland and savannah vegetation of Cameroon.

We use modern pollen assemblages from soil samples and related vegetation surveys from 31 sites and the ERV-model to estimate RPPs of major taxa in the study region. We apply the LRA (REVEALS and LOVE models) using Holocene pollen records from two crater lakes/ponds (16.5 ha and 198 ha) in mountain woodlands and three lakes (46.7 ha, 25 ha and 8 ha) in savannahs.

The RPP estimates suggest that, relatively to Gramineae (RPP=1), taxa such as *Schefflera* and Combretaceae have high RPP values (>1), while e.g. *Podocarpus*, Asteraceae, and Cyperaceae have RPPs close to Gramineae, and e.g. *Alchemilla* and *Celtis* have low RPPs (< 1). LRA reconstructions of regional and local vegetation cover indicate more wooded landscapes than suggested by pollen percentages over the entire Holocene at sites located today in mountain woodland and mixed woodland-savannah landscapes. Moreover, the decreases in woodland cover at 3 ka BP and from 1.5 ka BP are generally more pronounced in the LRA reconstructions than in pollen percentages. LRA reconstructions in combination with land-use reconstructions inferred from archaeological data will be an important step towards more realistic descriptions of past anthropogenic land-cover and land-use change in western Africa for e.g. earth-system modelling.



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*References: Duffin K. I., Bunting M. J. 2008 *Veget Hist Archaeobot* 17:507–525; Sugita S. 2007a *Holocene* 17:229–241; Sugita S. 2007b *Holocene* 17:243–257*

O-5085

## Proglacial lake records of Holocene glacier behaviour, Zackenberg, Northeast Greenland

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### Abstract

Arctic air temperatures are currently rising at twice the global average rate. Understanding Arctic glacier and ice cap sensitivity to past climate change is important for predicting future retreat patterns. Geomorphological records of glacier behaviour, including moraines and alluvial sequences, are inherently fragmentary, but proglacial lakes can provide continuous, high-resolution archives of glacier behaviour. However, they have not been widely examined in the High Arctic – one of the most environmentally sensitive parts of the world.

We present sedimentary records from proglacial lakes close to Zackenberg in Northeast Greenland (74°N), 60 km east of the Greenland Ice Sheet. The lakes are situated downstream of an ice cap outlet and a neighbouring independent valley glacier, allowing us to examine in detail the nature and timing of glacier behaviour in response to Holocene environmental change, and how this behaviour is recorded in the lake sedimentary archive.

A combination of high-resolution sediment geochemistry (X-Ray Fluorescence and X-Ray Diffraction), particle size, magnetic susceptibility, total organic carbon analysis, and <sup>14</sup>C ages is used alongside geomorphological mapping to constrain glacier response to Late Holocene environmental change.

The sediment datasets indicate that lake sediment variation is driven by glacier activity. Importantly, by combining high-resolution XRD and XRF data, we are able to examine small-scale fluctuations in proglacial lake sedimentation that are not visible using XRF, or other sediment geochemical and physical parameters, alone. We identify two phases of enhanced glacier activity prior to the Little Ice Age (LIA), which is consistent with evidence of pre-LIA glacier advance recorded in Svalbard and Canada. A third phase, which represents smaller scale glacier fluctuations, is associated with the onset of the LIA.

Our analysis provides detailed insights into Late Holocene glacier activity in Northeast Greenland, at a level of detail that is not recorded in the geomorphological archive. This highlights the value of high-resolution geochemical analysis of lake sediments to establish glacier dynamics in regions where chronological and morphostratigraphical control is limited.

O-5086

## Control of large proglacial lakes on past outlet glacier dynamics during the Last Glacial Maximum in New Zealand

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### Abstract

Proglacial lakes are known to affect the stability of mountain glaciers and can partly disengage glacier behaviour from climatic perturbations. Ice-contact proglacial lakes are pervasive across New Zealand and 33 % of the country's perennial ice terminates within lake-calving glaciers. Proglacial lakes have been recognised as an integral part of the onset and progression of ice sheet deglaciation. It has been widely suggested that the retreat of glaciers in the Southern Alps immediately after the Last Glacial Maximum (LGM, c. 30–20 ka BP) could have been relatively rapid, not only because of climate forcing, but in addition to the widespread formation of large proglacial lakes. Ice-contact proglacial lakes formed during deglaciation from LGM ice advance limits, infilling the overdeepening. These lakes would have caused a shift from land-terminating to lacustrine-calving glacier termini, and that would have accelerated ice margin recession in many valleys and consequently ice mass loss. Despite the importance of glacier-lake interactions in influencing deglaciation, these mechanisms are generally ignored by ice sheet model simulations. The importance of this omission has not been quantified.

We use BISICLES, a higher-order ice sheet model capable of adaptive mesh refinement, to present a simulation of the Tasman Glacier at the LGM and beyond in an attempt to constrain the effect of proglacial lakes on glacier retreat. The Tasman Glacier has abundant empirical data and is well chronologically constrained at the LGM, which is used to inform, validate and analyse our numerical ice sheet simulations in this study. We perform idealised experiments of the retreat under a constant hypothetical climate forcing to isolate the effects of lake-terminating processes, simulating retreat of the glacier under a constant warm surface mass balance and sub-ice shelf melt. We look at the effect on the glacier margin by running two simulations, once with, and once without the presence of a lake. The influence of a proglacial lake accelerates deglaciation and reduces the relative influence of surface melting. The presence of the lake also changes the surface profile of the glacier during deglaciation, making it a stronger match for the empirical evidence. The change in surface slope in turn effects the influence of climate warming, introducing a positive feedback mechanism. As the lake evolves it creates hysteresis within the system. These results highlight the importance of including ice-contact proglacial lakes in palaeo-ice sheet modelling, as well as the need for a coherent regional model of ice-lobe and palaeo-lake evolution that reconciles all dating evidence in order to elucidate the pattern of retreat following the LGM in New Zealand.

O-5087

## The Development, Configuration and Chronology of the Ice-Dammed Lakes of the Ungava Peninsula (Northern Quebec, Canada) during the Last Deglaciation

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### Abstract

The retreat of the Laurentide Ice Sheet over the Ungava Peninsula led to the formation of several large ice-dammed lakes that have left an extensive record of raised shorelines in the main river valleys and low-lying basins. These glacial lakes drained through Ungava Bay and into the Labrador Sea, a critical area of the North Atlantic where deepwater formation occurs. However, assessing the impact of the drainage of these lakes on the ocean system is prevented by the lack of data on their configuration, volume, and chronology. Furthermore, the development of these lakes is intimately linked to the configuration of the ice margin and its position throughout the deglaciation, which are still poorly constrained, as is the chronology of ice retreat for this sector. Here, we reconstruct the extent and bathymetry of 3 major glacial lakes of the Ungava Peninsula (Nantais, Klotz and Payne) through detailed mapping of raised shorelines and associated landforms. We also document the pattern of ice withdrawal through systematic mapping of eskers and moraines using aerial-photographs, high-resolution satellite imagery (RapidEye) and DEMs. Observations were validated through fieldwork that allowed elevation measurements of the main shoreline sequences using high-precision DGPS. The lake development chronology was constrained through Terrestrial Cosmogenic Nuclide (<sup>10</sup>Be) dating of boulders sampled from the most representative shorelines. Our mapping results indicate that these lakes formed along a NW-SE oriented ice margin that was retreating towards the west-southwest. The pattern of ice withdrawal caused the opening of a series of southward-flowing outlets formed by the Lepellé, Lestage and Vachon river valleys, which allowed the meltwater bodies to successively spread into lower-elevation basins. The shoreline sequences show a progressive lowering of lake surfaces and a temporary connection between Lakes Nantais and Klotz. Ultimately, ice retreat allowed the final drawdown of the lakes through the Payne River, a major E-W depression linking the Peninsula interior to Ungava Bay. Preliminary <sup>10</sup>Be ages indicate that the sequential development of these glacial lakes occurred in a narrow timeframe centered around 8.7-9.7 ka. The context of ice withdrawal also implies that the lakes likely drained over a short time interval, suggesting that these meltwater discharges and those from other glacial lakes of the Ungava-Labrador region may have been an important component of the overall freshwater forcing(s) that altered the late deglacial and early Holocene climate. Altogether, these results refine our understanding of the development of glacial lakes in north-central Ungava and improve paleogeographic reconstructions by providing important constraints on the position and timing of the ice margin during the deglaciation of the Labrador Sector in this region.

O-5088

## Deciphering the palaeogeography of glacial Lake Fraser, British Columbia, Canada, using high resolution DEMs

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### Abstract

Glacial Lake Fraser (GLF) occupied the central interior of British Columbia (BC), Canada, at the close of the last Pleistocene glaciation. The lake was impounded behind the deteriorating Cordilleran Ice Sheet. This research focusses on understanding the changing palaeogeography of GLF and involves mapping shoreline features, such as beach ridges and wave-cut benches, using high resolution Digital Elevation Models.

Up to three phases of the lake have been defined: the McBride and Prince George phases, and possibly the Quesnel phase. The lake during the McBride phase is estimated to have been 370 km long, with an area of 8700 km<sup>2</sup>. It covered the Rocky Mountain Trench between Summit Lake and south of the Mica Dam, and had a surface that ranged in elevation between 1160 and 806 m a.s.l. The lake during the Prince George phase extended between Valemount and to at least 25 km east of Burns Lake, a distance of 430 km, and between Summit Lake and Williams Lake, a distance of 250 km (Figure 1). It had an estimated area of 12,500 km<sup>2</sup> and its surface ranged in elevation between 806 and 708 m a.s.l. The Quesnel phase occupied the Fraser River valley between Williams Lake and north of Quesnel, a maximum distance of 170 km. This phase had an estimated maximum area of 340 km<sup>2</sup>, and a maximum surface elevation of 548 m a.s.l.

During the McBride and Prince George phases, GLF drained northward into the Peace River watershed, drawing down lake levels by up to 452 m, from 1160 m a.s.l. to near 708 m a.s.l. The Prince George phase ended with rapid emptying of GLF during a jökulhlaup along the Fraser River valley. Evidence for this event within the GLF basin includes digitate, amphitheatre-shaped erosional forms in subaqueous outwash sands and silts produced during the rapid drawdown of the lake. The Quesnel phase drained southward through the Fraser River valley.

The evolution of GLF provides an opportunity to elucidate the distribution of remnant Cordilleran ice at the end of the Pleistocene Epoch in central BC. During the McBride phase, remnant glacier ice constrained GLF to the Rocky Mountain Trench. During the Prince George phase, much of the lower elevation areas of central BC, including the valleys of the Nechako and Fraser rivers, were occupied by a subaerial lake while glacier dams prevented westward flow beyond Burns Lake, and southward flow in the Fraser River valley south of Williams Lake.

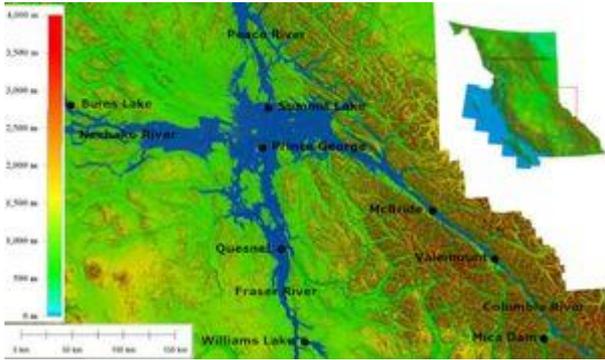


Figure 1. Approximate extent of glacial lakes in the central interior of BC during the Prince George phase of GLF.

O-5089

## Glacial Lake Shanadithit and regional ice dynamics in the Red Indian Lake Basin, Newfoundland, Canada

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### Abstract

At the late Wisconsinan glacial maximum, the island of Newfoundland was covered by a series of coalescent ice caps that extended out to the continental shelf, forming the Newfoundland Ice Cap. The radial and diachronous pattern of retreat, coupled with the topography of central Newfoundland, created an environment for the formation of ice-marginal lakes.

The spatial distribution and elevation of features such as deltas and shorelines, along with the presence of fine-grained sediment, have enabled the delineation of glacial Lake Shanadithit which occupied a surface area of 349 km<sup>2</sup> within the present day Red Indian Lake Basin. The location of topographic lows, and the pattern of glacial retreat, suggest that glacial Lake Shanadithit experienced four phases of ice-marginal lake development.

The proposed paleogeographic reconstruction model has important implications for both glacio-isostasy and for regional ice-retreat dynamics, which differ from previous glacio-isostasy and ice-retreat models.

De-levelled shoreline features and corresponding outlets indicate that the basin has undergone a minimum isostatic tilt of 0.22 m km<sup>-1</sup>. This is the first evidence of isostatic tilt within the interior of Newfoundland and indicates that the Newfoundland Ice Cap itself influenced the amount of glacio-isostasy on the island and was not over shadowed by the Laurentide Ice Sheet, as previously thought.

The active retreat and formation of glacial Lake Shanadithit within the Red Indian Lake Basin, as indicated by the proposed paleogeographic reconstruction model, indicates that the regional ice retreat pattern left isolated ice remnants on the highlands west of Buchans, and a larger ice remnant over the areas of northeast and south of Red Indian Lake. This is in contrast to the current model of a large ice mass situation over all of Red Indian Lake.

O-5090

## Proglacial environments and the southwest margin of the Laurentide Ice Sheet: Stratigraphy and geochronology of glacial Lake Great Falls

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### Abstract

Ice-dammed proglacial lakes can form where glacial ice lobes obstruct river drainages, and sediments associated with the proglacial lakes thus can be linked to patterns of advance and retreat of glacial margins. Sedimentary deposits along the upper Missouri River in Montana (U.S.A.) are interpreted as proglacial lake (glaciolacustrine) and till deposits. The results of stratigraphic and chronologic studies provide information on the extent, depositional environments, and timing of the Late Wisconsin Laurentide Ice Sheet (LIS). Two stratigraphic localities were studied and sampled for luminescence dating: Holter Lake (near Wolf Creek, U.S.G.S. Beartooth Mountain 7.5 minute quadrangle) and Hower Coulee (the Belt Creek area, east of Great Falls, U.S.G.S. Morony Dam 7.5 minute quadrangle). At Holter Lake, lake sediments include laminated deposits interpreted as varves. Luminescence samples were collected from laminated silts (UW355) and from overlying sands (UW356). The luminescence measurements indicate that both the laminated silts and the overlying sands are associated with Oxygen Isotope Stage (OIS) 2. If the overlying sands (UW356) are post-glacial aeolian sediments deposited after the drainage of glacial Lake Great Falls, then the LIS margin would have been north of this ice-free location after about 15,000 years ago. In the Hower Coulee area, the lower part of the stratigraphic sequence consists of fluvial gravels and sands overlain by laminated lake silts and other sediments (the "lower lake"). In "Outhouse Coulee" this sequence is over 8 m thick. Rythmites consisting of silts and clays are interpreted as varves and there are also beds of cross-bedded sands. The lower lake sediments are buried below a diamicton interpreted as a till deposited by a lobe of the LIS (the Loma sublobe of the Havre lobe). The diamicton is composed of a matrix of silt and clay supporting gravels and boulders. The till is overlain by several lithofacies related to a later stage of glacial Lake Great Falls (the "upper lake"). U-series measurements on shells indicate that the fluvial gravels below the lower lake sediments may be associated with the last interglacial (OIS 5). Luminescence samples from deposits of the lower lake (UW468, UW469) and the deposits of the upper lake (UW454, UW467) indicate the proglacial lake sediments are associated with OIS 2. Direct-dating of the sediments support a late-Wisconsin age for the Holter Lake and Hower Coulee stratigraphic sequences. This implies that a proglacial lake was formed in this part of the present-day Missouri Valley by a lobe of the LIS, indicating the maximum extent of the Late-Wisconsin southwest margin of the LIS.

O-5091

## A 25,000-year history of glaciation from Fish Lake, UT and the potential to extend this record through multiple glacial cycles

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### Abstract

The Quaternary paleoenvironmental history of the Bonneville Basin has been the focus of numerous studies for over a century, but the region continues to attract attention because many uncertainties about the mechanism driving the expansion of pluvial lakes during glacial conditions remain. The lake is moderate in size (~7x1.5 km), relatively deep (37 m) and located within the high elevation, formerly glaciated, Fish Lake Plateau (3545 m) where precipitation is heavily influenced by the North American Monsoon. The lake occupies a NE-striking tectonic graben. Seismic and gravity measurements suggest that Fish Lake may contain sediment thickness on the order of 240 m. Fish Lake Plateau exposure ages indicate late Pleistocene moraine deposition during Pinedale (15-23 ka) and Bull Lake (130-150 ka) times. One outlet glacier deposited moraines and outwash into the northern margin of Fish Lake, but the main basin was never glaciated.

We collected cores through the ice in February of 2014 using a 9-cm-diameter UWITECH coring system in 31 m of water. An 11.2-m-long composite core was constructed from overlapping 2 m drives taken in triplicate and dated using 12 radiocarbon measurements and 3 know-age tephras. Core lithology, CT scans, magnetic susceptibility (MS), sediment density, organic matter content (OM), and biogenic silica concentration (BSi) demonstrate complete recovery with three distinct sediment packages: 1) a Holocene to post-glacial interval characterized by high OM and BSi, and low clastic content and MS, 2) a fine-grained, high MS minerogenic glacial section with low OM and BSi, and 3) a short section of inferred pre-LGM sediment with intermediate composition. The paleomagnetic record, though weak in the Holocene, compares well with the high-quality record from proximal Fish Lake, Oregon and Bear Lake, Utah. Beyond the Holocene, a much stronger MS signal is preserved that compares well with a paleomagnetic secular variation correlation template we are developing from marine records from the Northeast Pacific. These data and extrapolation of the age model to the maximum estimated sediment thickness suggest a complete Fish Lake record may be older than 500-700 ka, and that a complete sedimentary record likely contains paleoclimatic and paleoenvironmental information that spans multiple glacial cycles.

Few continuous geologic archives in the Bonneville Basin have sufficient duration, temporal resolution, and dating control to address multiple glacial-interglacial climate variations, including forcing and feedbacks and relationships with local glacial extents and vegetation change. Some existing paleoclimate records suggest that Bonneville Basin paleoclimate was asynchronous with orbital variations and global boundary conditions, which raises significant questions about the nature timing and length of previous interglacial periods and the influence of the North American Monsoon, which is relevant for understanding potential change for the region in the future.

O-5092

## An empty desert? Hominin responses to environmental fluctuation in Arabia.

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### Abstract

The Arabian Peninsula is a vast and poorly understood area at the interface of Africa and Eurasia. The area has traditionally been sidelined in accounts of human prehistory. Yet, understanding the prehistory of Arabia can cast light on hominin dispersals, biogeography and responses to environmental change. How, for example, did hominin populations respond to abrupt transitions to aridity at the end of humid phases? While the surface of Arabia is covered in millions of artefacts, it is only in the last decade that dated archaeological sites have been studied in the area. In this talk I will outline recent multidisciplinary fieldwork in Arabia, extending from Middle Pleistocene Lower Palaeolithic assemblages through to the early Holocene and the transition to the Neolithic. A variety of datasets – including vertebrate palaeontology, diatom ecology and sedimentology – provide contextual information to understand the ecological and environmental settings of different human occupations. Together these findings indicate multiple hominin dispersals into Arabia over at least the last 500,000 years, followed by contractions to southern Arabia as the monsoon rains faded with each return to aridity. This led to a complex pattern of indigenous cultural developments. I will explore how this emerging Arabian record is both fascinating in terms of local human behavioural and demographic dynamics, as well as being of profound global importance in terms of factors such as calibrating the dispersal of *Homo sapiens* into Eurasia. As an arid region at the nexus of Africa and Eurasia, Arabia is well positioned to elucidate human abilities to survive in extreme environments, in an area generally characterised by aridity, but punctuated by occasional humid episodes. This ability to survive extreme conditions was essential to the global spread of our species, and the Arabian record indicates the social and technological factors which need to be understood in sync with the ecological and climatic contexts of hominin occupation.

O-5093

## Adaptive strategy to dryland among Paleolithic hunter–gatherers: ethno-archaeological approach of using water and animals in southern Jordan

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### Abstract

The inland Levant, including southern Jordan, is currently characterized by hyper-arid environments with less than 50 mm annual precipitation. Although paleoclimatic records show occurrences of more humid conditions in the Pleistocene, they were still in the range of semi-arid environments. Paleolithic adaptation to such dryland areas is a key topic for investigations of densely distributed Paleolithic sites in southern Jordan, particularly late Middle Paleolithic, Upper Paleolithic, and Epipaleolithic sites (Henry 1995; Kadowaki and Henry 2019). Herein, we present results of ethno-archaeological fieldwork examining the procurement of water and bird hunting in mountainous drylands in southern Jordan. The study area is used today by people subsisting on livestock herding (sheep, goat, and camels). In this very dry area, our survey found that local people use several pools to retain water for a long time after rainfall. Some pools, natural depressions in sandstone bedrock, are located near some Paleolithic sites, particularly Upper Paleolithic sites. The water is depleted at various times depending on the pool, but some pools apparently maintained water almost year-round. We also report our survey of bird hunting by local people using stone fall-traps to catch chukars. Chukars are one species identified from faunal remains from Tor Hamar, an Upper Paleolithic site in the same area. The use of such small birds in the Upper Paleolithic contrasts against the use in that area of ostriches during the Middle Paleolithic. In this way, our ethnographic fieldwork found exploitation of water and small birds even in the currently hyper-arid settings. These resource-use behaviors were achieved using simple technologies that are expected to have also been available in the Paleolithic. Therefore, they might have been key adaptive behaviors used by Paleolithic hunter–gatherers in the marginal settings of southern Jordan.

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**O-5094**

## **Climate as a driver of stage 3 human dispersal through northern Mongolia**

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### **Abstract**

The fluctuating climate of stage 3 has been seen as an important driver of human dispersal and cultural adaptation globally; climate-dependent changes in the extent and carrying capacity of the Eurasian steppe may have driven human dispersals across it. While much is known about the effects of high amplitude climatic oscillation in Europe, the magnitude and nature of these events in extreme continental central Asia is now a subject of considerable research interest. In northern Mongolia, which currently sits at the limit of the influence of the East Asian monsoon, stage 3 may have experienced a different precipitation regime than today. New terrestrial sedimentary records at upper Palaeolithic sites in northern Mongolia give evidence for climate and precipitation in this region over the past 45,000 years and more. The records preserve evidence for several successive human incursions during climatic ameliorations throughout stages 3 and 2, and for regional abandonment during deteriorations. These incursions include what is likely to be the first AMH presence in the region; because of its topography, northern Mongolia may have acted as a gateway to East Asia, and our research shows that this gateway probably opened and closed several times during stage 3.

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**O-5095**

**50,000 years of continuity and change in the southern Kimberley deserts of Western Australia.**

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**Abstract**

Excavations on the edge of the Great Sandy Desert, southern Kimberley, Australia, have revealed 50,000 years of Aboriginal occupation. Recent research on a variety of local records from both archaeological and non-archaeological sites, including from fauna, macrobotanical remains, pollen, charcoal and speleothems, has provided a very detailed picture of environmental changes for this region over the same period. These records show that despite periods of weakening monsoon during the LGM and late Holocene, the deserts and semi arid zone were continuously occupied, albeit with likely restructuring of groups in the landscape and seasonally. There is also good evidence in the archaeological sites for changes in technology that might reflect adaptation to weakening monsoon activity. In this paper we discuss the occupation of arid Australia in the context of the broader Australian archaeological record.

O-5096

## People in an extreme climatic place? Tasmanian Aboriginal responses during the LGM.

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### Abstract

The remarkable story of the earliest Tasmanian people begins with sea crossings in the tropical north of Sahul (New Guinea-Australia-Tasmania) about 55,000 years ago. Over the next 600 generations, they traversed the length of the continent for thousands of kilometres reaching what was then a rugged peninsula jutting into the Southern Ocean. By at least 40,000 years ago people walked across the exposed Bassian Plain when sea levels were 130 m below the present day and entered the frozen Tasmania landscape, making them the most southerly people on Earth at that time. They lived through the peak of the Last Glacial Maximum, inhabiting the river valleys of southwest Tasmania. Archaeological research here has identified numerous limestone caves and open sites that attest to the resilience and skill of these people, particularly their economic and social adaptations to this extreme late Pleistocene environment (Allen et al. 2016). These people planned their land use and utilized resources in a systematic manner in a challenging palaeoenvironmental setting.

Using skeletochronology (Pike-Tay et al. 2008), stable isotopes  $\delta^{15}\text{N}/\delta^{13}\text{C}/\delta^{18}\text{O}$  in teeth and bone and, Fatty Acid Profile (FAMES - Fatty Acid Methyl Esters) methodologies, we have identified significant patterning in the rich faunal assemblages for systematic, seasonal resource acquisition in late Pleistocene southwest Tasmania. Paradoxically however, there is very little nutritional variability in the major prey animal, Bennett's wallaby, based on sex, age, geography or season (Garvey 2011). This marsupial appears to remain a reliable and stable source of high quality fatty acids in their bone marrow. This differs significantly from northern hemisphere reindeer that have greater nutrient variability according to sex, geography and season. Given the hemispherical dichotomy between seasonally stable and unstable resources, we postulate that this is also reflected in the two region's differing stone technologies during the LGM.

In this presentation we review more recent research on stable isotopes, comparative nutritional returns from the hunted prey animals and the technology used to acquire them.

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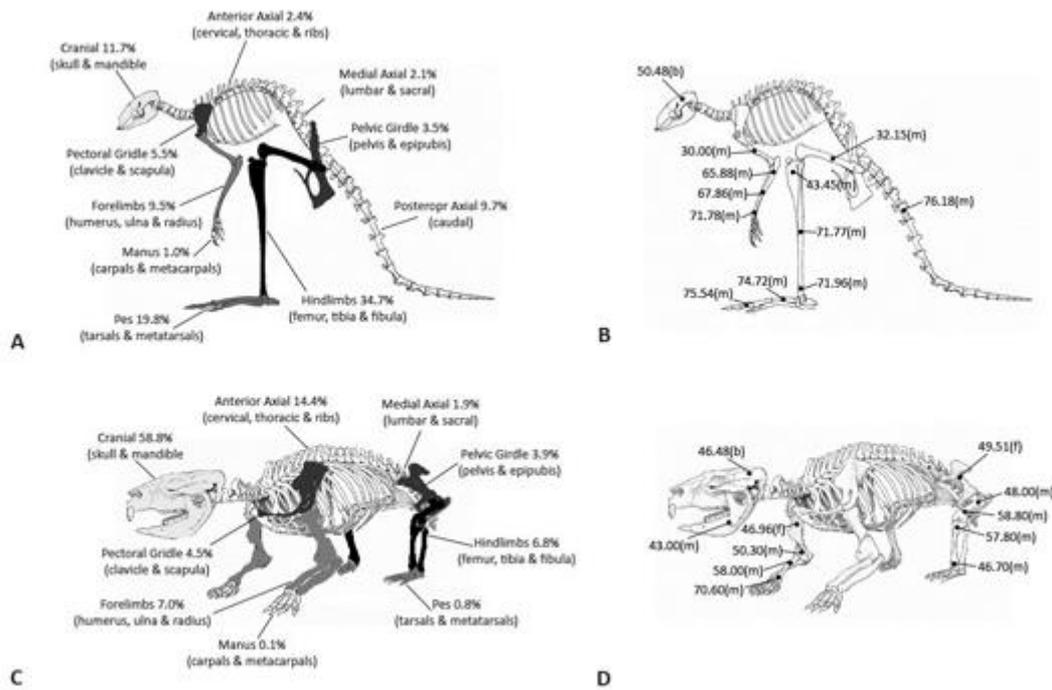
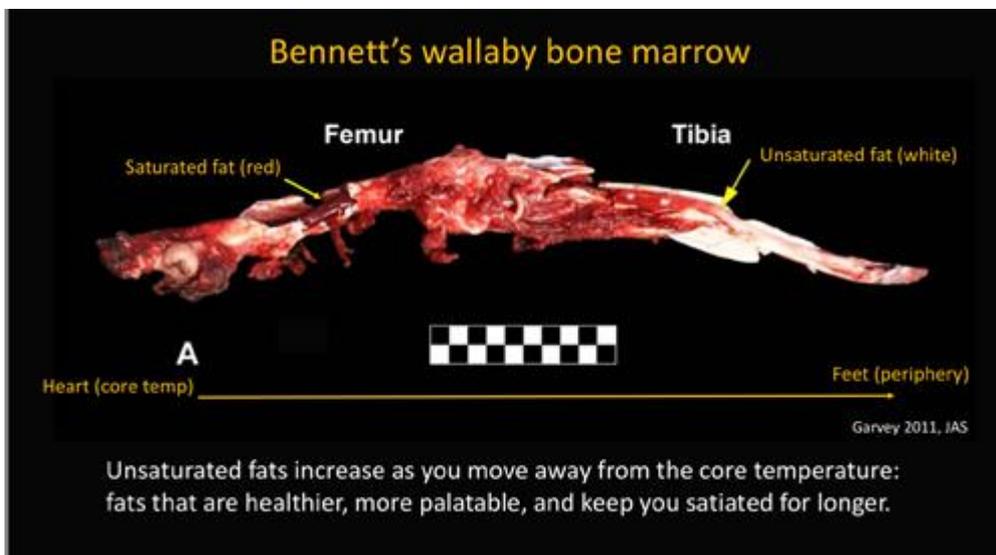


Figure 1. A & C: The distribution of skeletal elements of the Bennett's wallaby (*Macropus rufogriseus*) and the common wombat (*Vombatus ursinus*) in LGM archaeological sites. B & D: The percentage of the total unsaturated fatty acids in the bone marrow for both species.



Figure

O-5097

## The Younger Dryas and the colonisation of the Amazon

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### Abstract

New archaeological data from Serrania de la Lindosa, Colombia, suggest climatic impacts on resources drove early human colonisation of the Amazon forest during the Younger Dryas. At the end of the Pleistocene, humans had entered South America and colonised the Bogota plateau when rising temperatures and greater precipitation established marshes and oak/alder landscapes that supported an abundance of resources, including megafauna. The return to glacial conditions during the Younger Dryas stressed high-altitude resources and drove the tree line down 300-600 m. This period coincides with the first evidence of human colonisation of the lowland forest-savanna ecotone, as revealed by multiple new contexts dating to ca. 12.5 kya in the rock shelters of Serrania de la Lindosa. The rock shelters show evidence of sustained and continued occupation and are accompanied by extensive rock art, which includes depictions of plants, animals, hand prints, geometric designs and now extinct megafauna. Archaeobotanical data reveal an increasing reliance on plant resources, many of which later become Amazonian hyperdominants. Integrated archaeological, archaeobotanical, climatic, and paleoecological data indicate that climatic change during the Pleistocene-Holocene transition impacted resources, causing a “push” from the Andean Plateau, and a “pull” to lowland forests, establishing the early human colonisation of the Amazon.

O-5098

## Did extreme aridity drive the earliest efflorescence of human culture?

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### Abstract

The Aterian technocomplex is associated with the Last Interglacial and the spread of early *Homo sapiens* across North Africa. Aterian lithic technology has been described as 'arid adapted', while ecological studies have documented substantial environmental amelioration across the Sahara. With the archaeological and environmental dynamics mapped at different scales, there is an apparent mismatch between a 'Green Sahara' and the idea of humans living on the desert fringes. In this paper, the reasons why Aterian lithic technology are regarded as 'arid adapted' are critically assessed in the context of climate proxies and models for North Africa in Marine Isotope Stages (MIS) 5-3. These give insights into the ongoing attempt to identify how 'green was green', when it comes to the Sahara in MIS 5. Carrying capacity, mobility patterns and regional cultural variation are also explored in order to shed light on varied subsistence strategies and their relationships with the broader ecological patchwork of North Africa between MIS 5-3. The results will settle the debate: was the Aterian innovation the result of extreme aridity or not?

O-5099

## Tracing environmental changes in the Pacific island of Espiritu Santo, Vanuatu

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### Abstract

Small islands are paradigmatic cases of anthropogenic impacts on ecosystems. Using lake sediment cores to reconstruct past human activities can help retrieve information about the environmental responses to different rates and degrees of change on these vulnerable ecosystems. On islands in Remote Oceania, the origin and timing of the first human settlements, and consequent ecosystem modifications are still under debate. Past landscape changes have been demonstrated by archaeological, palaeontological, palynological and geomorphological investigations. However, few sedimentological studies have been conducted so far on this topic in the area. In our study, we used a multiproxy approach, combining geochemical tools based on biomarkers (fossil molecules of known origin) with traditional sedimentological methods (total organic carbon, biogenic silica, grain size) on cores from three lakes of the west coast of Espiritu Santo, Vanuatu, each dating back ~ 1000 years. The catchments of the three lakes are under different anthropogenic influence. Lake Nopovois is located near a village, lake Vesalea is located near a garden, and lake Wunawae has no human settlement nearby. From the results, it is possible to identify different phases of human occupation. Lake Nopovois shows at the bottom of the core (60-80 cm) an undisturbed baseline. Starting from 60 cm all proxies indicate a modification in the catchment, here interpreted as human induced changes (*i.e.* soil erosion – increase in total organic carbon and grain size; lake eutrophication – increase in biogenic silica; changes in vegetation – *n*-alkanes results indicating a shift towards a less forested area and an increase in macrophytes on the lake surface). This signal is interrupted by the occurrence of two volcanic eruptions, confirmed by preliminary observations of tephra layers as well as by a sharp decrease of mean grain size. The results from the other two lakes (lake Vesalea and lake Wunawae) will allow us to compare catchments with different histories of human occupation and trace anthropogenic impacts linked to land use changes in the area.

O-5100

## Reconstructing last millennium hydroclimate from Kiritimati sediments using lipid biomarkers

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### Abstract

Tropical Pacific climate phenomena, such as the El Niño Southern Oscillation (ENSO) and the Intertropical Convergence Zone (ITCZ), are major components of the global climate system. Due to the short and sparse observational record from the tropical Pacific, paleoclimate archives are necessary to understand the full range of climate variability in this region. Lake sediment records are particularly advantageous for assessing decadal- to centennial-scale terrestrial climate variability as they are typically continuous with high temporal resolution. To date there are only two lake sediment records from the central tropical Pacific, a key ENSO 'center of action' where precipitation is also highly sensitive to movements of the ITCZ. Here we use a lake sediment record from Kiritimati (2°N, 157°W), to reconstruct changes in lake water chemistry and climate over the last millennium.

A 91 cm sediment core spanning ~1150 years was collected from Lake 30, a brackish lake (28 ppt), in June 2017. High resolution X-ray fluorescence measurements show an increase in S relative to Ca (S/Ca) from 900 to 1300 CE, indicating a period of gypsum deposition, consistent with previous work. To more quantitatively assess changes in lake water balance and salinity, bulk hydrogen isotope values of total lipid extracts ( $\delta D_{TLE}$ ) were measured at decadal resolution over the last millennium, and biomarkers were extracted for subsequent compound-specific  $\delta D$  analysis.  $\delta D_{TLE}$  increases significantly from 900 to 1300 CE, coinciding with the episode of gypsum precipitation, and the two variables are significantly correlated downcore ( $r=0.53$ ,  $n=67$ ,  $p<0.001$ ).

The presence of gypsum is qualitatively indicative of more saline conditions, and enriched  $\delta D_{TLE}$  values during this period also indicate higher salinity, based on the empirical relationship between salinity and  $\delta D_{TLE}$  in surface sediments in Kiritimati lakes (Sachse and Sachs, 2008). This relationship, thought to be driven by changes in net lipid-water D/H fractionation under changing salinity, suggests a salinity range of 4-135 ppt in Lake 30 over the last millennium, with maximum values from 900-1000 CE. However, comparison of  $\delta D_{TLE}$  values with core lithology show depleted  $\delta D_{TLE}$  values corresponding to thicker, darker microbial mat units. This association between  $\delta D_{TLE}$  and microbial mat structures suggests variations in  $\delta D_{TLE}$  may also be driven by varying microbial community structure downcore. As microbial communities and salinity are likely correlated, understanding the effects of both salinity and microbial community structure on  $\delta D_{TLE}$  requires additional analysis. We plan future research on compound-specific  $\delta D$ , paired with inorganic carbonate  $\delta^{18}O$  and detailed isotope-based hydrologic balance modeling, to further define the relationship between biomarker  $\delta D$ , salinity, and lake hydrology.

O-5101

## Did climate drive the human colonisation of Eastern Polynesia? New evidence from multi-proxy lake sediment records.

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### Abstract

The island archipelagos of the South Pacific were among the last places colonised by humans. Debates exist over the precise timing of the arrival of people, and the duration of the “long pause” between arrival in Tonga and Samoa, and the move east into remote Polynesia. There is also a debate over the driving motivation for the long voyages east with different scientific communities advocating climate, social unrest, population growth and a process of exploration. In part the debates have been caused by two issues; first the disparity between archaeological dates and those from other palaeoenvironmental archives, and secondly the absence of robust palaeoclimate records from the region. In this paper we report a new suite of multiproxy lake sediment archives from Samoa and the southern Cook Islands that reconstruct both hydroclimate and the process of human arrival. Use of short-lived materials for radiocarbon dating, brings lake dates in line with archaeologically derived estimates for the date of human arrival in both islands. Reconstructed hydroclimate from the same cores, reveal settlement occurring during or shortly after major dry phases on Samoa that coincide with a period of regional climate change supporting arguments for a climatic forcing for the decision to migrate east into the Pacific.

O-5102

## Record of environmental changes around the Rano Aroi pond (Easter Island) over the last 1200 years

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### Abstract

Drastic changes in the vegetation diversity on Easter Island have been fairly documented by pioneer studies (Flenley and King, 1984; Orliac and Orliac, 2000). These rapid modifications, estimated between the XVI and the XVIII century, have been attributed to different potential origins, such as anthropogenic forcings (Flenley and Banh, 2007) or flora consumption by rats (Hunt and Lipo, 2007). Climatic variations, such as changes in the hydrological budget (drought occurrence), have also been suggested (Orliac, 2000; Rull et al., 2016), according to a possible migration of climatic fronts over the Pacific, expected within the Little Ice Age period (LIA), and/or unusual ENSO activities such as long-lasting La Nina events (Sachs et al., 2008; Nelson et Sachs, 2016; Delcroix et al., 2018).

This study focuses on a lacustrine sediment core taken from the Rano Aroi pond in May 2017. According to <sup>14</sup>C measurements, this record covers the last 1200 years. A multi-proxy approach, focused on both the organic and inorganic fractions of these lacustrine sediments, is developed along the core and includes classic pollen, geochemical (bulk elemental composition, stable isotopes) and mineralogical (clay mineralogy) analyses, as well as microcharcoal quantification. By combining the past variations of these different tracers, episodes of erosion and/or weathering associated with the deforestation observed around the lake will be discussed, remembering that a temporal and spatial heterogeneity can exist between different local environmental records, as recently observed by Rull et al. (2015), between inland and coastal records.

O-5103

## Tracking human arrival to North Island, New Zealand using fecal sterols and leaf wax data: An Implication of Pre-Maori arrival

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### Abstract

The arrival of Maori in New Zealand brought tremendous environment modifications to the island including clearing of forests by burning. Aside from landscape modifications, the Maori practiced horticulture and pasture, introducing non-native animals. However, the timing of their arrival stirs a debate on when exactly they landed on New Zealand: archaeological evidence suggests that Maori arrival commenced around 700 to 800 cal BP. However, oral Maori traditions suggest otherwise and that Maori could have arrived earlier than existing archaeological evidence.

Here we present downcore fecal sterol and leaf wax records from Lake Pupuke in the North Island of New Zealand spanning the past ~1700 years. Fecal sterols ( $5\beta$ -coprostanol+  $5\beta$ -epicoprostanol) are found in human wastes and can be used as tracers for prehistoric human presence. Leaf wax data (long-chain *n*-alkanoic acids) will allow us to evaluate changes in horticultural and pastoral activities.

Downcore coprostanol concentrations sharply increased at around 70 cm (~700 cal BP) which coincides with the known Maori arrival. They then decreased to the top of the core. Average chain length (ACL) and even-odd predominance (EOP) of long-chain *n*-alkanoic acids also co-vary with the sterol data, with an increase at around 70 cm (~700 cal BP) then showed an overall declining trend towards the top of the core. Interestingly, coprostanols were also detected between 160 – 130 cm (~1700 – 1500 cal BP). Similarly, ACL and EOP of *n*-alkanoic acid data showed an increasing trend at the same depth.

The detection of coprostanol at lower depths could imply a pre-Maori human presence on the island. Recent results from this core will also help us unravel when Maoris started pastoral activities around the lake and its implications on the land use change. These biomarker footprints will also help us to further define the timing of the arrival of Polynesians in the North Island of New Zealand as well as possible implications of concurrent climatic changes.

O-5104

## Changing conditions – the impact on chronological models of human colonisation of the South Pacific.

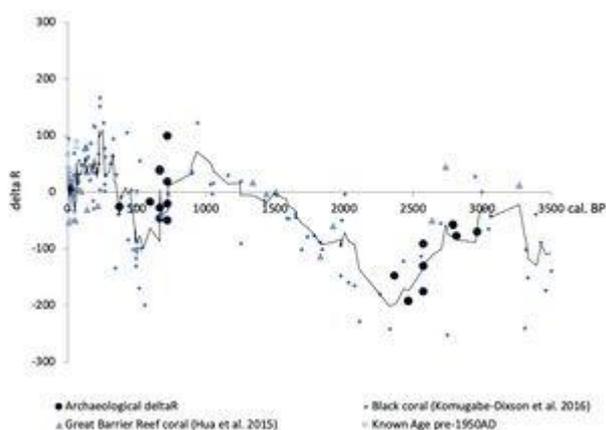
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### Abstract

While Holocene climate is of major interest globally, the period of specific importance to human colonisation across the Pacific region – the last 3500 years – has been poorly studied. This dearth of information has obvious implications for our understanding of the development of human societies, but few researchers have considered the impact of environmental changes on the  $^{14}\text{C}$  dates which form the backbone chronology for human dispersal. Indeed, many supposed erroneous marine and estuarine shell  $^{14}\text{C}$  dates are caused by differences in carbon circulation in the immediate environment (Petchey et al. 2018) and, when correctly interpreted, these dates can provide valuable information about past environments as well as significantly refining temporal models. Of note, new research into  $^{14}\text{C}$  reservoir offsets (delta R) using archaeological material collected from the central Pacific Gyre suggest that a significant shift occurred between 2650 and 2250 years ago in response to changes in ocean circulation (Figure 1). Consequently, previously reported calibrated shell ages for this time period have been up to 200 years too old. This added chronological uncertainty has contributed to our inability to identify directionality and the drivers behind human movement. Moreover, this reservoir shift occurs at a critical time – a period of transition between earlier Lapita and later Polynesian cultures.

In this presentation, I apply these new reservoir findings to radiocarbon dates from key early archaeological sites in Tonga and Samoa. The results display demonstrable refinement to the chronology of this region with a suggestion of settlement, abandonment and resettlement as people forged ahead into new lands.



**Figure 1.** Change in marine reservoir offset (delta R) within the South Pacific over the last 3500 years.

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O-5106

## Tectonics and sedimentation along the southern margin of the Alps (northern Italy) during the Pleistocene

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### Abstract

Sedimentation along the southern margin of the Alps (northern Italy) during Pleistocene has been mostly dominated by glacial and fluvioglacial depositional systems. New stratigraphic and chronologic data gathered in the last decade provided new hints about the role of tectonics in controlling their spatial distribution and preservation during the Pleistocene. Early Pleistocene morainic deposits at the foothills of western and central Alps (Piedmont and Lombardy) have no preserved morphology and are usually completely buried under younger Middle Pleistocene deposits (stratigraphic mode 1). Conversely, Middle Pleistocene landforms are partially to fully preserved, according to a dominant pattern of nested morphologic units, getting progressively younger toward the inner part of the morainic amphitheatre (stratigraphic mode 2). In the Lake Garda area (Lombardy-Veneto), Early Pleistocene deposits are also preserved according to the mode 1. The mode 2 is only observed in its western part, as mode 1 remains dominant also during the Middle and Late Pleistocene. More eastward (Veneto and Friuli), the mode 1 is the only dominant stratigraphic style.

The occurrence of mode 1 and mode 2 stratigraphic arrangements is interpreted to reflect specific tectonic regimes, which acted along the southern margin of the Alps during the Pleistocene. Mode 1 is produced by low to moderate subsidence, getting the older units progressively buried under the younger ones, with no preservation of morphology. Such subsidence is ascribable to the geodynamic activity of Apennines, which dominated since the Pliocene tilting southward the Alpine foreland. To the East, Apennines-driven subsidence may have been locally enhanced by Alpine thrusts load. Mode 2 is interpreted to have been produced by the isostatic rock uplift of the Alpine range because of erosional unloading. Such isostatic uplift apparently became the dominant tectonic regime in the western and central Alps since Middle Pleistocene, due to enhanced climatic-drive erosion in the axial chain and likely to a progressively weaker activity of Apennines tectonics. In this scenario, the Lake Garda area lies well at the boundary between the western-central Alpine area, dominated by passive isostatic tectonics and the eastern Alps, where active tectonics produced by the Apennines northward migration and Adria plate indentation is still the main regime. The net product of this two competing regimes produced a progressive counterclockwise rotation of successive morainic amphitheatres during the Pleistocene. Geodetic topographic levelling is consistent with this interpretation, suggesting that both tectonic regimes are still ongoing today.

O-5107

## Middle– early Late Pleistocene Faunal complexes of Eastern Europe: recent interpretation

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### Abstract

The main biostratigraphic subdivisions of the Pleistocene of Eastern Europe were traditionally based on large mammal associations (Gromov, 1948; Vereshchagin, 1957; Alekseeva, 1990). Subsequently, data on small mammals and other animal groups were added to their definitions (Shevchenko, 1965; Aleksandrova, 1976; Markova, 1982; Tesakov, 2004). The stratigraphic limits and sequence of faunal associations are constantly revised and modified with the emerging new data on stratigraphy, taxonomic diversity, and methods of dating. Currently Tiraspol and Khazar faunal complexes are distinguished for Eastern European Middle Pleistocene.

The Tiraspol theriocomplex (0.8-0.5 Ma, Galerian, MIS19-12) is characterised by *Lagurus transiens*, *Microtus gr. ratticepoides*, *Microtus nivaloides*, *Stenocranius gregaloides*, *Ursus deningeri*, *Mammuthus trogontherii*, *Equus suessenbornensis*, *E. cf. mosbachensis*, *Stephanorhinus hundsheimensis*, *S. kirchbergensis*, *Praemegaceros verticornis*, *Cervus acoronatus*, *C. elaphoides*, *Capreolus suessenbornensis*, *Alces latifrons*, *Bison schoetensacki* (Verestchagin, 1959; Nikiforova, et al. 1971; Vislobokova et al., 1990; Vangengeim et al., 2001). This association, typical for Eastern Europe, was also widespread in northern Eurasia. It is known from the south of Western Siberia (Vyatkino complex), Kazakhstan (Koshkurgan complex), and from North-Western China. In Western Europe its close biochronological match is the Cromerian fauna.

The Khazar faunistic complex (0.5-0.08 Ma, Aurelian, MIS11-8-5) includes *Spermophilus pygmaeus*, *Castor fiber*, *Trogontherium cf. cuvieri*, *Cricetulus migratorius*, *Ellobius talpinus*, *Lagurus lagurus*, *Eolagurus luteus*, *Arvicola ex gr. mosbachensis-chosaricus*, *Microtus oeconomus*, *M. arvalis*, *M. gregalis*, *Ursus (Spelearctos) savini rossicus*, *Mammuthus trogontherii chosaricus*, *M. intermedius*, *Palaeoloxodon antiquus*, *Stephanorhinus kirchbergensis*, *Elasmotherium sibiricum*, *Camelus knoblochi*, *Megaloceros giganteus*, *Cervus elaphus*, *Bison priscus*, *Saiga tatarica* (Gromov, 1933; Alekseeva, 1969; Titov, Golovachev, 2018). The volume of the Khazar theriocomplex has recently been extended after the revision of the fauna and stratigraphy of its type region in Lower Volga area. It is reasonable to merge the Singil and Shkurlat complexes with the Khazar one (Zastrozhnov et al., 2018). Thus, the Khazar complex spans a time interval between the Likhvin (=Holsteinian) interglacial up to the end of Mikulino/Eemian interglacial. It is also operationally reasonable to consider the Khazar complex as a biochron between the early Middle Pleistocene Tiraspol complex and the Late Pleistocene Mammoth complex. But until the better knowledge of the large mammal association of the mid Middle Pleistocene warm interglacials (MIS9 + MIS11), previously known as the “Singil theriocomplex”, it is proposed to refer to it as “Likhvin” or “Gun’ki” fauna (Markova, 2007). This association is mostly characterized by small mammals. The range of the Khazar complex comprised a vast area from East Europe in the west through southern Western Siberia to Kazakhstan (Irtys complex) in the east. The correlative Aurelian faunas of Western Europe were generally similar in composition but had a number of differences at the genus/species level.

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O-5108

## Re-assessing litho-, morpho- and chrono-stratigraphy of Grotta Romanelli (Southern Italy): a key-site for the Middle-Late Pleistocene Stratigraphy of Europe

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### Abstract

Grotta Romanelli (GR) is a cave opening along the Apulian coastline, considered since decades a key-site for the Paleolithic of Europe because of its infilling sediments revealing human frequentation since the Middle Pleistocene and. At the beginning of the last century, excavation activities developed in the cave until 40 years ago when a stratigraphic framework supported by radiometric datings (C14 and U/Th), geomorphological evidences, abundant fossil remains and archaeological findings was assessed. The stratigraphic setting recognized by Blanc (1928) revealed a complex sedimentary sequence. The lower succession was described, from the bottom to the top, as a high-energy beach deposit (K), referred to the MIS5e, a bone breccia (I) covered by a stalagmitic layer (H) U/Th dated at <69ky by Fornaca -Rinaldi and Radmilli (1968), the so-called 'terre rosse' (G), bearing Middle Palaeolithic artefacts and vertebrate fauna bounded on top by a second stalagmitic layer (F), U/Th dated at  $40 \pm 3$ ky by Fornaca-Rinaldi and Radmilli (1968). However, the chronology of this lower sequence was repeatedly questioned and thus a new campaign of field work initiated in 2015, focussing on its reassessment.

The overall litho-stratigraphic framework was confirmed although the new detailed investigations revealed a more complex and differentiated succession of layers with different palaeoenvironmental significance. In order to solve the questions related to the reliability of the radiometric datings performed more than 50 years ago, eight samples from the two stalagmitic layers were U/Th dated and yielded dates ranging from  $359 \pm 86$ ky ( $2\sigma$ ) to  $112 \pm 1.3$ ky ( $2\sigma$ ). These new dates indicate that the succession formed between MIS11 and MIS5. To better constraint the palaeoenvironmental conditions for the succession we performed also C and O isotope analyses on the stalagmites, and micromorphological, sedimentological and mineralogical analysis of the 'terre rosse' layers. The new chrono-stratigraphical setting casts new light also on the sea-level changes features observable inside and outside of the cave. In fact, the beach deposits at the base of the succession overlay a notch carved in the Cretaceous limestone with *Lithophaga* boreholes extending from 7.3 m (cave entrance) up to 9.8 m asl (cave interior). The previous interpretation correlated the notch to the Last Interglacial sea level. The new studies evidenced the presence of a lower notch and a sub-horizontal terrace with gravelly beach deposits at about 4.4 m asl that, in the framework of the new chronostratigraphic framework, might be correlated to the MIS5e.



Fig. 1 – Location of Grotta Romanelli.

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O-5109

## Impact Proxies from Europe Postdate Laacher See Eruption, Mark Younger Dryas Onset, and May Relate to Hiawatha Crater in Greenland.

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### Abstract

The Younger Dryas (YD) climate episode (~12,850–11,650 calendar years before present [cal BP]) is an event recorded widely across the Northern Hemisphere. We conducted multiple analyses at high resolution of a YD-age sedimentary sequence from Stara Jimka, a paleolake in the Bohemian Forest, Czech Republic. Age-depth modeling indicates that, in our record, a central European warming trend was interrupted at ~13,020+/-110 cal BP by the sudden onset of cooling (120 y) known as the Gerzensee climate oscillation and marked by the deposition of fine-grained sediment at this location. That cooling episode ended at ~13,001+/-66 cal BP and was followed by a ~120-y-long warming trend. After that, the Laacher See tephra depositional event, dating to ~12,820+/-20 cal BP, continued an overall warming trend. The composition of the Laacher See volcanic tephra in this section likely corresponds to the middle eruption sequence. Finally, the deposition of glassy microspherules marks the onset of the YD climate change at ~12,755+/-92 cal BP. The sequence across the YD onset is marked by (1) a peak in glassy microspherules (117,000/kg), (2) a peak in framboidal spherules (14,000/kg), (3) significant changes in the lake's weathering proxies, and (4) major changes in local fauna (cladocerans, chironomids) and flora (pollen record, fire regime), showing a shift to unfavorable environmental conditions (decrease in temperature and lake trophy status). Collectively, this evidence is consistent with the co-called YD impact hypothesis and evidence of one or more cosmic airburst events occurring at this time. We have analyzed the radar ice record and both gravity and magnetic data over the Hiawatha crater in northwest Greenland and found not only that the impact was likely directed southward, but also that this impact could be the source of iron rich microspherules observed in the lake sediments in Czechia 12750 cal years BP.

O-5110

## Why should we care about biogeography when correlating Quaternary deposits? A perspective from the Europe's eastern border

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### Abstract

Biological proxies are traditionally used for relative dating and for correlation of sedimentary layers over different spatial scales. This study aimed to consider the potential and challenges of the geographic variation in implementing biotic proxies for geological correlation and for integration of regional data into continent-wide stratigraphic frameworks. The study is undertaken in the region of Trans-Urals, which delineate the Europe's eastern border along the meridionally stretched Ural Mountains. Among a variety of biotic proxies, we primarily focus on arvicoline rodents as the most biochronologically informative taxonomic group of small vertebrates in the Quaternary terrestrial ecosystems of the Northern Hemisphere. A region-wide revision of the subfamily Arvicolinae in the quaternary micromammal assemblages and correlation with the European micromammal faunas reveals incongruent positioning of several officially accepted stratigraphic units in the regional stratigraphic chart of the Southern Trans-Urals. Considering possible causes of those incongruences, we raise the question on the need to distinguish clearly between a biochronologically significant change and a biogeographical or ecological specificity of the species assemblages. Underestimated biogeographic patterns appear to be a major challenge for accurate geological correlation and for integration of regional data into continent-wide stratigraphic frameworks. However, when properly studied, geographic variation in the structure of natural communities provides a potential solution for the problem of continent-wide correlations across multiple natural landscape zones. Five latitudinal biochronological zones are established using the key taxa of arvicoline rodents for trans-zonal correlation of the Quaternary deposits across the Northern Eurasia. The developed approach of trans-zonal correlation is applied to link the European, Trans-Uralian, and West Siberian micromammal faunas dated back to the Early, Middle, and Late Pleistocene, including new data from the north of Western Siberia obtained during the field campaigns of 2016-2018. The study is supported by Russian Foundation for Basic Research, grant № 19-04-00966.

O-5111

## A radical reassessment of the stratigraphy, palaeoenvironmental processes and dating of the Middle Pleistocene deposits at Schöningen, northern Germany

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### Abstract

Middle Pleistocene sediments exposed, between Elsterian and Saalian glacial deposits, during lignite quarrying at Schöningen have been a subject of continuing controversy. Famous for the discovery of Palaeolithic wooden hunting spears and evidence of horse butchery, Mania (Mania & Altermann 2014) and Urban (2007) recognised three separate interglacial intervals, associated with channel infills traversing the site. Authors of a Monograph on Schöningen (Behre 2012), however, considered the deposits assigned by Urban to Holsteinian and the Reinsdorf Interglacial as both of Holsteinian age, related to MIS 9, and laid down in a lake infilling a glacial tunnel valley, like other Holsteinian sites in northern Germany, consequently proposing, that the Elsterian glaciation related to MIS 10, not MIS 12, as generally believed in northern Europe.

This controversy highlights a failure to recognise the palaeoenvironments in which the channels and sediment sequences deposited within them were formed. Our new interpretation recognises a series of alluvial fans, on the western side of the valley in which the sequence of Quaternary deposits was conserved. These fans were initially formed at the onset of the Elsterian late-glacial, following melting of permafrost covering the Elm, the adjacent Muschelkalk massif, and reactivated after subsequent cold-climate stages. Powerful meltwater streams incised channels down the face of the alluvial fans and channels draining along the distal margins of the fans, cutting into glacial sediments flooring the valley.

In the North Pit organic deposits within channels cut into the fans, yielded characteristic but discontinuous Holsteinian pollen records. Some, originally referred to late-glacial interstadials, are reinterpreted and assigned to the earliest part of the interglacial. In the South Pit deposits of the Reinsdorf Interglacial, were preserved in a wide, well-incised marginal channel, cut by powerful meltwater, then abandoned and infilled by partly organic sediments, a repeated series of five shallowing cycles, showing typical seral development from open-water to fen woodland or reedswamp. Pollen analysis showed a sequence, beginning with fully temperate zones of an interglacial vegetational succession to a succeeding stadial and interstadial. Palaeolithic artefacts occur at all levels in this sequence, with the spear horizon belonging to cycle 4 (interstadial). The Reinsdorf Interglacial vegetational succession differs from that of the Holsteinian in significant characteristics, but also well-preserved large and small mammal faunas are distinctly different from those from Hoxnian deposits in England and other Holsteinian deposits, all ascribed to MIS 11. We relate the Reinsdorf sequence to MIS 9,

A third interglacial horizon, the Schöningen Interglacial of Urban, occupied a similar, smaller channel, incised along the margin of the fans in the North Pit. Palynologically, differing considerably from the Holsteinian and Reinsdorf Interglacials, it correlates closely with the Dömnitz Interglacial of Erd (1973) and is referred to MIS 7.

O-5112

## From classic to modern stratigraphy in the European context – an Alpine perspective (a contribution to the DATESTRA project)

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### Abstract

Marine Isotope stratigraphy (MIS) shows that numerous glaciations (> 50) had a significant impact on a global scale, but it is a well-known challenge that these glaciations are only represented in a highly fragmented terrestrial records. This calls for an undisputable way of correlating terrestrial sediment records like the fourfold Alpine terrace staircases of fluvial meltwater terraces with the marine stratigraphy. Morphostratigraphical correlations, especially of meltwater terraces, by counting backwards using isolated continental erosional remains in a world of multiple sedimentation events during the Quaternary induced by bundles of cold spells, may likely be misleading.

In addition, it was demonstrated in Middle Pleistocene palynological maar sequences in Central France, that the pollen successions of different interglacials may resemble each other very closely. For Early Pleistocene pollen sequences this issue is also well known and documented. The close resemblance of the sedimentological and petrographical characteristics of the fragmented glacial and glaciofluvial sedimentary records on a regional scale, makes over-regional or global correlations highly challenging. However, during the last decades, numerical dating techniques have evolved as an important tool for the correlation of such records on a continental or even global scale. As the boundaries of dating techniques, and their resolution has been constantly pushed forward on a methodological level, an increasing number of data is available for time slices beyond the penultimate glacial cycle. For example, staircases of cover gravels in northern Switzerland were likely deposited during multiple glaciations, as revealed by numerical dating. First results from the Vienna basin area also indicate the preservation of deposits originating from multiple glacial cycles reaching back to the Early Quaternary. Furthermore, results based on numerical dating techniques may often contradict existing stratigraphical models. However, a thorough interpretation of numerical dating results against the background of sedimentological, petrographical, and geomorphological evidence is inevitable. Additionally, existing numerical data may have to be re-evaluated because of methodological progress during the recent past.

For the DATESTRA project it is recommended to focus on a thoughtful evaluation of numerical age data, to create a new backbone of European Quaternary stratigraphy. This attempt should be undertaken without the confining heritage of classical local and regional concepts of Quaternary stratigraphy.

O-5113

## The importance of Periglacial Processes in the Mercia Mudstone weathering profile, seen through current infrastructure projects in the English Midlands

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### Abstract

The weathering profile of the Mercia Mudstone, as described by Chandler and Davis, reflects a variety of physical and chemical processes. Data from various infrastructure projects, including High Speed Two (HS2) Limited, has highlighted the importance of periglacial processes in the weathering profile of the near-surface Mercia Mudstone. A revision of the overlying glacial deposits in the English Midlands to the younger Wolstonian Stage, has further implication for identifying periglacial activity. The brecciation of the rock mass seen in the weathering profile (Zone III) and the inclusion of rare to occasional glacial-fluvial gravel in the near surface profile, are identified as the result primarily of periglacial processes, from the action of repeated cycles of permafrost advance and retreat over multiple Middle - Upper Pleistocene glacial stages. Near the surface this largely overprints the weathering resulting from the dissolution of the Carbonate and Sulphate component, which is more prominent with depth, particularly where there was originally a notable minor gypsum component.

The intense periglacial brecciation of the Mercia Mudstone in the Midlands, from multiple cold stages, generates a material with extremely closely spaced discontinuities, traditionally described as 'lithorelics'. The 'breccia' has enhanced permeability, and minor amounts of groundwater is frequently present, within a material that normally has low permeability. Sampling disturbance of the periglacial breccia, especially when little completely commutated material is present (clay matrix), can unhelpfully result in the material being described as 'gravel'. This is misleading, as Mercia Mudstone Zone III periglacial breccia is a very weak / extremely weak rock.

O-5114

## Distribution, morphology and preliminary dating of past thermal-contraction-cracking features in the Czech Republic

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### Abstract

Thermal-contraction-cracking features, such as ice or sand wedges, develop due to rapid temperature drops in perennially frozen sediments. They typically occur in regions with mean annual air temperature lower than  $-8$  to  $-4$  °C and at least discontinuous permafrost. Their relict imprints therefore testify to very low temperatures and permafrost presence at the time they evolved. These pseudomorphs and casts have been extensively surveyed across Europe in order to delimit former permafrost extent and to infer paleoclimate conditions. The evidence from Central Europe and the Czech Republic in particular is, however, very scattered and mostly concealed to the international audience. Our intent therefore is to describe the distribution and morphology of past thermal-contraction-cracking features in the Czech Republic and to provide their first dating results.

We inventoried relict ice-wedge and sand-wedge occurrences based on mapping of their polygonal cropmarks identifiable on aerial images (from 2001, 2003, 2006, 2009–2010, 2012, 2014–2015, 2016–2017), field investigations in mining pits or technical excavations, and literature survey. Surface and subsurface morphology of former ice and sand wedges was investigated on selected sites in detail and samples of their infill as well as host materials were collected for sedimentary analyses and OSL dating.

We identified over 2000 sites where ice-wedge pseudomorphs and sand-wedge casts occur. The patterns concentrate particularly in the lowlands of the Bohemian Cretaceous Basin, Moravian Basins, and South Bohemian Basins, with altitudes of up to around 300 m asl. The wedges mostly occur in sand-gravel materials of Pleistocene river terraces or silt-rich loess covers and consist of aeolian sands, fossil soils, or collapsed host materials. They usually have a width of 0.1–1.5 m and are mostly up to 1.5–2.0 m deep. The polygons are between 2 and 32 m in diameter and usually have five to six sides. Their networks are therefore believed to have reached the mature stage of development. The preliminary OSL ages suggest that the wedges underwent multiple periods of activity during the Last Glacial Period, with the final phase probably coincident with the Last Permafrost Maximum.

Our database of past thermal-contraction-cracking features in the Czech Republic is one of the most extensive in the world and well documents the Late Pleistocene permafrost extent and its evolution in Central Europe.

The Czech Science Foundation, project number 17-21612S, supported this research.

O-5115

## Dating large ice wedge casts and associated permafrost events in Last Glacial European loess series: a northern France perspective

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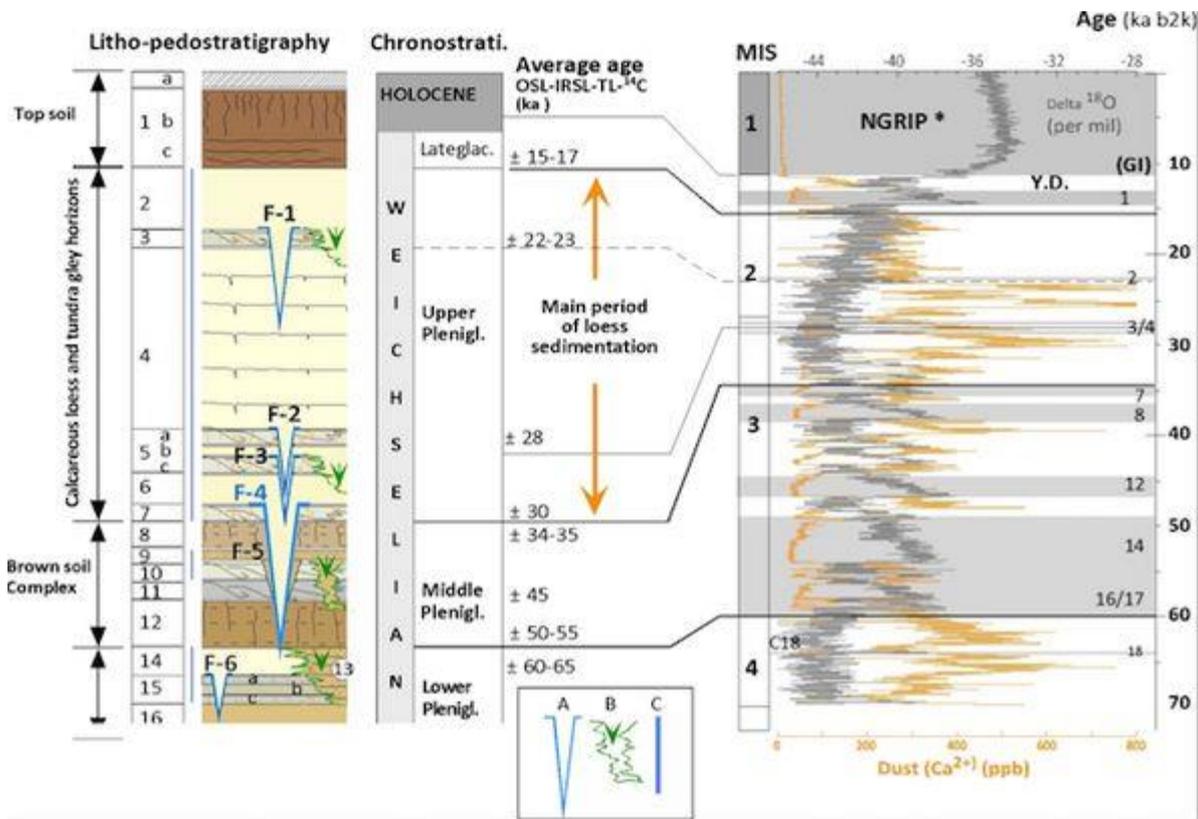
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### Abstract

The European Loess Belt is the most extensive continental archive of the Last Glacial period (Weichselian) in Europe. Located eastward of the North Atlantic region, this large area was ideally situated to record the impact of millennial-timescale climatic fluctuations (i.e. Dansgaard-Oeschger cycles, Heinrich Events). In the western part of the European Loess Belt, strongly affected by periglacial processes during the Last Glacial, recent investigations focusing on the most continuous loess-palaeosol records (pedostratigraphy, dating, sedimentology, malacology), allowed to evidence numerous occurrences of periglacial features and especially large ice-wedge casts. Several networks of ice wedge casts have been studied and dated by luminescence (OSL) and radiocarbon (<sup>14</sup>C) methods during the last 10 years. By comparison with present-day high-latitude tundra environments, these features are considered as the best witnesses of permafrost conditions in northwestern Europe. In this presentation we will focus only on the northern France loess-palaeosol records in which at least four large ice wedge casts polygonal networks (10-20 m in diameter), separated by loess deposits, have been identified within the Last Glacial sequences. They are systematically connected with tundra gley horizons representing former permafrost active layers. On the basis of a new <sup>14</sup>C dating protocol developed for earthworm calcite granules, which are particularly abundant in the upper part of tundra gley horizons, a robust chronology is now available. It reveals that tundra gley layers associated to the four main ice wedge cast networks are dated between ca. 45 and 22 ka. According to their geographical distribution pattern, these features appear to be typical of the west-European loess domain where they are connected with permafrost environments richer in ice than eastward. However, based on accurate dating of the loess infilling of the different ice-wedge casts, and detailed correlations with the North GRIP climate record, ice-wedge networks appears to have developed only during some specific phases. Thus, these features typify original palaeoenvironmental and palaeoclimatic conditions that are still to be characterised in the frame of a modelling approach involving inlandis, sea-ice extent, atmospheric circulation and North GRIP temperature reconstructions.

### Reference

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A: large ice wedge networks, B: Thermokarst erosion features, C: calcareous part of the sequence

**Figure 1:** location of the various ice wedges cast networks and tundra gley horizons (n°15a,c, 10, 7, 5a,c, 3) within the last glacial global pedostratigraphic sequence of northern France (modified according to Antoine et al., 2016, Quaternary International, modified).

O-5116

## Characterisation of a Late Quaternary periglacial ramparted depression in the Hautes Fagnes, Belgium

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### Abstract

Perennial frost mounds (pingos, palsas and lithalsas), also known as 'ice-cored hills', are indicative of cold, periglacial environments. During the Last Glacial Maximum (LGM) (c. 23–19 ka) frost mounds formed across northwest Europe, North America and northern Asia. Upon melting, frost mound relict forms comprise depressions with surrounding ramparts, otherwise known as periglacial ramparted depressions (PRDs). The surface geometry of PRDs is well-documented, but there is little agreement on: (i) the definitive identification of PRDs, and (ii) PRD genesis. This research characterises the internal structure of a PRD (a relict lithalsa), on the Belgium-German border at the micro-scale. Microstructures include those indicative of (i) cryogenic origins (e.g. frost-jacked grains, aggregates, fragmented domains, silt/clay grain and void cappings etc.), and (ii) PRD formation (e.g. tilted strata, grain arrangements/concentrations/coatings, multiple domains, fragmented domains, plasmic fabric etc.). This specific suite of microstructures, for the first time, provides a toolkit for the identification of suspected relict frost mounds elsewhere, which is critical to inform (i) landform evolution, (ii) palaeoenvironmental reconstruction, and (iii) civil engineering projects in Quaternary periglacial deposits.

O-5117

## Glacial ice-buttressing controls occurrence and timing of a rock slope failure (RSF) during Late-Pleistocene deglaciation: English Lake District case study.

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### Abstract

The role of glacial ice in buttressing rock slopes and thus preventing slope failure until ice down-wasting leads to loss of ice-support is speculative/controversial, as are the mechanics of failure where ice-support is progressively removed. The latter two issues are the focus of this presentation. An arrested, translational, rock slope failure (RSF) is described, dated, and the controls on the failure mechanisms are modelled. The hypothesis '*that glacial-ice buttressed an otherwise steep, faulted, and incompetent rock slope*' is tested. The RSF location is within Great Coum (Lat. N: 54.392311; E: -2.605696), a small cirque in the Southern Shap Fells.

The bedrock is Silurian Coniston Group, a jointed, friable greywacke, in thin beds <3m thick. Nevertheless, the bedding in the RSF is undistorted showing the wedge descended very slowly. Small-scale faulting in the parent rock is frequent, so fault alignment and dips in the vicinity of the RSF were mapped. The unsupported rock wedge was modelled using *Swedge*<sup>®</sup> version 6.0 (2018) rock-slope stability software, to analyse the 3D failure as the rock mass slid along a basal failure plane bounded on each side by a fault. Field-derived parameter values determine the stability of an ice-free rock mass. Uncertainty was considered: > 30,000 simulations, varying values systematically to isolate the most probable model. The probability of slope failure was 96%; factor of safety: 0.74 - 0.94. In 4% of cases, a marginal factor of safety: 1.07 - 1.22 was achieved, but wetting 20 - 30% of the fault planes caused the slope to fail.

Thus, the need to consider the role of ice buttressing of the wedge is evident, as there is no other way in which the slope could have been supported to descend slowly. Three scenarios were considered: (i) ice was a static load variably distributed across the slope; (ii) ice moved towards the slope; (iii) ice moved away from the slope. In any permutation, the ice cover required to maintain slope stability is 17 - 29% of the potential maximum ice volume above the slope, indicating that the slope would have remained stable as long as there was a sufficient small degree of ice buttressing - which implies slow failure occurred beneath partial ice cover during final cirque deglaciation, supporting the hypothesis.

To determine when the slope was first exposed to light as ice receded from the cirque, two surface rock samples were obtained from a prominent thick strata within the RSF mass. In addition, two samples were obtained from a slickenside surface in the headwall above the RSF to determine when the RSF first exposed the failure plane. Two samples are submitted for cosmogenic dating and two samples are submitted for luminescence exposure dating. These results should be available in July 2019.

O-5118

## Glaciation of the northern Peak District, England: Evidence of plateau icefield and cirque glaciations

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### Abstract

The northern Peak District, England, has traditionally been considered a relict periglacial landscape that lay beyond the limits of the last Quaternary glaciation (Burek, 1991; Clark et al., 2018). However, a variety of landform assemblages and sedimentary evidence indicates two independent episodes of glaciation: cirque glaciation, and more extensive plateau icefield glaciation.

Three cirques are proposed: two on the Peak District's highest hill, Kinder Scout, and one on Bleaklow Hill. Evidence includes rounded head walls, morainic ridges, and channel-like features. The Seal Coombes, on Kinder Scout (first described by Johnson, 1987), are the most unequivocal palaeo-glaciers in the northern Peak District. Reconstructed Equilibrium Line Altitudes (ELA) for these glaciers is c. 549 m asl. Barrow Clough, on Bleaklow Hill, has undergone significant post-glacial fluvial erosion. Nevertheless, the compelling glacial landforms indicate cirque glaciation at this site. Reconstructed ELA for this glacier is c. 555 m asl.

Plateau icefield glaciation is proposed for the plateaux of the northern Peak District. The glacial signature is recorded in channel-like features, hummocky terrain, and arcuate and linear ridges. The orientation of the landforms, radiating from the plateaux, suggests that ice cover on the plateaux flowed down pre-existing valleys. This is supported by analysis of clasts within morainic landforms, which indicates glacial transportation of material from the plateaux to the valleys. Gritstone tors across the Peak District were recorded to assess their distribution. A lack of tall (> 1 m) tors in the centre of expansive plateaux was observed, with tall tors being more abundant on narrower summits. This suggests that ice cover on plateaux preferentially removed tors or inhibited their development, while protective ice cover on narrower summits above valleys would have protected tors. Degraded tor stumps are observed on narrow summits away from plateaux, indicating a lack of ice cover during glacial episodes on these summits. Plateau ice would have been predominantly thin and protective, while channelled ice at valley heads would have been thicker, allowing modest glacial erosion. Transient, 3D model experiments, forced under a range of probable climate scenarios through the last glacial period, support the evidence for independent cold-based ice cap(s) within this marginal region of upland glaciation.

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Clark, C. D., et al. (2018) BRITICE Glacial Map, version 2: a map and GIS database of glacial landforms of the last British-Irish Ice Sheet. *Boreas*, 47, pp.11-27.

Johnson, R.H. (1987) Some evidence for a glacial corrie at Seal Edge, Kinder Scout, North Derbyshire. *The Manchester Geographer*, 8, pp.33-48.

O-5119

## The geomorphological and sedimentological implications of bedrock megarafts in central Alberta

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### Abstract

The creation of subglacial bedforms by substrate groove-ploughing remains as a hypothesis in need of more systematic testing, especially in field settings. The accomplishment of groove-ploughing by rough ice stream soles has so far not received much support, but small scale groove-ploughing by clasts has long been acknowledged in till sedimentology and hence the potential for large bedrock blocks to be ploughed through ice stream beds to create streamlined landforms needs to be investigated. Glacitectonically displaced and glacial overridden/streamlined bedrock blocks are widely recognized on the prairies where their landform imprint has been classified as “rubble moraine/terrain”. Landform mapping from LiDAR imagery combined with sedimentological investigations of the palaeo-ice stream beds of central Alberta has identified a range of diagnostic landforms indicative of substrate ploughing and grooving by bedrock megarafts. We identify: a) isolated bedrock plough marks and shallow grooves flanked by paraxial ridges with terminal bedrock blocks in place; b) ridge/furrow corrugations terminating at arcuate frontal sediment prows; c) flutings extending down-flow from bedrock blocks; and d) elongate assemblages of apparent bedrock blocks that comprise “rubble flutings”. In situ bedrock megarafts are associated with complex glacitectonites derived partially from the disintegration of the rafts in combination with the cannibalization of pre-existing Quaternary deposits. Such stratigraphic relationships support the notion that the megarafts have been dragged through the substrate, ploughing it up to form prows and ridges and thereby lodging at the ice stream bed. The styles of landform so created are indicative of the stage of ice stream operation at their time of production in the deforming layer.

O-5120

## Leveraging Big Data in palaeoentomology: direct linking and conceptually mapping between archaeology and palaeoecology

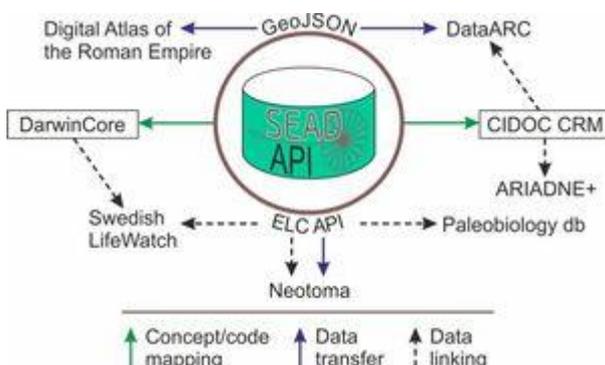
Philip Buckland, Francesca Pilotto, Mattias Sjölander  
Environmental Archaeology Lab, Umeå University, Umeå, Sweden

### Abstract

The Bugs fossil insect database evolved from a research bibliography ([www.bugscep.com/qbib.html](http://www.bugscep.com/qbib.html)) into a database of palaeoentomological research results, with species internally linked to referenced modern habitat and distribution data. Its current form, the Bugs Coleopteran Ecology Package ([www.bugscep.com](http://www.bugscep.com)), is a freely downloadable integrated database and software package for analysing both fossil and modern insect assemblages, including a number of statistical tools for interrogating the fossil and modern data in combination. Approximately half of the 1300 datasets are from archaeological sites, and half from other Quaternary sites. The system is being replaced by components in the online, collaboratively managed, multiproxy Strategic Environmental Archaeology Database ([www.sead.se](http://www.sead.se)), where insects are just one of numerous data types.

SEAD forms part of a network of palaeoecological and archaeological research data infrastructure, including Neotoma, PBDB, DataARC, Ariadne and a number of other systems linked through API's, data feeds and concept maps. This network provides almost limitless possibilities for interrogating changes in Quaternary environments, climates and human-environment interactions. It also poses a number of challenges for both users and developers in terms of the use of the data across disciplinary boundaries, and the provision of tools that facilitate powerful, reproducible analyses through intuitive interfaces.

This presentation will highlight recent advances, and emerging challenges, in the use and development of this infrastructure ecosystem, and showcase some preliminary results provided by the linking of fossil insect data to modern biodiversity platforms through the Swedish LifeWatch ([www.swedishlifewatch.se](http://www.swedishlifewatch.se)) and Swedish Biodiversity Data Infrastructure (<https://bioatlas.se/>) initiatives.



O-5121

## The HORNET project: applying 'big data' to reconstruct the climate of the Northern Hemisphere during the Holocene

Philipp S. Sommer<sup>1</sup>, Basil A. S. Davis<sup>1</sup>, Manuel Chevalier<sup>1</sup>, Jian Ni<sup>2</sup>, John Tipton<sup>3</sup>

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### Abstract

Pollen data remains one of the most widely geographically distributed, publicly accessible and most thoroughly documented sources of quantitative palaeoclimate data. It represents one of the primary terrestrial proxies in understanding the spatial pattern of past climate change at centennial to millennial timescales, and a great example of 'big data' in the palaeoclimate sciences. The HORNET project is based on the synthesis and analysis of thousands of fossil and modern pollen samples to create a spatially and seasonally explicit record of climate change covering the whole Northern Hemisphere over the last 12,000 years, using a common reconstruction and error accounting methodology. This type of study has been made possible only through long-term community led efforts to advance the availability of 'open big data', and represents a good example of what can now be achieved within this new paradigm.

Primary pollen data for the HORNET project was collected not only from open public databases such as Neotoma, Pangaea and the European Pollen Database, but also by encouraging individual scientists and research groups to share their data for the purposes of the project and these open databases, and through the use of specifically developed digitisation tools which can bring previously inaccessible data into this open digital world. The resulting project database includes over 3000 fossil pollen sites, as well as 16000 modern pollen samples for use in the pollen-climate calibration transfer-function. Building and managing such a large database has been a considerable challenge that has been met primarily through the application and development of open source software, which provide important cost and resource effective tools for the analysis of open data.

The HORNET database can be interfaced through a newly developed, simple, freely accessible, and intuitive clickable map based web interface. This interface, hosted on the version control system Github, has been used mainly for quality control, method development and sharing the results and source database. Additionally, it provides the opportunity for other applications such as the comparison with other reconstructions based on other proxies, which we have also included in the database. We present the challenges in building and sharing such a large open database within the typically limited resources and funding that most scientific projects operate.

O-5122

## Recent advances with the Neotoma Paleocology Database

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### Abstract

Databases incorporating paleodata across time and space have been instrumental for understanding earth system history. Initially, computerized databases were typically designed for individual data types or groups of organisms. These databases were highly successful, used to address a broad range of scientific research questions, and supported numerous publications. A major advantage of the single proxy databases was that disciplinary experts controlled taxonomy and data quality. Disadvantages were maintenance of continued funding and difficulty of using single-proxy databases to address interdisciplinary multiproxy questions. In addition, no databases existed for some data types, and the existing databases were not easily extensible. To address these problems, the Neotoma Paleocology Database ([www.neotomadb.org](http://www.neotomadb.org)) was developed.

Neotoma was initially developed to incorporate a range of existing databases for pollen, plant macrofossils, vertebrate fauna, ostracodes, and diatoms, with the intent to incorporate additional data types for which no databases currently existed. The database is highly normalized, which facilitates the wide range of data types. New tables can be added to accommodate idiosyncrasies of additional data types. Although Neotoma is a centralized database, it is designed as underlying cyberinfrastructure for a consortium of constituent databases for individual proxies. These constituent databases can control their own taxonomies and data quality. Central to the concept of Neotoma is that it is a community-curated data resource (CCDR). Constituent databases appoint data stewards who ensure data completeness and quality; thus the data are curated and vetted, not simply deposited. Moreover, Neotoma is a living database. While original contributions are archived, the living database incorporates updated, taxonomic revisions, and new age models based, for example, on new radiocarbon calibration curves or new age modeling techniques.

New data types incorporated into Neotoma include, among others, insects, testate amoebae, organic biomarkers, stable isotopes, and deep-time palynological data. Some of these data types, such as insects, testate amoebae, and organic biomarkers, fit within the existing Neotoma data structure. Others required additional tables or fields. Accommodation of stable-isotope data required the addition several new metadata tables. An addition to the general Neotoma structure has been support for specimen-level data, for example, individual mammal bones or teeth, which may have museum catalog numbers. Currently, stable-isotope measurements and radiocarbon dates can be stored for individual specimens. Deep-time palynological data are “form taxa” that may have well to poorly understood affinities to modern taxa. While, the form taxa can be accommodated within the existing Neotoma Taxa table, a new table is required to record differing opinions regarding taxonomic affinity. Neotoma welcomes inquiries from potential contributors and collaborators with expertise in existing or new paleo data types.

O-5123

## Specimen Level Stable Isotope Data in the Neotoma Paleoecology Database: Mobilization and Applications in North America

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### Abstract

The Neotoma Paleoecology Database ([neotomadb.org](http://neotomadb.org)) functions as an interdisciplinary, open access database for the paleoecology community. Primary data types include proxies such as pollen, vertebrate remains, diatoms, and middens. A new repository within Neotoma has recently been created, allowing for the integration of specimen-specific stable isotope data with existing data types at the site and regional level. Neotoma serves as a hub for storing and accessing diverse types of data and offers an unparalleled opportunity for visualizing the intersection of multiple strands for paleoecological reconstruction from the macroscopic to microscopic and biogeochemical scales. To date, one of the limiting factors in stable isotope studies for our understanding of variability across not only spatial but also long-term temporal scales has been a lack of data exchange and integration. As multiple stable isotope data repository initiatives have arisen in the last few years, Neotoma has the ability link these various open data sources, allowing a cross-comparative, big-data approach. This paper discusses the development, launch, and initial population of the stable isotope repository with published stable isotope data from archaeological sites across North America. It explores data integration along with issues that exist as challenges for the future, including establishing best practices and standardization in recording/reporting, monitoring data quality, linking datasets, and increasing accessibility while protecting sensitive information.

O-5124

## Global patterns of climate change since the Last Glacial; the speleothem perspective from the SISAL database

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### Abstract

Speleothems provide highly resolved records with the potential to reconstruct past changes in mean regional climate and climate variability on annual to millennial timescales. The most common type of measurements made on speleothems – the stable isotopes of oxygen ( $\delta^{18}\text{O}$ ) – can be used to evaluate climate models that explicitly include isotopic tracers, although this has rarely been done because of the lack of a global synthesis of the records. Here we compare speleothem isotope data from the SISAL (Speleothem Isotopes Synthesis and Analysis) database and the outputs of the isotope-enabled ECHAM5-wiso model for the Last Glacial Maximum (21 ka; LGM), the Mid-Holocene (6ka; MH) and the modern (1850 – 2013) periods.

The speleothem records have less temporal variability than either the GNIP measurements or model outputs, as a result of the low-pass filter that is effectively applied to these records because of the groundwater residence time in the aquifer. However, ECHAM5-wiso is able to reproduce the SISAL observations both globally and for several key transects during the MH and the LGM. Similar global patterns are found in the oxygen isotope MH anomalies of both SISAL data and ECHAM5-wiso simulations ( $n=34$ ), albeit with different absolute values probably due to the temperature-dependent isotope fractionation between  $\delta^{18}\text{O}$  in precipitation and that of calcite. The limited availability of SISAL data covering both the LGM and the pre-industrial ( $n=11$ ) precludes the construction of global anomaly patterns for this time period. Yet, MH vs LGM comparisons ( $n=20$ ) are in accordance with simulated deviations in  $\delta^{18}\text{O}$ . We observe a good agreement in  $\delta^{18}\text{O}$  gradients over a N-S transect from mid-latitude Europe to south Africa during the LGM, although sites adjacent to the Black Sea and some sites in coastal regions of western Europe show strong differences from the simulated data. A good data-model agreement is also observed in a NE-SW transect over America. These results are also consistent with pollen-based mean annual temperature reconstructions. Speleothem age-depth model uncertainties, and choices of the temporal window width do impact the mean isotope values obtained for the LGM and thereby the uncertainties for data-model comparisons, but not strongly.

In this presentation, we will also highlight the use of metadata included in the SISAL database to screen the paleorecords used for data-model comparisons, discuss the benefits and weaknesses of using speleothem records for such comparisons, and how our approach can be applied to assess other isotope-enabled climate model simulations.

O-5125

## Evaluating the influence of climate and humans on functional diversity gradients in North America and Europe

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### Abstract

The latitudinal biodiversity gradient (LGB) is the fundamental, global pattern of species distributions and is described as the phenomenon of declining net biodiversity with increasing absolute latitude. Although the LGB is hypothesized to be a universal biogeographical diversity pattern, there has yet to be a consensus reached on the causal mechanisms driving the gradient. Additionally, modern patterns are dependent on previous environmental conditions that established over geologic time, but an understanding of how these patterns developed in relation to climatic configurations over long-time scales is largely uncertain. Within the global configuration, however, is an apparent macro-scale pattern of functional biodiversity.

In the current study, we assess how the latitudinal functional diversity gradient changed in North America and Europe over the past 15,000 years. Functional traits are linked to pollen records and Hutchinsonian hypervolumes are used to quantify estimations of functional trait space at alpha and gamma diversity scales. We also compared trends in diversity to known, large-scale paleoclimate drivers of vegetation change, namely humans and temperature reconstructions from the NGRIP ice core to identify drivers of biodiversity.

Results indicate the dynamics of this diversity pattern, in that the functional gradients of the two continents developed independent from one another as the exchange of function between sub-regions varied through space and time. Significant changes in the gradients of the two continents correspond with climatic and anthropogenic influence. In total, the outcomes provide a basis for understanding how the LGB may be altered with continued global change.

O-5127

## New data about deglaciation of the Eastern Gulf of Finland basin, the Baltic Sea

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### Abstract

Despite long history of investigations, reconstruction of the Late Weichselian ice sheet retreat through the eastern Gulf of Finland (EGoF) basin, the Baltic Sea, is still a problem due to lack of data from the marine environment. Morphological and chronological deglaciation markers are primarily located onshore, showing that deglaciation occurred between 13.8 ka BP (Pandivere-Neva stage) and 12.25 ka BP (Salpausselkä I stage).

Geographic Information System (GIS) analyses of modern sea-bottom relief map of the EGoF, recent bottom and relict (till surface) relief, and sediment cores description allowed to establish the most probable location of the submerged Late Weichselian end-moraine complexes.

In 2017, a detailed study of the eastern Gulf of Finland seafloor was executed to identify and map submerged glacial and postglacial geomorphologic features. Two key areas within the Gulf were investigated using a multibeam echosounder SeaBat 8111 and an EdgeTech 3300-HM acoustic sub-bottom profiling system. These data and resultant thematic maps revealed for the first time such features as streamlined till ridges, end-moraine ridges, and De Geer moraines that are used for reconstruction of the deglaciation in the eastern Gulf of Finland.

High-resolution study of sediment cores has shown that varves of proximal facies consist of alternation of brown clays and grey silty-clays; varves of distal facies are finer. Sedimentation rate of glaciolacustrine proximal facies varies from 20 to 100 mm/year; distal facies – from 6 to 37 mm/year. Sediments of the Baltic Ice Lake for the most part of the cores are characterized by very fine grained composition indicating very calm near-bottom dynamics, and practically do not change laterally. Paleomagnetic investigations of the Baltic Ice Lake sediments allowed to receive the first dates for sequence forming the Baltic Ice Lake deposits of EGoF. It was dated for time period from 13.3 to 11.7 ka BP. According to paleomagnetic data, sedimentation rates in the upper part of Baltic Ice Lake sediment sequence is about 1 mm/year.

Interpretations of the seismic-reflection profiles, 3D models showing the surfaces of till, and the identification of the Late Pleistocene sediment and modern bottom relief indicate deep relative water-level fall in the Early Holocene.

Several 4D models of ice thickness and relevant isostatic transformations during the late-glacial deglaciation are tested different methods and sets of constraints. The approach is to get best fit scenarios of ice retreat and landscape evolution in agreement with geological - geophysical research in key areas, chronostratigraphy and reasonable parameters in GIA reconstructions.

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O-5128

## Maximum extent and readvance dynamics of the Irish Sea Ice Stream since the Last Glacial Maximum

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### Abstract

The Irish Sea Ice Stream (ISIS) has long had one of the best documented retreat histories of the British-Irish Ice Sheet (BIIS) and was the first ice stream to be constrained by Bayesian analysis of geochronological data. These attributes made it a model system for the BRITICE-CHRONO research project, which aims to produce the best constrained retreat record of any palaeo-ice sheet contributing key observational constraints for ice sheet modelling. The project has generated a suite of new radiocarbon ages from deglacial sequences offshore in the Celtic and Irish seas and terrestrial cosmogenic nuclide and optically-stimulated luminescence ages from ice-marginal sites in the Isles of Scilly, Ireland, Wales and NW England. The ISIS was unusual within the former BIIS, in that it was a compound ice stream with two outlets, one marine terminating that flowed through the Irish Sea Basin into the Celtic Sea, and a terrestrial terminus that flowed southwards through Cheshire-Shropshire lowlands into the English Midlands around 25.5 ka. Here we assess the retreat dynamics across the entirety of the ISIS, integrating the new chronology in a revised Bayesian analysis that constrains the pattern and timing ice marginal fluctuations. The retreat chronology in the Irish Sea is better constrained than in the Celtic Sea, where the ISIS is now recognised to have extended as far as the continental shelf break to the SW of Britain and Ireland between 24 and 27 ka; this advance was synchronous with independently-dated ice-rafted detritus from ISIS in adjacent deep-sea cores. The ISIS then retreated rapidly northwards through the Celtic Sea, with evidence for readvance phases, deglaciating the Isles of Scilly at 25.5 ka, reaching St Georges Channel by 24.3 ka and the Llŷn Peninsula by 23.9 ka. The initiation of retreat from both the eastern (terrestrial) and western (marine) components of ISIS was synchronous. The eastern terrestrial lobe had vacated the Cheshire-Shropshire lowlands by 22-21 ka. The complex readvance sequences identified on the Llŷn (24-20ka) and in eastern Ireland have now been tightly constrained to register centennial-scale oscillations of the ice front driven by internal ice dynamics over topographic pinning points and constrictions of the ice-stream. Retreat northwards into the northern Irish Sea then accelerated, first evacuating the deeper water of the western Irish Sea, and developing pronounced ice margins across the northern Isle of Man by 19.1 ka. The final retreat phase, with ice margins pulling back onto terrestrial settings in the English Lake District, the north of Ireland and SW Scotland around 17 ka, was a deglaciation accomplished in a fully marine context evidenced by the preservation on the seabed of subglacial landforms and by increasing influence of local ice sources with flow realignment during draw-down and ice margin retreat.

O-5129

## The erosional impact of the Eurasian ice complex during the Weichselian glacial cycle

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### Abstract

The Eurasian landscape has experienced repeated large-scale glaciations throughout the Late Quaternary. However, the scarcity of empirical evidence for glaciations prior to the Last Glacial Maximum has limited modelling insights, despite the importance of recurring ice sheet glaciation on, for example, landscape evolution, geohazards and hydrocarbon reservoir dynamics. We simulate the evolving Eurasian ice sheet complex since the last interglacial (Eemian; MIS 5e, < 122ka) by extending and adapting previous empirically constrained, high-resolution experiments of the Late Weichselian ice complex to a full glacial cycle. Three major ice advances are considered: 1) the Early Weichselian (MIS 5d-5a; 100-75 cal ka BP), 2) the Mid Weichselian (MIS 4-3; 70-50 cal ka BP), and 3) the Late Weichselian (MIS 3-2; 35-10 cal ka BP). Current consensus indicates a general east-to-west trend of glacial dominance during these successive glaciations, shifting from a Kara Sea-centric ice complex to one monopolized by the terrestrial-based Fennoscandian ice sheet. The broad-scale pattern and impacts of glaciation thus diverged significantly, likely intensified by shifting patterns in the distribution of snowfall through the glacial cycle. Using seismic-based volume estimates of glacial sediments deposited off the Norwegian and Barents Sea continental shelves, model outputs are scaled according to lithological variations to quantify the pattern and rates of glacial denudation across Eurasia since the last interglacial. Up to 160 m of bedrock erosion is predicted beneath corridors of greatest ice discharge, with long-term subglacial erosion rates up to 5.5 mm per year comparable with inferred estimates from the Greenland ice sheet. Conversely, areas of landscape preservation and extremely low rates of erosion are widespread, largely found in upland and diverging flow areas of the British Isles, Fennoscandia and Barents-Kara seas. Despite complex patterns of glacial readvance, the widespread conservation of preglacial surfaces in these interior regions is interpreted to be the result of topographically induced and self-sustaining basal thermal patterns.

O-5130

## The last British-Irish Ice Sheet in the southern North Sea: ice limits, timing and the influence of the Dogger Bank

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### Abstract

The southern North Sea is a particularly important area for understanding the behaviour of the British-Irish Ice Sheet (BIIS) during the last glacial cycle. It preserves a record of the maximum extent of the eastern sector of the BIIS as well as evidence for multiple different ice flow phases and the dynamic re-organisation of the BIIS. This paper explores the origin and age of the Dogger Bank (DB); re-assesses the extent and age of the glaciogenic deposits across the shallow areas of the North Sea adjacent to the Dogger Bank and; re-examines the dynamic behaviour of the BIIS in the southern North Sea between 30 – 19 ka.

The DB is composed predominantly by glaciolacustrine sediment deposited between 31.6 – 25.8 ka. Following its formation the western end of the Dogger lake was overridden with initial ice override and retreat northwards back across the Dogger lake complete by 23.1 ka. This resulted in widespread compressive glaciotectonism of the lake sediments and the formation of thrust moraine complexes. Along the northern edge of the DB, moraines are on-lapped by later phase glaciolacustrine and marine sediments but do not show evidence of subsequent ice override.

The seafloor to the west/southwest of the DB records several later phases of ice advance and retreat as the North Sea Lobe (NSL) flowed between the DB and the Yorkshire/Lincolnshire coast. New OSL ages limit the arrival of the BIIS on the Norfolk coast to 22.8 – 21.5 ka, after which multiple till sheets and moraines on the seafloor mark northwards retreat of the NSL. This pattern of behaviour is broadly synchronous with the terrestrial sedimentary record along the Yorkshire coast which relates to post Dimlington Stadial NSL oscillation and retreat (~ 21.5 ka)

With respect to forcing mechanisms it is likely that during the early phases of the LGM (~30-23ka) the interaction between the southern margin of the BIIS and the Dogger Lake was critical in influencing flow instability and rapid ice advance and retreat. However, during the latter part of the LGM (22 - 21 ka) late-phase ice advance in the southern North Sea became restricted to the western side of the DB which was a substantial topographic feature by this time. This topographic confinement, in addition to decoupling of the BIIS and the Fennoscandian Ice Sheet further north, enabled ice to reach the Norfolk coast, subsequently overprinting the seabed with late-phase tills of the Bolders Bank Fm.

O-5131

## Investigating palaeo-subglacial lakes in the central Barents Sea

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### Abstract

Subglacial lakes are important components of subglacial drainage systems, regulating water supply to the bed and influencing basal shear stress, with implications for ice sheet dynamics and mass balance on potentially rapid timescales. Improving our understanding of subglacial hydrological systems is therefore important, but challenging due to the inaccessibility of contemporary subglacial environments. Whilst the beds of palaeo-ice sheets are easier to access, few palaeo-subglacial lakes have been identified due to lack of clear sedimentological and geomorphological diagnostic criteria. In this study we address these uncertainties, using a suite of sedimentological, geomorphological and modelling approaches to investigate sites of potential palaeo-subglacial lakes in the central Barents Sea. Hydraulic potential modelling indicates several possible locations for subglacial hydraulic sinks within the Sentralbankrenna glacial system during the early stages of ice retreat from the Last Glacial Maximum. These correspond with many of the sites where we observed geomorphological signatures of subglacial drainage, including basins interlinked by meltwater channels, esker systems, and tunnel valleys, some of which breach ice marginal deposits (grounding zone wedges and recessional moraines). Sedimentological analyses indicate that the depositional environments within the basins were influenced by their positioning within the subglacial hydrological system and later due to their proximity to the retreating ice margin. Using the combined results of the modelling, geomorphology, and sedimentological analyses, we propose that subglacial lakes were present on the northwestern flank of Thor Iversenbanken, central Barents Sea. This drainage system likely played a role in regulating water supply to the subglacial environment of the Sentralbankrenna Ice Stream, influencing ice stream dynamics and stability. In addition, our observations suggest that this drainage system remained active throughout the later phases of local deglaciation, when the ice margin was retreating through this area. Numerous other potential locations for palaeo-subglacial lakes are also identified in the central Barents Sea, which may be good target sites for future sedimentological studies.

O-5132

## A Race for Ice Discharge between Ice Streams on Glaciated Continental Shelves

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### Abstract

Ice stream networks constitute the arteries of ice sheets through which large volumes of glacial ice are rapidly delivered from the continent to the ocean. Modifications in ice stream networks have a major impact on ice sheets mass balance and global sea level. Reorganizations in the drainage network of ice streams have been reported in both modern and palaeo-ice sheets and usually result in ice streams switching their trajectory and/or shutting down. While some hypotheses for the reorganization of ice streams have emerged, the mechanisms that control ice stream switching remain poorly understood. Here, we interpret a flow switch in an ice stream system that occurred during the Pliocene-Pleistocene on the northeastern Baffin Island shelf (Arctic Canada) through glacial erosion of a marginal trough, i.e., deep parallel-to-coast bedrock moats located up-ice of cross-shelf troughs. Shelf geomorphology imaged by high-resolution swath bathymetry and seismostratigraphic data in the area points to the extension of ice streams from Scott and Hecla & Griper troughs towards the interior of the Laurentide Ice Sheet. We interpret that up-ice propagation of ice streams through marginal troughs led to the piracy of the neighboring ice catchment, which in turn induced an adjacent ice stream flow switch and shutdown. These results suggest that competition for ice discharge between ice streams, which implies piracy of ice-drainage basins via marginal troughs, was the driving mechanism behind ice flow-switching. In turn, the union of ice catchment by piracy increased the volume and discharge of Scott Ice Stream, allowing it to erode deeper and flow farther on the continental shelf. Similar trough systems observed on many other glaciated continental shelves may be the product of such a competition for ice discharge between catchments.

O-5133

## Ice-driven relative sea-level changes and sediments deposition: a proposed algorithm for a fully coupled system

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### Abstract

Marine sediments play a fundamental role in reconstructing past ice-sheets fluctuations. These are responsible for global ocean volume variations that can be extracted from the isotope record and that also show up as relative sea-level (RSL) changes in the geomorphological and stratigraphic records. The consequent bathymetric variations, which result in changes of accommodation space and distance from shore, affect the deposition of marine sediments. The RSL changes that stem from the exchange of mass between the continental ice-sheets and the oceans are not globally uniform. According to the theory of glacial isostatic adjustment (GIA), the meltwater redistribution is accompanied by solid Earth deformations and perturbation of the gravity field. The GIA signal is a function of the ice-sheets thickness chronology as well as of the solid Earth's rheology and it strongly depends on the distance with respect to the ice sheets. In the proximity of a fluctuating ice sheet, the RSL changes are opposite in sign and up to one order of magnitude larger than the global average (eustatic). A clear example of this discordance is found in the geological record of the Eocene-Oligocene Transition (~34.0 Ma). The first appearance of the Antarctic Ice Sheet (AIS), in fact, was accompanied by a regressive phase in the northern hemisphere (~70 m RSL drop, Priabona, North Italy) while sediments were deposited and preserved in the proximity of the AIS margins (Wilkes Land, East Antarctica) in response to a local RSL rise (>100 m) and consequent increase of accommodation space. In this work the contribution of GIA-driven RSL changes in drawing the architecture of stratigraphic sections is investigated by means of a novel numerical modeling approach. The latter consists in the full coupling between a GIA model, which is based on the Sea Level Equation, and two sedimentation models that are based, respectively, on (i) fuzzy logic and on (ii) the numerical solution of the diffusion equation. Among the several variables that regulate marine sedimentation, changes in bathymetry and distance from shore and ice-sheet margin are directly linked to the gravitationally self-consistent RSL changes that are driven by GIA. The latter is also influenced by the load of the sediments that contribute to solid Earth and gravitational perturbations. The proposed algorithm, therefore, handles the biunivocal relationship between RSL changes and sediment loading in a synergistic manner. Preliminary results show that the reconstructed ice-proximal stratigraphic sections, either based on fuzzy logic or diffusion, are significantly affected by the GIA process and that the eustatic approximation should be discarded. This model is proposed as a tool for the geology community.

**O-5134**

## **Vegetation Response to Past and Present Climate change in Nigeria**

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### **Abstract**

Part of the projections of the current climate change model is that the tropics would be one of the most vulnerable regions to the effects of climate change. To test this hypothesis, the response of forest and savanna vegetation types to past episodes of climate change namely the Early Holocene (*ca.* 10,000-9000 BP), Mid Holocene optimum (*ca.* 8500-5,000 BP) and Late Holocene dry phase (*ca.* 4,500-2,000 BP) in southern and north-central Nigeria was investigated. During the Early and Mid Holocene, the rainforest in southern Nigeria was extensive and diverse such that this vegetation belt moved slightly northwards; the savanna vegetation in north-central Nigeria was predominantly humid but occasional dry conditions existed. During the Late Holocene, in the southern parts, rainforest vegetation generally decreased but in certain areas, especially wetlands and areas with reliable hydrological systems, parts of the rainforest recovered subsequently. On the other hand, the savanna became drier, more open and cooler. The significance of this is that the savanna is comparatively likely to be more sensitive to climate change, and with more devastating impact on its human and animal population. However, despite these climatic challenges, human populations in both vegetation zones had interactions that led to the exchange of ideas, technologies (mainly pottery and lithics) and language, which had lasting effects on their collective survival.

O-5135

## Sedimentological and palynological assessment of three wells in eastern Dahomey Basin, southwestern Nigeria, West Africa

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### Abstract

Integrated studies have been carried out on one hundred and eleven (111) ditch samples retrieved from Lagos coastal area of Nigeria. The study aim at determining the provenance, heavy mineral assemblages, establishing the lowstand-highstand Quaternary episodes, deducing the palaeoenvironment and age estimation of the sediments. The lithofacies constitute sandstones and siltstones with thin beds of lignite. The sandstone range from medium to fine grained with the lignite consisting of plant fragment remains. The petrographic results show abundant detrital minerals with average modal composition of quartz (90%), feldspar (2%) and rock fragments (4%). The Quartz-Feldspar-Rock fragments (QFR) ternary plots revealed that the sands are super-matured quartz arenites derived from the continental block under humid climatic setting which have experienced medium transportation history and have been subjected to mechanical and chemical weathering. Heavy mineral assemblages suggest matured sediments. The Zircon-Tourmaline-Rutile (ZTR) index indicates the super maturity of the sediments. The Apatite: Tourmaline (ATi) ratio showed variations within the wells indicating differences in the rate of weathering and period of residence on the flood plain despite similar provenance and fluctuation in ratios suggesting sea level changes. Fifty two (52) species of palynomorphs recovered include *Rhizophora* sp., *Avicennia africana*, *Acrostichum aureum*, *Laevigatosporites* sp., *Combretaceae* sp., *Mitrogynaciliata*, *Sapotaceae* sp., *Disopyros* sp., *Elaeis guineensis* and *Alchronea* sp. The palaeoenvironment of deposition suggest graduation from mangrove to fresh water swamp due to occurrence of *Zonocostites ramonae*, *Acrostichum aureum* and *Avicennia africana*. The abundance of *Podocarpus milianjanus* and *Retitricolporites hians* and the absence of Miocene diagnostic forms suggest Pleistocene age (Tarantian 0.126Ma).

Keywords: Dahomey Basin, palynomorph, Sea level, palaeoenvironment, provenance, assemblages

O-5136

## Phytogeographic dynamics on crystalline-sedimentary contact in South-Benin (West Africa)

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### Abstract

The geographical distribution of flora and vegetation is governed by biotic and abiotic factors and their discrimination therefore represents the best analysis of the relationships between vegetation and climatic, edaphic, topographical and human factors. This study aims to analyze the influence of climatic, morpho-pedological and anthropogenic factors on vegetation dynamics in South-Benin. The diachronic methods based on SPOT images from 1995 and 2015, phytosociological, predictive through Land Change Modeler and Maxent models, morphopedological surveys, socio-economic surveys and the Pettitt test were used. The study area is a contact zone between the sedimentary basin and the crystalline basement, a transition zone between the Guinean climate and the Sudanese climate, and a region of millennial cohabitation between two major sociolinguistic and cultural groups of Adja and Yoruba origin. Phytogeographically, it is part of the Guinea-Congolese region and the Sudano-Guinean regional transition zone. Between 1995 and 2015, natural plant formations developed mainly regressively (48%) to the benefit of crop and fallow mosaics and urban areas. Seven plant communities were determined, three on the crystalline, two on the transition and two on the sedimentary. A total of 223 species split into 179 genera and 63 families have been identified. The most dominant families are Leguminosae (15%); Poaceae (7.17%) and Rubiaceae (7.17%). The lowest Shannon diversity index is found on the lens (3.64 bits) and the highest on sediment and transition (4.54 and 4.67 bits). The crystalline lens is characterized by savannah formations with a high density (450 stems/ha) and a low basal area (10.72 m<sup>2</sup>/ha) of ligneous trees. However, sedimentary rocks are characterized by lower density forest formations (386 stems/ha) and a high basal area (37.42 m<sup>2</sup>/ha). Phytogeographically, there is a migration of Sudanese and Sudano-Guinean species to the Guinea-Congolese region. MaXent predictive modelling indicates that most species will undergo a reduction in their ecological niche. The annual rate of decline of around 18.30% and projections to 2030 predict a reduction in forests in favour of field and fallow mosaics and savannahs. Socio-economic surveys revealed that anthropogenic (98.87%) followed by climatic factors (82.86%) and edaphic (43.41%) factors are the main causes of vegetation decline dynamics. Besides, the fight against the vegetation deterioration should take both ecological and cultural dimensions into account.

**Keywords:** Phytogeographic dynamics, Crystalline; sedimentary; phytosociology, South Benin; West Africa.

O-5137

## Paleoecological reconstruction of the core of Venvé marsh in northwestern Benin: palynological study

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### Abstract

The detailed analysis of a core (length 2m) taken from a marsh located in Copargo (Djougou) allows us to reconstruct the environment from the beginning of its formation to the present day. The sporopollinic study is completed by stratigraphic analysis of organic sequences and floristic inventory. However, the chronostratigraphic framework remains undetermined. The results obtained make it possible to 1) understand the sedimentary dynamics of the marsh and its gradual transformation into a peat bog and 2) verify the correspondence between fossil pollens and the current vegetation of the marsh. It was found that the old vegetation has not changed significantly from that found on the site today. Indeed, pollens of forest species such as *Trichilia* type, *Diospyros* type, *Entada* type, *Terminalia* type, *Bombax* sp, *Newbouldia laevis* were observed during the pollen analysis. Studies on the climate in this area and dates would explain the establishment of this type of vegetation in the region.

Keywords : Pollen analysis – Vegetation – semi-deciduous forest - Venvé

O-5138

## Vegetation and Climate Change in Lejja, Southeastern-Nigeria: An Archaeobotanical Investigation

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### Abstract

Climatic changes and response are linked in various ways to human behaviour and socioeconomic processes, especially during the Holocene. In this study, macrobotanical evidence from an iron smelting site was used to examine late Holocene climatic perturbations and cultural transformation. Located in Igboland, Southeastern Nigeria -Lejja- is a small village where iron smelting as an indigenous craft specialization flourished on an industrial from around 2000 BC and lasted until the later part of the twentieth century, The vast number of slag blocks on the surface reveals that iron working in this region was a highly sophisticated, long-lived and well-developed tradition with techniques that involve relatively large scale metal production.

Carbonized and mineralized plant remains from two trenches of 2 X 2 meters provide proof of availability with regards to the various plant foods exploited 2,000 years ago in this region. A wide range of forest savannah plants was exploited in the lower and upper layers respectively. In the lower layers (Layers 4, 5 and 6) there was evidence of *Vigna spp*, *Senna tora*, *Syzygium aromaticum*, *Asteraceae*, *Cleome*. These layers marked the beginning of agricultural activities which is indicated by the presence of *Asteraceae* suggesting intense agricultural activities. Additionally, two pottery traditions which include maize cob rouletting and net impression were identified together with other ironworking remains.

The presence of *Elaeis guineensis*, *Dracaena*, *Cyperaceae esculenta* in the upper layers (Layer 1, 2 and 3) suggests very humid and wetter conditions which may have favoured the growth and development of plants. In Africa, *Dracaena* plants are indicative of moist evergreen or semi-deciduous forest while *Cyperaceae* demonstrates lowering of lake levels. Other finds include dimpled base potsherds, horizontal/vertical grooves, comb stamping, channelling, punctuates, slag, tuyere fragments, furnace remains and charcoal. A significant change to the environmental conditions at Lejja could be attributed to the intensive iron smelting activities, indiscriminate cutting down of hardwood for charcoal which must have led to deforestation among other environmental factors. Understanding the diversity of the plants exploited and the climatic condition in this region will elucidate the general framework of the occupation of the landscape and will inform our knowledge of late Holocene palaeoenvironmental record.

O-5139

## **Pollen preservation in Late Stone Age Rock Shelters in the Tropics: implications for palaeoenvironmental reconstruction.**

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### **Abstract**

It is assumed that most tropical soils are acidic. However, few archaeological materials (human skeletal remains) have been recovered from West Africa compared to East and South Africa. Hence, due to the dearth of human remains in West Africa, attention has been focused on plant remains to understand Late Stone Age culture and environment. These plant remains, mainly pollen and spores known to preserve well in acidic soils have been successfully used to reconstruct palaeoenvironment.

This study attempts to determine the preservation status of palynomorphs in Late Stone Age rock shelter sites and ascertain its implication on the reconstruction of palaeoenvironment of the sites. The study is based on archaeological excavation of Iresi, a LSA rock shelter site in the forest zone of southwestern Nigeria, palynological, sedimentological and pH analyses of sediment samples obtained from the rock shelter.

The pH result of the sediment samples ranged from 3.75 to 5.04 which was presumably conducive for the preservation of pollen grains. However, the recovered pollen grains were poorly preserved such that pollen identification was very difficult, and pollen sum was very low; pollen sum of duplicate or triplicate slides/sample ranged from about 100-230 pollen grains per gram. In contrast, however, non-pollen palynomorphs (NPPs) such as pteridophyte and fungal spores were abundant between about 1667 and 15,000 spores per gram and diverse in occurrence. The palynomorph data from Iresi were comparable to Mejiro Cave, Ita-Ogbolu, and Abeokuta (AB1) (other LSA rock shelter sites) in southwestern Nigeria hence the potentials of NPPs in providing Palaeoecological data are high and should serve complementary role to pollen.

**Keywords:** Archaeopalynology, Rock shelter, Late Stone Age, Pollen preservation, Non-pollen palynomorphs, southwestern Nigeria.

O-5140

## Palynological evidence of Climate Change in the Plio-Pleistocene transition in the Continental Shelf of the Niger Delta, Nigeria.

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### Abstract

The climate has significant effects on a wide spectrum of environments from terrestrial to estuarine and marine. Since the composition and structure of the vegetation in a region respond to change in climate, the climate of such region can be deciphered by its vegetation.

Consequently, climate change in tropical equatorial region is marked by wet and dry climate trends which is reflected by variations on vegetation rainforest (wet) and savanna (dry). These alternations between wet and dry climate phases result in correlatable cyclicity within a region.

Ditch cutting samples have been analysed palynologically from four wells from the Continental Shelf of the Niger Delta basin. The resultant palynofloral assemblage from the quantitative study is made of a variety of pollen (mangrove, savanna, freshwater/rainforest), fern spores, fungal elements, dinoflagellate cysts and algae. The identified palynomorphs have been attributed to parent plants derived from the proximal and distal provenances such as the coastal swamp, tropical rainforest, savanna and mountain regions.

From the identified plant, vegetation trends and changing abundances are recognized which are related to climatic cycles. These cycles are, in most cases, associated with identified condensed sections of Haq *et al.* (1988).

## POSTER PRESENTATIONS

**P-1001**

### **Impacts of sedimentation and erosion on the inference of the Antarctic deglaciation history by GIA modeling**

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#### **Abstract**

Late Pleistocene and Holocene sea-level records along the coast of Antarctica mainly reflect on the glacial isostatic adjustment (GIA) due to the deglaciation of the Antarctic Ice Sheet (AIS). Numerical modeling of the GIA has contributed to the inferring deglaciation history of AIS as a surface load change, effectively using geomorphological and geological evidence of Antarctica (e.g., Whitehouse et al., 2012).

On the other hand, sediment redistribution due to sedimentation and erosion is supposed to induce the isostatic crustal deformation and to influence the relative sea-level changes in the coastal regions (e.g., Blum et al., 2008). We can find the sediment redistribution driven by glacial activity in the topographic relief around Antarctica, and Antarctica and the marginal seafloor have experienced gradual changes in topography since the intensification of the AIS glaciation at about 34 million years ago. Previous studies on the GIA in the Antarctic region did not accurately take into account the component of crustal deformation caused by the sediment redistribution. Therefore, we have modeled solid Earth deformation and sea level change in response to sediment loading as well as past ice and ocean loadings in the Antarctic region. In this presentation, we show the numerically estimated crustal deformation induced by sediment loading and its contribution to observed sea-level changes along the coast of Antarctica. And also, based on the numerical results, we discuss the impacts of sediment and erosion around Antarctica on the GIA-inferred AIS deglaciation history.

**P-1002**

## **Reconstruction of paleo-channel and sea level around the ancient port related to Dangseong Fortress during the Medieval Warm Period**

Dong-Yoon Yang<sup>1</sup>, Min Han<sup>1</sup>, Kaoru Kashima<sup>2</sup>, Han Woo Choi<sup>1</sup>, Jin Cheol Kim<sup>1</sup>, Sangheon Yi<sup>1</sup>

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### **Abstract**

The trade route between the Unified Silla's Dangseong and Tang's Dengzhou seems to have been optimal in the respect of the sailing distance and the seasonal wind direction. The seasonal winds is thought to have been used for a main driving force of sailboats about 1000 years ago. That is, the bilateral trade routes of Dengzhou to Dangseong and Dangseong to Dengzhou were relied on the winter northwesterly and the summer southwesterly, respectively. This estimation is supported by the historical record of the trade activities between the Unified Silla and Tang, and by the archaeological data which are analyzed by a number of relics excavated from Dangseong. The Korean media reported that the Dangseong fortress in the West Sea was the starting point of eastern Silk Road based on the excavation report. However, it was not known that the exact location of the nearest ancient port toward the fortress and the sailing channel to the place. In this study, the nearest tidal channel from the coast to Dangseong was estimated to be the present agricultural channel similar to that shown in the 1918 map. The ancient port site connected with the channel was also analyzed by geological/geomorphological methods. In 3D graphics, the best location as an ancient port related to Dangseong was estimated, and it was also confirmed by 3D graphic results through the borehole sediments analysis and seismic exploration. Diatom data was used to estimate the sea level about 1000 years ago. Considering the load waterline of the sailboat, the minimum water depths of the channel and the port were calculated under the condition of the sea level change during the Medieval Warm Period and the Little Ice Age. Lastly, it was verified whether the trade sailboat could enter the ancient port through the estimated channel through the computer simulation.

P-1003

## Paleoenvironmental Context of Postglacial/Early Holocene Maritime Occupation on Isla Cedros, Baja California, Mexico

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### Abstract

Isla Cedros is a large mountainous island located in the Pacific Ocean ~23 km off Punta Eugenio, midway along the western margin of the Baja California peninsula. Part of the mainland during the early post-glacial period, the island separated by ~11,000 cal yr BP as sea level rose. Isla Cedros is predominantly arid desert heavily influenced by marine-layer moisture, giving it the native moniker “Island of Fogs”; its highest mountains support remnant patches of coniferous woodlands.

Recent archaeological work on the island has revealed a rich prehistoric record of human occupation (des Lauriers 2010, *Island of Fogs*, U Utah Press) including several maritime-oriented shell middens provisionally dating between 11,000-12,300 cal yr BP and likely earlier. These early sites are located near extinct freshwater springs at the heads of alluvial fans, locations that saved them from drowning under rising post-glacial seas. A sophisticated maritime subsistence economy is indicated by the tool assemblage, including the oldest dated fishhooks known from North America (des Lauriers et al. 2017, *Am. Antiq.* 82:498-516), and by abundant remains of shellfish, near-shore and pelagic fish, and other marine biota. These sites provide invaluable evidence for early coastal colonization of the Americas, and we are initiating a long-term program to explore these early occupations in detail. The paleoenvironmental context of these occupations remains largely unknown in detail. Important questions concern the nature and resource richness of the coastal marine and terrestrial habitats around the sites during occupation, and the marine ecosystems the inhabitants exploited.

These occupations depended on the fresh water supply from local springs. What sources fed these now-dead springs, and what climatic conditions allowed them to be active? Greater groundwater flow may have derived from stronger tropical inputs or greater winter Pacific frontal storm inputs. We are examining this issue using isotopic analyses of sediments, plant remains and gastropods in the spring deposits as well as modern water isotope analyses.

Local shellfish reserves differed from today, with extra-local species such as red abalone and lion’s paw scallop represented in the sites. We are developing near-shore environmental reconstructions that give us a better understanding of the rich maritime environment upon which these early North American colonists survived, and the near-shore maritime conditions that prevailed during the postglacial/early Holocene. We are also developing a better understanding of the history of local terrestrial biota. Plant resources such as agave may have been important not just for food but also for critically important fiber for fishing nets and line. Pollen, packrat midden, starch and detailed faunal analyses help us gain a better understanding of terrestrial habitats and available resources.

P-1004

## Recent changes of the diatom assemblages in relation to anthropogenic impact in Baltic Sea coastal inlets

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### Abstract

Diatoms are dominant primary producers, and are sensitive to the environmental change in coastal ecosystems. We investigated the distribution of diatoms in sediment records from two coastal inlets to place the consequences of multiple stressors on coastal ecosystems into a larger temporal context. The Baltic Sea coastal zone is a naturally vulnerable system and subject to significant human-induced impacts such as eutrophication and pollution. In this study, we present temporal changes of diatom assemblages from two coastal fjord-like inlets: Gåsfjärden (site VG1; core length 45 cm) and from Gropviken (site Gp2, c.l. 49 cm) on the Swedish southeast coast. Gåsfjärden has been the recipient of copper mining waste whereas Gropviken has “only” been affected by eutrophication.

The cores from VG1 represent the last ~400 years whereas the Gp2 site has a higher accumulation rate and represent the last 100 years, the cores were using <sup>210</sup>Pb and <sup>137</sup>Cs as well as correlated with previous dated cores at the Gropviken site.

The diatom analyses from the two sites resulted in a distribution of many typical taxa in this type of environment from the Baltic Sea (e.g. Snoeijs, 1993), such as *Skeletonema costatum*, *Thalassiosira levanderi*, *Cyclotella choctawhachiana*, and *Paulinella taeniata*. The in situ-planktonic diatoms, which reflect the surface-water production displayed increasing trend in the uppermost horizon at VG1, and in 36.5-32.5cm and 2.5-0.5 cm at Gp2. The epiphytic taxa, which include allotropic (freshwater) diatoms at Gåsfjärden (VG1) was more abundant than at Gropviken (Gp2) with relative abundances. The temporal variation of diatom assemblage suggested as follows: 1) Diatom production of GP2 site is much higher than site VG1, 2) Many of epiphytic taxa are transported from shallower part close to the core sites, 3) The effect of freshwater in Gåsfjärden is stronger than in Gropviken, 4) Change in diatom assemblage in western Baltic Sea coincides with the substantial use of artificial fertilizers after the 1950s, and further change occurred in 10 years. The results from the diatom analyses will be compared with a suite of environmental variables such as elemental - and grain-size distribution.

Reference: Snoeijs, P. (ed) 1993. Intercalibration and distribution of diatom species in the Baltic Sea. Vol. 1. 129 pp. Opulus Press. Uppsala.

P-1005

## Magnetic properties of core sediments in the southwestern sea area of Hainan Island: implications for provenance and sea level change

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### Abstract

Material source is one of the most important research topics for coastal offshore sediments. It has been one of the controversial issues whether the imported materials from the Beibu Gulf can enter the South China Sea (SCS). Environmental magnetism is an effective method for sediment provenance research and has been widely used for marine research.

Detail rock and environmental magnetic investigation is performed for a sediment core (located at 108.29° E, 18.36° N with water depth 74 m) to analyze their provenance and sea level change implication collected from the Southwestern Waters of Hainan Island in the present study. The results and previous study suggested that the lower section of the core (below 15.25m) should be the Late Pleistocene paleo-delta deposits. Magnetic properties and their significance is discussed for sediments deposited after the paleo-delta formation. Combining the previous research for the paleo-delta and AMS <sup>14</sup>C dating results for upper part of the core, the time span of this study is 5.4~33.2 ka.

The rock magnetic results indicate that main magnetic-carries of the core sediments are different fraction of single-domain and multi-domain magnetite and a small amount of hematite. Similar to previous studies, the ratio parameter  $\chi_{ARM}/\chi$  can represent the variation of magnetic particle size and then reflect regional sea level change, i.e. transgression and regression. From the variation of magnetic particle size, the sampling site of the study core was undergone at least four regression-transgression cycles since 33.2 ka. A significant positive correlation between magnetic susceptibility and non-hysteretic remanence is appeared in transgressive sediments but not in regressive sediments, indicating that more ocean action produced single domain magnetic particles were occurred in transgressive sediments. The significant positive correlation between  $\chi_{ARM}/\chi$  and S-ratio of transgressive sediments indicates that relative content of magnetite increases with the fineness of magnetic particles. The significant negative correlation among L-ratio, hard remanence and S-ratio indicates that the absolute and relative content of hard magnetic minerals decreases and increase with the source change of hard magnetic mineral such as hematite, respectively. Using the scatter plot of S-ratio and  $\chi_{ARM}/\chi$ , which is effective for material source identification, the sediments of transgressive and regressive period are compared with those of the surrounding possible provenances. The results the transgressive period sediments was relatively single provided by the Beibu Gulf. However, many sources such as Beibu Gulf, Qinzhou Bay, Red River and Hainan Island rivers were contributed for regressive sediments.

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P-1006

## Geoarchaeological evidence of the Bronze Age occupation along the Black Sea coast of Georgia – the Colchian settlement mounds

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### Abstract

More than 70 settlement mounds (local name: *Dikhagudzuba*) are evidence of a once densely populated landscape on the Colchian plain in western Georgia. According to ceramic finds they date to the Bronze Age. As yet, only limited information is available on their internal architecture, their palaeoenvironmental context, and the chronology of the different layers.

Based on archaeological sources, sediment cores taken from three mounds and their closer surroundings, as well as remote sensing data, the spatial extent, internal structure, and environmental setting were revealed. Analyses of element contents (XRF) and granulometry helped to identify stratigraphical layers and differentiate between natural and anthropogenic strata; by means of orthophotos and the Structure-from-Motion (SfM) technique the mounds' dimensions and distribution were calculated.

The investigated settlement mounds are similar in their stratigraphy and relatively small dimension. Heavy metal and phosphorus pollution in the anthropogenic layers indicate metallurgic and agricultural activity during the occupation phase(s). According to the <sup>14</sup>C chronology, their formation occurred during the first half of the 2<sup>nd</sup> millennium BC, which confirms the archaeological interpretation of their Bronze Age origin. The narrow age difference between the lowermost and uppermost anthropogenic layers indicates an intentional construction of the mounds rather than a successive accumulation of construction debris. Therefore, the mounds are classified as intentionally constructed dwelling forms, not as tells. The construction material originated from their direct vicinity, most likely from the surrounding circular moats. The environment of the mounds was dominated by fluvial and alluvial processes in a warm and humid climate, and the majority of the mounds is located in close vicinity to (palaeo-) river beds.

P-1007

## Aeolian sand influx in peat deposits as an indicator of past storminess: a critical evaluation and its application

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### Abstract

Records of aeolian sand influx (ASI) are frequently used to reconstruct the past changes in storminess along coastal areas in southern Scandinavia and other parts of Europe. However, this method has not been critically evaluated against instrumentally or historically recorded changes in storminess. We obtained high resolution records of ASI from four peat bogs along the Estonian coast and evaluated the extent to which the ASI-based estimates reflect the changes in past storminess in the region. All the peat cores are well dated (10 AMS dates per each peat core ca. 30 cm in depth), covering at least the last 150 years. Samples are analysed contiguously at every 3 mm to provide ASI and grain-size records (>65  $\mu\text{m}$ ) with a high temporal resolution. The results were compared with instrumentally-recorded storminess records (starting from 1920 A.D.) from Estonia and with meteorological records and reconstructions from around the Baltic Sea since the mid 19th century. Changes in forest cover within a 5-km radius from each site were estimated from historical maps available to evaluate the effects of land cover change on ASI.

Among the three sites, the ASI records show significant positive cross-correlations; however, the fourth site differs from the others, indicating potential variations in local sedimentary conditions. The ASI is high around the mid 19th century and the period from the 1950s to the 1980s at those three sites; those ASI sequences have also significant positive cross-correlations with the instrumentally-recorded storminess data. The ASI peaks in the mid 19th century correspond to positive NAO and intensive cyclonic activity reconstructed in southern Sweden. Sand grains smaller than 250  $\mu\text{m}$  proved to be more informative for detecting the changes in storminess than those >250  $\mu\text{m}$  that are less abundant and often miss the periods of increased storminess. Records of the grain-size distribution and median diameter of mineral grains indicated several shifts in the source material. Changes in forest cover around the study sites appear not to correspond to the changes in ASI. Previous studies have hypothesized that winter storms are the main factor affecting ASI; however, our results do not support it. We conclude that the ASI in peat bogs of coastal areas is effective for detecting the changes in past storminess, in general, but a careful examination of local sedimentary conditions is necessary.

In addition, we obtained long ASI records at those four sites covering the last 8000 years. Our preliminary analyses suggest that: (1) there were distinct stormier periods around 7500, 6400, 6000, 3500, 3000, 2000, 1500 cal yr BP, and during the last 1200 years, and (2) major regime shifts in storm frequency and/or magnitude occurred around 3500 and 1200 cal yr BP.

P-1008

## Updated mangrove pollen keys: an aid to palynological interpretation of tropical estuary and marine deposits

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### Abstract

Pollen analysis of mangrove sediments is a useful method for both palaeoecological reconstructions of coastal vegetation and determinations of palaeoenvironment in tropical regions. Effective reconstructions based on pollen data largely depend on accurate identifications of pollen and spores, and in this respect keys to the products of the extant mangrove flora are very valuable. Morphological studies have been carried out previously on mangrove pollen from both sides of the Atlantic Ocean, the Indian subcontinent, south-east Asia and the western Pacific, but keys to the identification of the palynological products of a wide range of mangrove taxa are not generally available. In this study, a pollen morphological “atlas” and identification keys for most of the mangrove flora are presented, including an interspecific key to the major mangrove elements in *Rhizophora* and *Sonneratia* (Fig. 1: example of triporate pollen types & interspecific key). The morphology of the pollen from more than 45 species of living mangrove and associated plants is described and illustrated by transmitting light photographs and/or scanning electron micrographs. These descriptions and illustrations, and the identification keys are presented at the achievable taxonomic level. The keys are yet open to the future development, so that pollen of other mangrove and associated plants can be accommodated when available. In their present form they should nevertheless aid palynological analyses of Quaternary mangrove and associated estuarine and marine deposits.

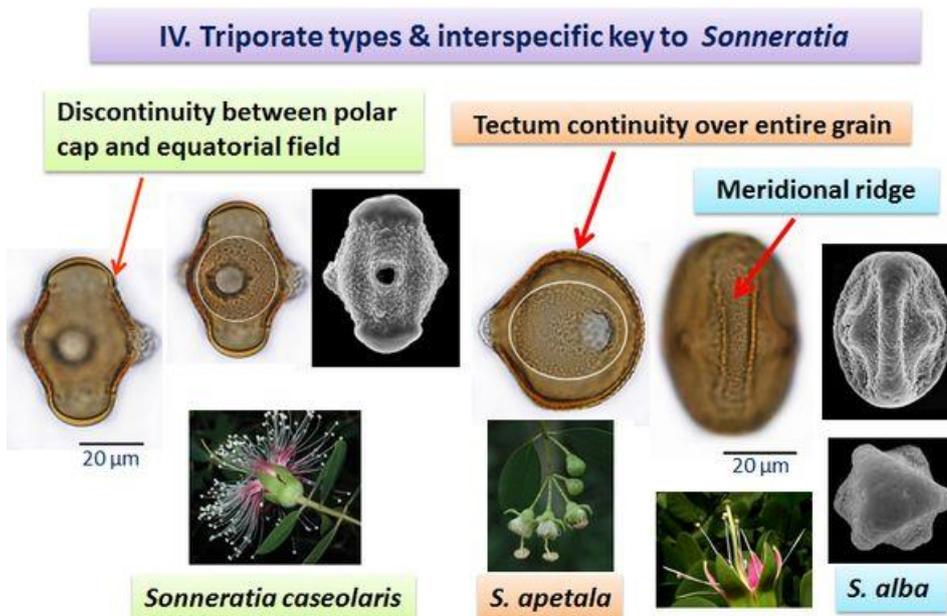


Fig. 1: Example of triporate pollen types & interspecific key to *Sonneratia*

P-1009

## Reconstruction of environmental change in northern Japan after the mid-Holocene and its implication for human activity

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### Abstract

Coastal sediments collected from bays provide a special advantage to present quantitative estimates of summer atmospheric temperature (AT) based upon the high correlation between AT and sea surface temperature (SST) and to examine the relationship between climatic changes and the human activity. The SSTs (ATs) around Funaka Bay, northern Japan, showed long-term increases due to gradual warming up in summer by stronger ocean currents and milder winter by weaker atmospheric circulation during the mid-late Holocene with low-frequency oscillations in the millennial-scale to sub millennial-scale. The alkenone SSTs showed a variation of 8.7 °C (14.5 °C to 23.2 °C). Large temperature falls occurred in 6.4-6.0, 4.5-4.0 and 1.2-0.9 cal. kyr BP with smaller peaks in 6.5, 4.5, 1.2 cal. kyr BP and the modern day. Although the SSTs (ATs) observed in this study were generally lower than those near Sannai-Maruyama, a famous archaeological Jōmon site, because the location of the present study is over 150 km north, both sites showed a similar general profile. Although a large decline in temperature in 0.95-0.65 cal. kyr BP, excluding the possibility of Medieval Warm Period in Japan, might have been influenced by an El Niño occurrence, a cold climate was definitely observed in the ash layer in 1640–1894 AD, which almost corresponded to the Little Ice Age. Our results are consistent with the contention that cold periods (5-10th century BC, 6th century AD, 11-12th century AD and 18-19th century AD) coincided with major shifts in social systems in Japan. Two additional cold episodes that correspond to the major societal changes were identified in this study using high-time resolution.

**P-1010**

## **Topography and sediment characterizing tide-dominated large-river deltas: the Mekong and other four examples**

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### **Abstract**

The fluvio-distributary channels of tide-dominated large-river deltas have characteristic features of upstream to downstream morphological trends in width, sinuosity, and depth. The river morphology (depth, width, and sinuosity) and bottom sediment of the Mekong River delta show clearly these characters. Here we show that these morphological trends in five modern tide-dominated river deltas in the world are summarized, using original data collected from satellite images and bathymetric maps, and published data from field surveys. The studied channels show two distinct upstream and downstream tracts separated by areas of morphological changes. The upstream tracts are characterized by constant width, relatively high sinuosity, and seaward-increasing depth, and are mainly controlled by the fluvial dynamics. The downstream tracts are characterized by seaward-increasing width, relatively low sinuosity, and seaward-decreasing depth, and are mainly controlled by the tidal dynamics. The delineation of this morphological configuration of the channels is crucial to understand the response of deltas to the interacting fluvial and marine dynamics. Additionally, this has important implications for understanding the controls on sedimentation, hydraulic models, the long-term evolution of these systems, and the assessment of natural versus human-induced modifications.

P-1011

## Recent anthropogenic signature on the coastal vegetation of the eastern Cantabrian coast (N. Spain).

Aitor Fernández Martín-Consuegra<sup>1</sup>, Sebastián Pérez-Díaz<sup>2</sup>, Alejandro Cearreta<sup>1</sup>

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### Abstract

The Anthropocene concept refers to the recent history of our planet characterized by a rapid and profound geological change provoked by numerous human activities and reflected in the sedimentary record. This impact can be studied through a great variety of proxies as, for example, buried pollen in estuarine settings. The objective of this work is to reconstruct the process of anthropization of the coastal vegetal landscape in the eastern Cantabrian coast (northern Iberian Peninsula).

We present here the results obtained from two cores, one located in the central area of the Suances estuary and the other from the upper Zumaia estuary. Both cores have a length of 50 cm and contain a sedimentary record that spans approximately from 1850 CE to the present.

The results show that, at present, the forestry exploitation is reduced in both areas, since the arboreal pollen of the typical taxa of the Cantabrian coastal vegetation (e.g., *Alnus*, *Betula*, deciduous *Quercus* and *Pinus pinaster*) increases through time. Additionally, presence of pollen from herbaceous and shrubby plants (e.g., Apiaceae, *Cerealia* t., Chichorioideae, Poaceae and *Erica* t.) is greater in the lower samples and decreases towards the top. Abundant taxa as *Cerealia* t., Poaceae (whose expansion is often linked to deforestation and infrastructure construction) and *Sordaria* t. in the lower core sections are indicative of intense agricultural activities and the presence of livestock animals.

Human activities have left a clear signal on the recent paleopalynological record of this region. Firstly, with the agricultural and timber exploitation that caused a reduction of the arboreal species in favour of the herbaceous taxa (e.g., Apiaceae, *Cerealia* t., Chichorioideae and Poaceae) since the 1850s until 1970s. Secondly, with the abandonment of these activities in the 1970s the arboreal forests recover naturally their spaces appearing forms like *Alnus* that usually grow in humid environments near coastal areas or river courses. In the case of the Suances estuary, the presence of the allochthonous taxon *Eucalyptus* sp. since 1990s is also very significative. Before that date, its presence is rare although it appears practically in the whole core. It is also present in Zumaia although more scarcely, and reflects abundant human plantations to take advantage of the qualities of this fast-growing tree for its timber and medicinal properties that now leaves its signature on the coastal sedimentary record of the northern Iberian Peninsula.

P-1012

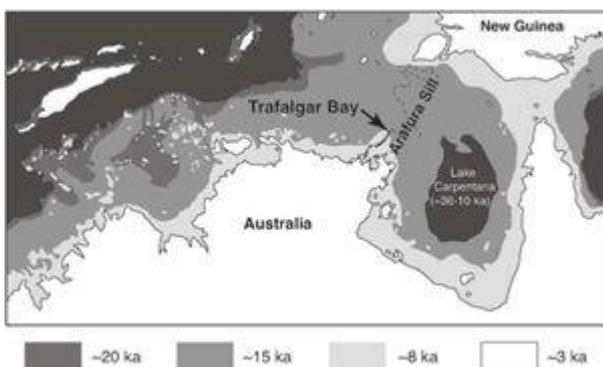
## Coastal submergence and the peopling of the Arafura Sill, northern Australia

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### Abstract

The Wessel Islands chain in the Northern Territory forms part of the Arafura Sill, a Pleistocene land bridge between northern Australia and New Guinea. This was breached by rising seas from ~12,000 years ago flooding the eastern Arafura Shelf, swamping freshwater Lake Carpentaria and forming the Gulf of Carpentaria. A record of this transition from land bridge to fully marine conditions is contained in the beach ridge and dunefield sequences of the island chain. Trafalgar Bay at the northern end of Marchinbar Island is a shallow, northwest-facing embayment on the gentle backslope of a sandstone cuesta. The bay shore is protected by two prominent headlands and two small offshore islands. Shoreline progradation under fair-weather wave conditions has resulted in the development of a ~500 m wide beach ridge plain. The most landward beach ridge is entirely siliclastic and has a well-developed dune podsol. It also has a steep shoreface. The ridge seaward is built on the lower part of this shoreface and is composed of beach calcarenite capped by pale yellow dune sand. The younger ridges that complete the sequence are dune-capped coarse shelly sand. We dated these units using OSL to determine the onset of beach ridge formation, the timing of the transition from siliclastic to bioclastic sedimentation and the rate of shoreline progradation. The chronology is relevant to understanding human occupation of the Wessel Islands. The breaching of the Arafura Sill would have displaced Aboriginal peoples from the continental shelf to the Wessel Islands and mainland coast. Human habitation from this early period, or even earlier, is likely to be present in the abundant rockshelters of the Marchinbar Sandstone. However, resource-rich coastal environments favourable to Aboriginal occupation had probably not been established until after the siliclastic-bioclastic transition.



**Figure 1.** Trafalgar Bay in the Wessel Islands chain and shorelines since ~20,000 years ago.

**P-1013**

**From Romans to artificial pebble beaches: human and natural influences on the Arno River delta history morpho-sedimentary evolution, (Tuscany, Italy).**

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**Abstract**

Marine coasts and river deltas are environments that are strongly subjected to human activities as much as to natural effects of climate changes. Therefore, they represent ideal areas to estimate the anthropogenic and/or natural factors that have a significant impact on land/marine environments. The morpho-sedimentary dynamic evolution of the Arno River delta has been increasingly driven by human activities since the Roman Age (e.g., reclamation of wetland areas, widespread centuriation of the coastal plain). During the Middle Ages additional waterworks such as meander channel cuts, excavation of artificial ditches, erection of levees, were carried out extensively. However, the most dramatic changes occurred during the last 500 years: in 1606 CE the mouth was artificially offset north of its natural location, which determined a huge seaward progradation of the delta. The progradation went on for about 250 years; later, changes in land use, reforestation, riverbed dredging, resulted in a harsh decrease of river sediment bedload, which was responsible of a massive coastline retreat of about 1.5 km since 1850. The erosion processes were tackled only with protection structures such as seawalls, breakwaters, and groynes. Recently, the coast was further engineered by raising artificial pebble beaches that replaced the sandy beaches wiped out by the sea. Along with human activities, climatic oscillations also triggered remarkable hydrological changes within the Arno River delta and in the adjacent areas. In particular, changes in frequency and severity of intense rainfall episodes directly impact the occurrence of floods, which in turn end up affecting many human and natural systems. As this kind of studies requires a multidisciplinary approach, in this work we highlight the evolution of the Arno River delta describing its current state throughout the correlation of data from land and marine archives provided by different surveys and analyses. Land archives comprise datasets including the geoarchaeological context, results of sedimentological and micropaleontological analyses of boreholes, geophysical surveys, coastal sediment dynamic and satellite image analyses. Marine archives consist of two relatively shallow-water sediment cores, recovered in the shelf in front of the Arno River mouth, that have been used for a high-resolution micropaleontological study of the calcareous nannofossils. Micropaleontological data have been correlated with some indexes which reflect variability of precipitations and river discharge (e.g., large and exceptional floods during the last 2 millennia, changes of the distance of the sea from Pisa) in order to reconstruct the past millennium significant hydrological events in the Arno River basin. The synthesis between land and marine archives reveal a close relationship between human activities and natural factors in the past 2000 years of the Arno River evolution

**P-1014**

## **Holocene relative sea-level changes in west Wales: new results from Dyffryn Dysynni**

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### **Abstract**

At present Holocene sea level changes in west Wales are poorly constrained with only 14 reliable sea level index points published (Shennan et al. 2018). This paucity of data, particularly for the Late Holocene, potentially results in lack of precision in predictions from glacio isostatic models for the region, and prevents changing coastal configuration and environment-human interactions to be fully explored. This research reconstructs Holocene sea level changes in west Wales and integrates these data with known archaeological sites to establish how patterns in settlement and land use were affected by coastal and sea-level changes. The Dysynni Valley in west Wales is a characteristic low lying coastal valley that contains well-preserved estuarine sediments and a rich archaeological record, from prehistory to the medieval period.

Fieldwork, including stratigraphic analysis, sampling, mapping and surveying was undertaken at two sites, Penllyn and Perfeddnant, approximately 6.5km apart, in order to establish the horizontal extent of marine inundation in the valley. The stratigraphy at Penllyn revealed a basal peat subsequently dated to between 7787-7665 cal BP, overlain by blue-grey clay, and then overlain by a woody peat dated to 6402-6297 cal BP. Laboratory work included loss on ignition, particle size and diatom analyses to establish the salinity and geophysical properties of the sediments that could be related to sea level fluctuations and changing sedimentary dynamics.

The diatom analysis at Penllyn revealed that the clay was dominated by marine and brackish species such as *Nitzschia navicularis*, *Diploneis interrupta*, *D. didyma* and *D. stroemi*. This evidence suggests that a marine-estuarine environment existed at this site during the mid-Holocene and this is likely to correlate to the Main Postglacial Transgression in the area. The loss on ignition and particle size analyses show high organic content in the peat, with low organic and carbonate content in the clay, and grain size dominated by silts, corroborating the relative sea level rise. At Perfeddnant ongoing analyses is revealing similar trends in relative sea level. Continuing research will enable accurate mapping of the extent and timing of marine inundation in the valley, which will have important implications for understanding environment-human interactions in Dyffryn Dysynni and more broadly within coastal zones.

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**P-1015**

## **Multiple Approaches to Investigating Human-Environment Interactions in the Coastal Zone: Lessons from Urban Coastal Communities from India**

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### **Abstract**

Societies have lived with the vibrant nature of land and coastal environments for ages. Vulnerability of coastal areas to climate change is an important issue, which has gained attention recently. Faced with rising sea levels and the likelihood of increasing storminess, coastal communities are on the front line of climate change impacts. Coastal areas face multiple risks and stresses related to climate change and variability. Impacts of sea level rise are expected to have predominantly adverse effects on natural and human systems. Coastal communities are highly vulnerable to climate change impacts, mainly because of three main reasons, high resource dependency, high exposure and limited adaptive capacity. Coastal environments are also under pressure from increasing intensity of human activity. This raises concerns about coastal community's sustainability.

The Intergovernmental Panel for Climate Change Fourth Assessment Report has identified several low-lying deltas of Asia and Africa, which are highly urbanized and also vulnerable to climate change impacts. Thirteen of the world's twenty largest cities are located on the coast, and more than a third of the world's people live within 100 miles of a shoreline. Low-lying coastal areas represent about two per cent of the world's land area. This 2 per cent coastal land area contains 13 per cent of the urban population.

India has a 7,517 km long coastline with many low-lying and densely populated areas with nearly 260 million people living within 50 km of the seacoast. These highly vulnerable areas house a network of infrastructures. It is highly pertinent to start climate adaptive infrastructure and services, given the climate sensitive nature of the existing infrastructure systems in the coastal area. It could be maintained and managed in such a way that it is prepared to withstand sea level changes impacts.

This paper discusses on approaches that can increase resilience of infrastructure and the services in coastal urban areas of developing nations. It also explores the human-environment interactions in the coastal zone, including impacts of storms, inundation, coastal erosion and land use changes. It also highlights the Identification of vulnerable hot spots in the coastal areas, recommendations for climate proofing infrastructure and services and methodology for vulnerability assessment of coastal communities to climate variability and sea-level changes. It also recommends appropriate policy and institutional reform, capacity building and improved knowledge management towards increasing the resilience and adaptive capacity of these coastal communities to current and future sea level changes.

**P-1016**

## **Holocene coastal changes and human adaptation at the mouth of the Gironde estuary, France (SW France).**

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### **Abstract**

The North Medoc Peninsula is bordered by the Atlantic Ocean to the west and the Gironde estuary to the east. The coast is formed by sandy beaches, dune barriers, estuarine marshes and intertidal mudflats. This sea-land interface experienced significant coastal changes during the Holocene.

During the last three decades, intense winter storms have unearthed vestigial sedimentary deposits containing numerous archaeological remains on the Amélie beach, located on the coastal side of the Gironde estuary. While threatening those nature/culture dialectic archives, this erosional context paradoxically provides an easy access for paleoenvironment analysis. The interdisciplinary project LITAQ aimed to reconstruct the Holocene and Pleistocene environments and related human settlements in this geographical area. Now ended, this program has initiated a long-lasting collaboration between archaeologists and natural scientists through survey campaigns at the Amélie.

Combination of topography, stratigraphy, and radiocarbon/relative dating of the beach and associated dune barrier sediments led to chronostratigraphic reconstructions. Thanks to sedimentological analysis, micropaleontology and geochemistry, depositional environment identification was achieved. In addition, several relative sea levels were produced, following the “sea-level index points” method.

The nearly complete Holocene sequence of the Amélie was recognized, infilling the paleochannel of Soulac, a tidal inlet of the Gironde estuary, allowing paleogeographic restitutions of this coastal area.

Concomitant with a sea level rise slowdown, the tidal channel infilled with marine and estuarine facies around 5000 BC. Protected by coastal dune barriers, two coastal marsh generations were recorded, between ca. 3000 BC to ca. 1500 BC and between ca. 800 BC to AD 300. Around ca. 1500 and ca. 1000 BC, an episode of marine erosion brought coastal dune ridge breach and enhanced wave penetration inside saltmarshes. From AD 300 to 700, the estuarine marsh was gradually buried by coastal dunes.

Systematic spatial and stratigraphic analysis of archaeological remains generated correlations between human settlement and supporting environments. From early Neolithic to Antiquity, our research has allowed a better understanding of the human adaptation to environmental changes through time.

Additional cores were performed inside the dune ridge and in the eastern marshes, located at the estuarine side of the channel. Coupled with a database of ancient drillings, this data allowed Soulac channel sequencing. The chronostratigraphic framework clarified the environments succession/expansion and erosion/aggradation phases rhythmicity controlled by interplay between marine, aeolian and fluvial processes with variable intensity within the channel.

To better specify climate forcing, regional and interregional analogies were made, using indexes such as CSP, coarse grained sedimentation pulses or aeolian activity/stability phases.

Moreover, the existence of high resolution marine cores collected during the program HAMOC in the Bay of Biscay, offshore of the Medoc littoral, gave the opportunity to directly correlate climate/marine changes and coastal responses.

P-1017

## Reconstruction the shallow water ecosystem of the Strait of Magellan-Patagonia during the late Holocene: implications on human subsistence

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### Abstract

In the Patagonian archipelagos, marine hunter-gatherers based their subsistence mainly on the exploitation of marine resources. However, we can observe changes in their economy during the Holocene (San Román et al. 2016). Important transformations were seen in fishing strategies: during the period 6000 to 2000 years BP there was a strong tendency for the exploitation of demersal species (Torres et al. 2016). From 2000-1500 years BP onwards, exploitation shifted to taxa currently associated with kelp (*Macrocystis pyrifera*) forests and, in general, shallower waters. These shifts in target species may reflect cultural changes. Alternatively, they may reflect environmental change. Paleoceanographic studies show considerable dynamism in marine ecosystems during the Holocene, due to fluctuations in sea temperature, salinity change, meltwater and marine productivity (Aracena et al. 2015). Important inputs of meltwater occurred between 3250-2700 and 2000-1200 cal yr in the area, which affected marine productivity (op cit.) and could have had an impact on the prehistoric economy.

Our objective was to evaluate the changes in feeding mode, feeding behavior, and trophic level in these shallow-water fishes during the Late Holocene, in order to evaluate the responses of human populations. For this purpose, we undertook analyses of collagen  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  from benthic coastal and demersal fish remains found in archaeological sites of different dates within the Late Holocene was performed. The results were compared with similar taxa from the Intermediate Period (3200-2000 BP), Late Period (2000- 300 BP) and modern fish.

The analysis indicates that *C. gobio* had a similar core isotopic niche in both the late and intermediate periods. Modern *Patagonothen sp.* are considerably (ca. 4 ‰)  $^{13}\text{C}$  depleted relative to the Intermediate Period, suggesting a shift to the consumption of prey fueled by pelagic-derived C relative to the  $^{13}\text{C}$  enriched prey consumed in the Intermediate Period which were probably fueled by benthic-derived C (e.g. macroalgae).

The isotopic niche of *S. australis* differed in the Intermediate and Late Period, which could indicate that they fed in different environments. Conversely, modern *S. australis* are  $\delta^{15}\text{N}$  enriched potentially indicating an increase in trophic position, or shifts at the base of the food web.

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**P-1018**

## **Effects of short-term climate oscillation on ecosystem of eutrophic lagoons in East Asia**

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### **Abstract**

Although it is a common knowledge that natural climate change affects impacts for aquatic environment and ecosystem of lagoon, the effects of decadal and hundred scales climate fluctuations have been comparatively less discussed. Most previous researches on fishery using lagoon mainly discussed the effects of human-induced eutrophication, because human impact generally gives clear influences on lagoon environment and ecosystem. Thus, we investigated the effects of short-term climate oscillations like as Arctic Oscillation (AO) and Pacific Decadal Oscillation (PDO) on lagoon environment and ecosystem in the East Asia as Hokkaido and west Honshu Japan and northeast South Korea based on lagoon sediment analysis. Lagoon sediments were obtained by hand pushing piston corer, and diatom remains and mineral components in the lagoon sediments were investigated for the paleo lake environmental reconstruction. In all lagoon sediments, some diatom taxa and mineral components in lake sediments were corresponding with AO and/or PDO phases. However, the reaction patterns for these climate oscillations were difference in each lagoon. For example, Lakes Noto and Mokoto are adjacent seasonal frozen lagoons in Hokkaido, Japan. Ice-related diatom taxa in both lagoons showed clear relationship with AO. This is probably because the spring air temperature of this area is strongly controlled by AO phase. However, even foraminifera assemblage and primary production of Lake Noto also followed in AO phase, the effect of AO was limited in the Lake Mokoto. The relative abundances of major diatom taxa are related more stronger with PDO phase. This difference is probably depended on their geomorphological setting. Lake Noto is the large area and small catchment lagoon. In this lagoon, timing of lake ice melt and spring bloom type are important factors for primary ecosystem. On the other hand, in case of Lake Mokoto which is the small area and large catchment lagoon, autumn heavy precipitation and following land nutrient input probably affect stronger impact for primary ecosystem than the effect of spring temperature change. Such kind of relationship can be confirmed in other lagoon. Nutrient indicating diatom taxa and some mineral components in small lagoon, Lake Hwajinpo showed the good relationship with reconstructed PDO phase throughout the precipitation change. These results suggested the effect of short-term climate oscillations on lagoon ecosystem is complicatedly changed by surrounding environment. To understand the lagoon ecosystem, it is necessary to understand how the climate oscillation affect the impact for lagoon ecosystem.

**P-1019**

## **Late Holocene paleoenvironmental history by High resolution analysis of clastic varves in the brackish Lake Mokoto, Hokkaido, Japan**

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### **Abstract**

In the coastal area of the Sea of Okhotsk in the east part of Hokkaido located to subarctic zone, many brackish-water lakes are distributed. Lake Mokoto has two-layer structure of polyhaline surface waters and mixoeuhaline bottom water. The bottom water shows the anoxic conditions in summer season. In this reason, the sediments of Lake Mokoto consist of organic mud with the lamination. The 09Mk-1C core collected from Lake Mokoto at 2009. In the soft X-ray photograph, the cyclic lamina set is observed in their core. According to the meteorological data in Abashiri region, the annually precipitation is high from August to September. Probably, the cyclic lamina set is formed by seasonal change of precipitation. After that, the cyclic lamina set was certified as varvesediments by the analysis of 15Mk-3C core, which is collected at 2015.

In February 2018, we collected 18Mk-8C, 18Mk-1B, 18Mk-2B cores from the central part of Lake Mokoto (water depth 4.5 m). The 18Mk-8C core is collected from the surface sediment, and the core length is 176 cm. The flood lamina set formed in 2015 and 2016 was confirmed, and one set of laminar set can be observed above it. For this reason, it seems that it is collected almost from the surface sediment. The 18Mk-1B and 2B cores were collected at 1 m interval from 5 m and 5.5m below the surface water of the lake. The length of each core is about 19 m. These cores were mostly muddy varvesediments, and lower 2 m were sediments with massive or Bioturbation. Though these cores have loss horizons, they can be correlated by the lamina level. It can be regarded as a continuous core by integrating them. Three tephra were observed in integrated cores. The top tephra is Ta-a tephra, volcanic ash which fell in AD1739. The middle part of tephra is Ko-c2 tephra in AD1694. 42 lamina sets were counted between the two tephra. The bottom tephra is Mb-a tephra in the 10th century.

CNS element analysis was carried out on the horizon of late Holocene in integrated cores. The total organic carbon (TOC) and total sulfur (TS) contents show the high values in middle parts, and decrease upward. However, the flux of TOC and TS increase upward. This suggests eutrophication by human impact. Ultra high resolution analysis (about 10 samples per year) was carried out at the top. TOC contents showed a value of 4 to 5%, but TS contents showed a low value (less than 1%). The TS contents and the apparent density show a high correlation, suggesting that a large amount of clastic material flows from the river. The clastic material contains TOC, suggesting an increase in organic load from the watershed.

P-1020

## Break-up of Neolithic cultural layers in the coastal Qiantang River, eastern China: pollen evidence

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### Abstract

With discoveries of early rice-based agricultures such as Kuahuqiao Culture (c. 8-7 cal. ka BP) and Shangshan Culture (c.10 cal. ka BP) in recent years, a breakthrough has been made for Neolithic archaeology as well as environmental archaeology in the Qiantang River drainage region, eastern China. Here we reconstruct vegetation in order to reveal environment change and human activities based on the AMS <sup>14</sup>C chronology and pollen analyses of cultural layers of Loujiaqiao archaeological site after 6500 a BP. Such analyses have been focused on the interval sediment between cultural layers to **understand its formation**.

Our results show that: 1) a mixed evergreen and deciduous broad-leaved forest primarily composed of evergreen oaks (*Cyclobalanopsis*) and deciduous oaks (*Quercus*) flourished in the adjacent small hill during the early Hemudu Culture (6500-6300 cal. aBP). This forest suggests that the climate was warm and humid and favored local fishers, foragers and hunters to settle down. During this time, the forest vegetation remains closed with minor anthropogenic disturbance; 2) Subsequently, a visible natural interval layer occurred around 6100 cal. a BP overlaying the early cultural layers. It shows that pollen floral of this layer seems quite unusual: *Pinus* is dominant with first small occurrence of *Picea*, *Abies* and *Tsuga* which distribute in present subalpine mountains; moreover, marine algae such as *Spiniferites* and *Lingulodinium* made first appearance in abundance and fresh algae. Based on Holocene environmental evolution of Qiantang River, it is assumed that the Hangzhou estuary had been formed and then prompted strong tidal currents to migrate upward in long distance along the river valley to study site. Meanwhile, the river was blocked by the tidal currents and water level began to rise considerably. Thus, Loujiaqiao site **was completely inundated** leaving local people to abandon this site; 3) Afterward, Neolithic farmers came back to the study site probably due to the lowering the flood. A human-induced oak forest dominated in the surrounding hill and became an important economic nut forest for local people. The progressively opening of forest linked closely to local intensified rice farming.

**Key words:** Pollen analysis, Interval layer, rice farming, Sea tide, Archaeological site, Qiantang River

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P-1021

## A Late Holocene record of environmental change from the east coast of New South Wales, Australia.

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### Abstract

A multi-proxy palaeoenvironmental record from a lake (36° 5'37.33"S; 150° 7'26.02"E) on the east coast of Australia provides a record of coastal development and vegetation succession over the last 3,800 cal. yr BP. Lead-210 and <sup>14</sup>C dating built a robust age-depth chronology for the 61cm long core. Pollen, charcoal and x-ray fluorescence analysis provide records of vegetation change, fire regimes and catchment dynamics during the late Holocene. This study finds that an open coastal environment dominated by *Amaranthaceae* and *Eucalyptus* was present between 3,800 and 3,000 cal. yr BP when sea level on the east coast of Australia was ~1.7-1.5m higher than present. Rainforest indicators including *Cyathea*, *Pomaderris* and *Nothofagus* suggest a mixed wet Sclerophyll community was present either regionally or locally. Low pollen concentration and relatively high counts of Fe, S and Ca suggest iron sulfides and shell hash accumulated in a shallow or periodically exposed basin. Microscopic charcoal counts varied between 4,000 and 3,500 cal. yr BP and may indicate an increase in regional fire events. From 3,000 cal. yr BP Casuarinaceae and Poaceae increased and aquatic types *Typha* and Cyperaceae first appeared in the record suggesting the falling sea level allowed a barrier dune to form and a brackish to freshwater wetland to develop. Between 3,000 and 2,000 cal. yr BP Sr and Ti counts varied significantly, suggesting terrestrial and marine sediments may have periodically washed over the barrier dune and accumulated in the wetland during a period when sea level was ~1.1m higher than present.

Sclerophyll open forest dominated by Casuarinaceae expanded until 2,000 cal. yr BP and then remained constant until present. Local and regional fire indicators increased briefly at 2,000 cal. yr BP. The presence of European settlers in the region is clearly identified by the occurrence of *Pinus* and the significant increase in regional and local fire regimes from 1900 AD and 1920 AD respectively. This multi-proxy record from a coastal lake in eastern New South Wales identifies the impact of sea level change and coastal progradation on vegetation and fire regimes and investigates natural and anthropogenic driven environmental change during the late-Holocene.

P-1022

## Palaeoenvironmental evolution of Holocene–Modern back-barrier mangroves in the northern Mekong River delta, Vietnam

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### Abstract

Mangroves are sensitive to climate, sea level, intertidal elevation, salinity and the balance of river and marine processes. In the northern Mekong delta, mangroves inhabit a wave-protected, tide-influenced, back-barrier area (Can Gio) but their Holocene development is poorly constrained. This study combines sedimentary, stratigraphic and palynological analyses of Pleistocene–Modern sediment cores with radiocarbon and optically stimulated luminescence (OSL) dating to interpret the (1) local palaeo-environmental and geomorphological evolution and (2) regional controls on sedimentary dynamics impacting mangroves. Interpreted intertidal–upper subtidal facies comprise bioturbated carbonaceous mudstones with abundant mangrove organic fragments and palynomorphs. They gradationally overlie interpreted subtidal facies, which variably comprise bioturbated mudstones, sandy mudstones and heterolithic containing brackish-water shells. Radiocarbon dating indicates modern mangrove material occurs throughout the uppermost 3–4 m of sediment (c. <4 ka) suggesting root penetration and mixing by mangroves. The OSL dating suggests initial barrier formation by  $3.21 \pm 0.19$  ka, which is earlier than adjacent barriers and consistent with the ages of sandier core sediments (c. 5–3 ka) and archaeological sites (c. 2 ka). Substantial thinning (>10 m) of the Holocene succession southwards towards the barrier suggests its development was influenced by bedrock topography. Sand supply from the active Mekong delta during barrier development was limited by the relatively lateral and distal position. Instead, the proposed model for barrier development involves the gradual supply of suspended sediment with a small fraction of silt–sand, deposition across shallower bedrock, and preferential winnowing of mud to form a sandier deposit. Suspended sediment was most likely supplied by south-westward alongshore currents from sandy shorelines to the north-east, and the Saigon River and local rivers eroding sandy Pleistocene outcrops. The proposed geomorphological model illustrates the interaction of topography, sediment supply and fluvial–marine processes on early barrier development and mangrove expansion in the northern Mekong River delta.

P-1023

## Neolithic vegetation, environment and their relationship with human activities in the Baima Lake area, eastern China: Preliminary pollen result

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### Abstract

Relationship between human and nature during the early Neolithic in the eastern coastal areas of China remains problematic. Among them, the key issue that how ancient human initiated rice cultivation (*Oryza sativa*) has been hotly debated. Zong et al. (2007) suggested that prehistoric Kuahuqiao human removed the alder fen carrs (*Alnus*) by fire to start rice cultivation about 7700 years ago using "slash-and-burn" subsistence strategy, while Shu et al. (2010, 2012) presented more detailed research challenging the hypothesis.

However, previous studies focused on the Kuahuqiao site and other interesting subjects remain uncertain such as: What's the change in vegetation and environment around the site? How large is the scope of human activities? What is the extent of the marine transgression that caused the collapse of the Kuahuqiao site? We made a new core from the Lake Baimahu, less than 5km from Kuahuqiao site, trying to answer these questions.

Vegetation, environment were reconstructed based on AMS<sup>14</sup>C dating and sporo-pollen analyses. Three distinctive zones are well recognized: 1) **Zone I:** (8000-7750 cal. a BP), the period features the predominance of *Quercus*, *Pinus* and Poaceae. In this zone, *Cyclobalanopsis* and *Quercus* are abundant, Poaceae is prominent in the upper layers and increase visibly while *Pinus* experiences gradual decline. Charcoal increase slowly; 2) **Zone II:** (7750-7400 cal. a BP), this zone is dominated by *Pinus* and *Quercus* in percentage. *Quercus* showed a decreasing trend which is distinguished from Zone I, while *Cyclobalanopsis* have a slow rise. *Spiniferites* begin to increase. Charcoal was almost stable, which is significantly reduced compared with the previous area; 3) **Zone III:** (7400-7150 cal. a BP), this zone is characterized by the gradual increase of *Quercus*, *Typha*, *Spiniferites* and Poaceae, while the *Pinus* declined rapidly. At the same time, there are abundant Polypodiaceae-type and *Azolla* spores.

Dominance of *Quercus* and *Cyclobalanopsis* reflect the warm and humid climate; High content of Poaceae (<38 µm in diameter) indicate the grass distributed widespread in swampy wetlands. The expansion of Chenopodiaceae and Cyperaceae could be mainly encouraged by the rising sea level and the overwhelming marine transgression; In addition, the large amount of charcoal may indicate frequent human activities. However, there is no Poaceae (≥38µm) observed shows that rice cultivation was limited. These conclusion are similar with that at the Kuahuqiao site, so the ancient humans may have been reached and inflected the Baima Lake area.

Phytolith analysis will be incorporated in our study to better indicate the rice agriculture in the future.

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**Keywords:** Vegetation change, Pollen analysis, Human activities; rice cultivation, Kuahuqiao culture, Baima lake area

**P-1024**

## **Depositional process and provenance changes of the sediments in the East China Sea during the middle and late Holocene**

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### **Abstract**

Hydroclimate variations associated with the East Asian Summer Monsoon (EASM) precipitation exert significant impacts on lives of people inhabiting within the Yangtze River drainage and coastal zone. Seasonal shift of main precipitation area is attributable to the reposition of northern limit of summer monsoon, which would lead to provenance and composition changes of suspended materials transported by the Yangtze River. Therefore, the interannual to millennial time-scale variability of the position of rain belt mentioned above could be recorded in the long-term change in compositional variation of sediment originated from the suspended materials in the Yangtze River. The East China Sea(ECS) is of primary importance owing to massive inputs of terrestrial materials from the Yangtze River. The variation in the Yangtze River discharge and provenance could have been recorded in sediments of the Yangtze delta and ECS. Therefore, we could expect to recognize provenance changes in core sediments taken from the Yangtze subaqueous delta in association with EASM precipitation variability. In order to reconstruct the EASM precipitation and provenance variability during the middle and late Holocene from these sediment records, it is also necessary to examine the transportation mechanism of Yangtze-derived sediment including sediment reworking / re-deposition by coastal current, tide and local input, the migration of shoreline and estuary of the Yangtze River, as well as the change of depocenter in the Yangtze delta associated with the postglacial sea-level rise. Here, the sedimentary evolution, stratigraphy, age model and potential provenance change of MD06-3040 core covering the middle and late Holocene will be reported.

**P-1025**

## **Bridging the onshore-offshore gap: Investigation of unconsolidated sediments using shallow 2D seismic data, Isle of Sheppey, Southern North Sea**

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### **Abstract**

Identifying sediment budgets with the potential to be mobilized in the next few decades is an important area of investigation for the coastal engineering community [1]. This includes characterizing sediment type (consolidated, unconsolidated, grain size) from the terrestrial cliff-dune system to around 20-30m water depth offshore. The main problem area here is the very shallow, always submerged region that is too shallow for survey boats to operate safely. This is the region where much of the sediment is mobilised and energy dissipated. Here we combine the passive seismic survey method to obtain thickness of inland deposits with a shallow offshore seismic survey, helping to bridge the gap between onshore and nearshore along the coast of the Isle of Sheppey, North Sea, reducing the uncertainty in this critical area.

Offshore data was collected in 2017 by Clinton Marine. The survey area is 50km<sup>2</sup>, and comprises 1789km lines of 2D seismic data, acquired using Innomar's Medium SES-2000. Unconsolidated sediment is easily penetrated and imaged using this system, with resolution rapidly deteriorating once consolidated sediments are encountered. This is the basis upon which mobile sediments were interpreted and mapped. Offshore backscatter data processed and interpreted using Fledermaus FMGT reveal sediment grading from gravel to fine silts and muds, correlating with grab samples.

Onshore data was collected in February 2019 by the British Geological Survey using the passive seismic survey method. Passive seismic surveys measure background seismic noise to estimate the thickness of different lithologies through different time domains and spectral techniques. Passive seismic surveys consist of a series of single-station point recordings, generally arranged into linear transects or a grid pattern, the latter of which can be used to generate 3D surfaces of target horizons. We have used the Tromino ENGY-3G, a small, portable, broadband, three-component seismometer and the proprietary software Grilla (v7.0) that implements the Horizontal-to-Vertical Spectral Ratio (H/V) method [2, 3]. The reason behind using the spectral noise ratio is that seismic noise varies largely in amplitude as a function of the noise "strength" but the spectral ratio remains essentially unaffected and is tied to local subsoil structure [4]. The Grilla software also provides routines for quality control of the H/V analyses following the European SESAME project directives.

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**P-1026**

## **Estimates of carbon stocks in Swedish coastal areas of the Baltic Sea**

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### **Abstract**

Carbon storage in natural environments is an important factor for making both national and global carbon budgets. Presently, only carbon stocks in the terrestrial realm are systematically included in national carbon budgets. The large amount of carbon stored in coastal and marine sedimentary stocks are significant and may occur in the same order of magnitude as the terrestrial carbon stocks. Given the current rate of emissions and the pressing need for international agreements on reducing greenhouse gas emissions, a solid understanding of the different carbon stocks are of great importance for making realistic and useful assessments of national carbon budgets. Recently attention has been drawn to the carbon storage capacity of coastal sediments (Smith et al., 2015; Smeaton et al., 2016; Avelar et al., 2017). It has been shown that many coastal regions have high sediment carbon stocks, particularly in fjords (Smith, et al, 2015). Coastal sediment carbon stocks can also be significant when compared to terrestrial carbon stocks which are normally included in the assessments.

The aim of our project is to produce estimates of the marine carbon stocks in Sweden's Exclusive Economic Zone along the Swedish Baltic coast. We will present preliminary carbon-stock estimates based on published data and measurements on sediment cores. The sediment carbon stock estimates will be interpolated and spatially averaged using GIS and statistical tools. For coastal-marine settings we will develop a GIS model of basin shape and bottom type representing the Baltic coast. The purpose of including bottom type in our GIS averaging is to account for soft depositional bottoms with higher carbon accumulation and hard erosional bottoms with no or low accumulation. We aim to produce a data set that can show regional differences in carbon stocks along the Baltic coast as well as an estimate of the total carbon stock of the Baltic coast.

P-1027

## Vegetation history of Hyrcanian forest and the climate dynamics in northern Iran

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### Abstract

The Caspian Hyrcanian forest region, mainly located at the narrow elongate belt between the southern shores of the Caspian Sea and northern slopes of Alborz mountain range in northern Iran, forms a unique hotspot of biodiversity with ancient mixed broadleaf forest. The Hyrcanian forest constitutes the most important refugia and the last relicts of broad-leaved deciduous forests covered the temperate zones of the northern hemisphere before the Quaternary, such as the Arcto-Tertiary relict species *Parrotia persica* (Persian iron), *Zelkova carpinifolia*, and *Pterocarya fraxinifolia*. Due to its special geographical location, this ecosystem is very sensitive to environmental changes, therefore the environmental records from this region can provide important archives for the past vegetation and climate changes as well as human impact.

In this study, we are using multi-proxy analysis to reconstruct past environmental changes using a ca. 550 years old sediment record by applying pollen/spore, Non-Pollen Palynomorphs (NPPs) and geochemistry analysis. The NPPs results indicate active erosion process of the catchment area between 540 and 450 cal yr BP. The pollen analysis indicate that *Alnus*, *Carpinus betulus*, *Fagus*, *Quercus*, *Ostrya*, *Zelkova* and *Pterocarya* are the most dominate taxa in the Caspian Hyrcanian forest since ca. 450 cal yr BP. Human impact was not so strong during the recorded period, but increased recently. This study contributes to an in-depth understanding of the dynamics of Hyrcanian forest, past climate changes, human activities and also provides suggestions for the conservation and management of the Hyrcanian forest in northern Iran.

P-1028

## Reconstruction of Palaeoenvironment of Chilka Lagoon, East coast of India using Benthic Foraminiferal Records

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### Abstract

Anthropogenic impact on the water of Chilka lagoon (19°28'–19°54' N: 85°06'–85°35'E), the largest brackish lagoon of Asia, has been studied in details for the last few decades by using different environmental proxies. The present study is aimed to reconstruct the palaeoenvironmental and palaeoecological changes of the Chilka lagoon from a 70 cm long sediment core collected from the central section (19°39'41.40"N, 85°25'1.69"E) of Chilka lagoon by using biological proxy i.e benthic foraminifera.

In the present study, the 70 cm core was sliced into 1 cm and divided it into half ~ one for chronological analysis and another for microfossil analysis. The chronological data shows that the 15cm of the core is assign to 47 years from the present and the sedimentation rate of that area is 0.317cm/year. Hence from the sedimentation rate it can be concluded that bottom layer of the core (i.e. 70cm) is assigned to about 220 years from the present. For micropalaeontological analysis, the samples were wet sieved through 63 µm sieve and dried at 50°C. The sediment samples were split with the help of micro splitter and benthic foraminifera from 1gram of each split sediment sample was counted. The Total Foraminiferal Number (TFN) is very high in the upper part of the core and suddenly gets decreased from 14cm downwards. In the lower part of the core TFN slightly increases but not as much as upper part of the core. In the upper part of the core, the agglutinated species dominates (95-100%) and very few calcareous species (0-5%) are encountered there but in the lower part of the core, we find a vice versa scenario. The dominant agglutinated foraminiferal species are *Ammotium spp*, *Textularia agglutinans*, *Miliammina fusca*, *Trochammina spp*, and calcareous hyaline forms are *Ammonia parkinsoniana*, *Ammonia beccarii*, *Criboelphidium hispidulum*. In the first 11cm of the core, uniserial agglutinated species such as *Ammotium salsum*, *Ammobaculites sp.* and *Reophax sp.* dominates but from the 12 cm suddenly their percentage decreases. The presence of the highest percentage of uniserial agglutinated species indicates a typical anoxic stressed environment. The Murray's Ternary plot clearly shows two distinct cluster- one rich in agglutinated species in the upper and middle part of the core and another with a high percentage of calcareous hyaline species in the lower part of core indicating a stressed environment in the upper and middle part of the core. In the present study, the dominance of agglutinated species in the upper part of the core (up to 15cm which is assign to 47 years from the present) indicates a stressed environment that can be related to human interference in the lagoon in the past few decades.

P-1029

## Isotopic signature of ancient limpet shells as indicator of seasonal harvesting pattern in archaeological context

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### Abstract

Recent insight in *Patella vulgata* sclerochemistry and sclerochronology leads to the use of this species as a palaeo-environmental archive, mainly for the reconstruction of palaeo-SST through the study of  $\delta^{18}\text{O}$  in shells. But high-resolution  $\delta^{18}\text{O}$  profile can also be used to determine the season of death of the studied individuals. In archaeological context, it is possible to determine patterns of seasonal harvesting, as it has been achieved on several bivalve species.

For European Atlantic seashore, coastal shell middens hold high proportion of *Patella* shells, in particular in insular context, due to the abundance and the accessibility of these species for coastal populations. This archaeological material allows to study patterns of intertidal resources exploitation and insular site seasonal occupation. As a case study for this method, the site of Beniguet-2 (Le Conquet, Finistère, France), consists of three layers of shell middens interbedded in aeolian sand. These layers were radiocarbon dated back from Final Neolithic (2400 B.C.), Early Bronze Age (2000 B.C.) and Early Middle Age (650 A.D.). 10 shells from each occupation layers were studied, with two comparative methods.

Results show significant differences between the different shell layers, thus between the occupation periods. The Final Neolithic layer and the Early Middle age layer show year-long harvesting of *Patella*, while Bronze Age layer seems to contain only spring-collected shells. Interpretation of these results leads to several hypothesis, like seasonal or year-long occupation of insular sites, seasonal harvesting of particular resources, or single-meal shell pack. These results confirm the interest of *Patella vulgata* shells as palaeo-environmental and anthropological archive.

**P-1030**

### **3D imaging of calcite microfossils – messengers of recent environmental changes**

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#### **Abstract**

During the 21<sup>st</sup> century, the rising concentration of anthropogenic carbon dioxide in the atmosphere is likely to affect all marine calcifying organisms, and the ecosystems they inhabit, since the oceans act as a large sink for CO<sub>2</sub>; a process referred to as ocean acidification. Furthermore, on a regional scale, a number of additional processes such as increased land run-off, erosion, and inorganic - and organic matter deposition will contribute to lower the pH and alkalinity in coastal waters. Concurrently other large environmental changes occur in coastal zones such as increasing seawater temperatures, eutrophication with resulting increased hypoxia, and pollution from industry and traffic. We have studied recent environmental changes in Skagerrak, NE Atlantic and in the entrance of the Baltic Sea (the Öresund) by sampling marine sediment cores and its content of benthic foraminifera fauna together with a range of environmental variables (grain-size distribution, content of organic carbon, nitrogen, heavy metals, and black carbon). Here we present data from high-resolution X-ray microtomography analyses, performed at SPring-8, Japan, on benthic calcareous foraminifera. We analysed three foraminiferal species with respect to shell structure, surface/volume ratio, size and density. The microtomographic results show considerable variability but a tendency towards lower shell thickness and concurrently higher shell surface/volume ratios in the last two decades compared with earlier part of the record, suggesting that substantial changes in shell preservation (and thereby water chemistry) have occurred.

**P-1031**

## **The chronology and provenance of Holocene sediment in the Yangtze River (Changjiang) Delta, China: an OSL approach**

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### **Abstract**

Delta is formed under the interaction of climate, sea-level change, topography and sediment supply, which records the information of land-sea interaction. The Yangtze River Delta is home to China's largest coastal economic zone, and its evolution has drawn wide attentions. However, chronology framework of the Yangtze River Delta is a particularly troublesome problem due to the complicated sedimentary characteristics, and its provenance remains controversial. The development of optically stimulated luminescence (OSL) technique provides an opportunity to solve the above problems, since the luminescence signals of quartz or feldspar have widespread application in determining burial ages of Quaternary sediments. Meanwhile, it shows great potential in tracing the provenance of sediments.

In this study, the luminescence technique was used to determine the age of core HM and analyze its sediment provenance change. The single-aliquot regenerative-dose (SAR) protocol was applied to four different grain-size quartz fractions (4-11  $\mu\text{m}$ , 45-63  $\mu\text{m}$ , 63-90  $\mu\text{m}$ , 90-125  $\mu\text{m}$ ). The results show that the ages of the samples obtained with four different grain-size fractions are generally consistent with each other within the limits of experimental errors and the stratigraphical order for early Holocene sediment. However, fine grain-size fractions yield the apparent overestimated ages for late Holocene sediment. In addition, three quartz fractions (45-63  $\mu\text{m}$ , 63-90  $\mu\text{m}$ , 90-125  $\mu\text{m}$ ) were subjected to quartz luminescence sensitivity measurements. High variable luminescence sensitivity was observed among the different grain-size fractions and different sedimentary units of the Yangtze River delta. By integrating chronology and sediment provenance analysis, we speculate that change of the sediment supply during late Holocene affect the accuracy of fine-grain OSL ages.

P-1032

## The postglacial development of Narva-Luga Klint Bay (eastern Gulf of Finland. Baltic Sea)

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### Abstract

The abstract presented new results of geophysical and geoarcheological studies of the formation of coastal marine sediments developed in the area of the Narva-Luga Klint Bay (lowland between the Narva and Luga rivers). A multiple depositional sequence represented here mainly by periglacial accumulative sandy landforms was formed during the last ice sheet degradation at the end of Pleistocene. According to the OSL dating the age of subsurface part of the extended presumably glaciofluvial landform named Kuzemkino Spit (a series of pebble-sandy clinofolds forming the glacial delta according to GPR data) is 13-10.8 thousand cal. yrs. BP. During the Holocene the lowland was substantially transformed by coastal-marine and alluvial processes. Geological and geomorphological studies show traces of at least two transgressions happened in the post-Ancylus Lake time (middle Holocene). Two erosion horizons indicating the sea level fluctuations of the Baltic Sea in the Holocene were distinguished using GPR profiling and OSL dating. The glaciofluvial deposits are covered by a thin sandy layer which was formed  $8.1 \pm 0.8$  thousand cal. yrs. BP according to OSL dating of the sample collected at the height range from +11.8 to +12.3 m.s.l. The coastal scarp, the base of which is located at a height of +8.5 m, is developed hypsometrically lower in the same glaciofluvial complex. At the absolute level of 8.5 m, there was a relatively long-term stabilization of sea level. The beach and submarine sand ridges, subsequently not affected by marine transgressions and preserved as relict forms in the relief, were formed. According to archaeological data Kuzemkino landform was settled by ancient people after the Littorina transgression maximum. Earlier (Gerasimov et al., 2010) it was suggested that during the Early Neolithic time there were only short-term camp sites on the spits. The location of the archaeological sites is confined to the palaeo-beach line and confirms the formation of indentation in the second half of the Littorina Sea period. Geological and geophysical data analyses were carried out in frame of project № 17-77-20041 of Russian Science Foundation.

**P-1033**

## **Monitoring and understanding geomorphological risks to coastal heritage: insights from contrasting sites in Wales and Ireland.**

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### **Abstract**

Projections of future climate change and sea level rise suggest that the effects of more frequent storm activity are likely to become more significant. This includes the geomorphological processes of coastal erosion and sand inundation, especially in exposed, remote and unprotected coastal locations. This means that the historic environments of these landscapes and the historically-, archaeologically- and culturally- important heritage sites located within them are at risk of being lost, damaged or buried. Effective management of these sites, including recording, interpretation and planning protection measures requires a better understanding of the nature and rate of geomorphological processes and the factors which control them. Placing recent, historical changes in a longer term context of environmental change may also aid stakeholder and public discussions on management options.

We present data from preliminary desk-based work (historical maps, reports) and fieldwork (dGPS, UAV and geophysical survey, rapid coastal zone assessment, palaeoenvironmental work) undertaken as part of the CHERISH project at three such sites – Bardsey Island and Dinas Dinlle hillfort in north west Wales and Dunbeg promontory fort, County Kerry, Ireland. These sites are all currently experiencing erosion, but due to site-specific characteristics (e.g. geology and sediment type) variations in erosion processes and rates are evident. Significant archaeological material has been, and continues to be exposed, damaged and lost at all sites including possibly prehistoric cremation burials and other archaeological material on Bardsey and structural damage and loss to the prehistoric and early medieval promontory fort at Dunbeg and the prehistoric hillfort of Dinas Dinlle. Previous work has shown that ~ 8m of erosion has occurred at some sites on Enlli (1918-2014) and recent surveys have shown that this has erosion is continuing. Rates of erosion through the glacial sediment underlying Dinas Dinlle fort are in the order of 0.2 m/yr (1889-2017). At Dunbeg, historical rates have been faster (e.g. ~ 0.5 m/yr 1897-1915) and recent storms in winter 2017-2018 caused the loss of 3000 m<sup>3</sup> at this site. At Dinas Dinlle and Dunbeg, although wave action is the main erosive agent, the impact of overland flow pathways also appears to be significant.

These preliminary results suggest that erosion is likely to continue resulting in further exposure and/or loss of important archaeological material. Integration of these data with data from surveys of other sites on both sides of the Irish Sea will enable identification of areas of coastline to prioritise for targeted recording and management.

**P-1034**

## **Linking lake level changes and surface deformation in the Dead Sea**

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### **Abstract**

Loading and unloading of the crust controlled by lake level changes may exert an important influence on the patterns of surface deformation, seismogenesis and fault activity. However, the relative contribution of climatic and tectonic factors on surface deformation at millennial time scales still remains poorly understood and quantified. The Dead Sea is the deepest continental basin on Earth; it is characterized by a complex history of abrupt lake level changes, active faulting, and variable seismic recurrence during the late Pleistocene and Holocene. Elucidating the interaction between climate and tectonics in this area is an extremely relevant topic in virtue of potential seismic scenarios associated with global climate change and anthropogenic impacts that may alter current lake levels. Here we study the outstanding exposure of fossil lacustrine shorelines along the coast of the Dead Sea, these geomorphic markers resemble past lake level positions and can be used to determine surface deformation rates. We study nine sites distributed along the eastern and western coasts of the Dead Sea, performing field topographic surveys, field observations and sampling for dating in each site. This study for first time provides chronological constraints for the lacustrine shorelines sequence, including 30 radiocarbon ages from fossil stromatolites. We map the distribution of fossil shorelines using high-resolution drone and LiDAR topography coupled with surface classification models. Our results suggest a sequence of up to 20 levels of fossil lacustrine shorelines between -150 and -380 m and with ages ranging between ~10 and ~40 ka. This sequence resembles the progressive drop of the lake Lisan (paleo Dead Sea). The shoreline elevations display a long wavelength deformation pattern decreasing in elevation northwards and southwards and are locally offset by faults at Ein Gedi, Ye'elim Creek, Ein Boquek, Metzkoque Dragot, along the western coast and by the Sehati, and Movenpick faults along the eastern coast. By comparing the elevation among shorelines of different sites we estimate a continuous deceleration of vertical deformation rates towards the present. Based on the comparison with previously published lake level curves, we suggest that isostatic rebound associated with lake-level drop may locally counteract tectonic subsidence. This study emphasizes the link between climate and surface deformation processes in the Dead Sea. This work is supported by the German Science Foundation (DFG) grant JA 2860/1-1 "LIFE - Linking lake level changes, surface deformation and seismogenesis in the Dead Sea" and the German-Israeli Foundation for Scientific Research and Development (GIF), grant I-1280-301.8/2014.



Lacustrine regressive shorelines of the Dead Sea, the left panel display a Spot image and the right panel 0.5 m resolution drone topography

P-1035

## Early Holocene human-environmental interaction along the coast of Yoldia Sea and Ancylus Lake, Lithuania: multidisciplinary approach

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### Abstract

Traditionally, four main stages have been accepted describing the development of the Baltic Sea during the post-Glacial – Baltic Ice Lake, Yoldia Sea, Ancylus Lake and Litorina Sea. However, numerous questions related with the spatial-temporal resolution and ecological regime of the Yoldia Sea and Ancylus Lake still stays unsolved. And even less is known about the Late Palaeolithic-Mesolithic human groups that settled the area at that time. To explore these issues, a multidisciplinary approach that included both archaeological and geological investigations have been applied in Lithuanian' sector of the Baltic Sea.

To reconstruct the Early Holocene human-environmental interaction the data obtained from the bottom of the Baltic Sea and the coastal zone of the Lithuanian territory was studied involving palaeobotanical (pollen, diatom, plant macrofossil) survey, isotopic (<sup>14</sup>C) measurements and lithological (loss on ignition (LOI), grain-size and magnetic susceptibility (MS)) and archaeological investigations. Identified changes of the palaeoenvironmental regime and human history are discussed in the context of the circum-Baltic area.

Working on the reconstruction of the environmental history of the Early Holocene basins sediment cores of biogenic, limnic and marine sediments from the bottom (24 - 30 m b.s.l.) of the Baltic Sea were recovered. The part of the sequences, consisting of limnic and biogenic deposits and representing the Early Holocene, according to <sup>14</sup>C data, are discussed.

The results obtained show the existence of a shallow transparent water basin surrounded by the birch-pine-predominating forest during the Early Holocene. Investigated basin was surrounded by wetland with *Menyanthes trifoliata* and Typhaceae. Beside that numerous trunks of the pine tree have been discovered laying at about 24–25 m. b.s.l. Dated back to about 11410–10170 cal. BP (9.640–8.220 cal. BC) these fossils prove the existence of the dry land in territory. One more stage of the biogenic sedimentation took place between 9.150–8.520 cal. BP (7.200–6.570 cal. BC). Investigated beds are laying at 29 m b.s.l. proving existence of the regressive coastal line below mentioned absolute height during the Early Litorina Sea stage. Based on the information obtained two phases of the Early Holocene basin development have been identified - the first corresponds to Yoldia Sea–Ancylus Lake period while the second one could be correlated with the Early Litorina Sea time.

Discussing the Early Holocene population history representatives of Early Mesolithic Kunda (Pulli) and Maglemose cultural groups should be mentioned. While mostly of the archaeological settlements have been discovered far inland from the present sea coast. Since the access to water bodies was of particular importance for survival of these communities, settling close to the sea coast, i.e. westward migration could explain this phenomenon. And this idea has been approved during the resent underwater archaeological investigations.

**P-1036**

## **The search for the MIS 5e sea-level highstand from a slowly uplifting coastlines: lessons from the South Coast of England**

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### **Abstract**

Global sea level reconstructions are dependent on clastic deposits to provide wider spatial coverage than can be achieved using marine or coral reef sequences. However, these deposits are more complicated to interpret, as their relationship with mean sea level is less clear. In addition, on slowly uplifting coastlines, there is the potential for overprinting of multiple highstand events at similar altitudes within the landscape. Here we report on 35 years of research in the Sussex / Hampshire Coastal Corridor (SHCC) which is thought to exhibit a uniquely complete record of deposition during multiple phases within the last interglacial (LIG), both within deposits of the 'Pagham Raised Beach' (PRB) and further west within the Solent seaway. We show that none of these sequences were deposited at mean sea level during the highstand part of the interglacial. Indeed, all are likely to have been deposited at a significant elevation below this datum. This is problematic because the PRB deposits have been used uncritically to represent mean sea level in a previous global sea level reconstruction. We apply the lessons learned from detailed study of this sequence to other sequences that have also been used for sea level reconstructions and show that very few of the clastic sequences used to augment other more continuous records from marine or subsiding settings are from geomorphological settings that convincingly correspond to sea level highstand conditions during the mid interglacial.

P-1037

## A multiproxy approach to investigate Late Holocene hurricane-fire interactions from a coastal lagoon near Manatee Bay, Jamaica

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### Abstract

Complex interactions exist between hurricane and fire activity that produce diverse ecological impacts on tropical coastal ecosystems. The Hellshire Hills lie within the Portland Bight Protected Area (PBPA) in southern Jamaica and are dominated by a continuous fire-adapted, semi-deciduous dry-limestone forest surrounded by coastal mangrove and lagoon communities. Archaeological evidence suggests that the Hellshire Hills were inhabited as early as 650 CE by different Ostionoid and subsequently Meillacan cultures (950 CE), suggesting a long-history of human land use in the surrounding landscape. Additionally, extended periods of drought, as well as the passage of tropical cyclones resulting in the accumulation of organic matter in the landscape, can affect the intensity and frequency of subsequent forest fires. Consequently, there exists the potential for the influence of both anthropogenic and natural drivers on the fire regime of the Hellshire Hills. Comparisons between charcoal and additional sediment proxies recovered from coastal lagoon cores within the PBPA, provide the opportunity to examine long-term natural and anthropogenic controls on local fire dynamics within this unique dry-forest community.

Here we present preliminary analyses of a 5m (~2000-year long) sediment record from a coastal lagoon north of Manatee Bay. The sediment stratigraphy is dominated by organic peats and authigenic marl sediments separated by distinct layers of coarse marine bioclastic sediments and charcoal. Loss-on-Ignition measurements at 550°C and 950°C utilized with grain-size analyses of the coarse sediment fraction (> 63µm) confirm the presence of multiple coarse carbonate sand layers within the stratigraphy. The composition of these coarse sediments (marine organisms including coral fragments, the alga *Halimeda sp.* and foraminifera) suggests they are allochthonous with a marine provenance and were most likely deposited during the passage of historical tropical cyclones; although deposition of washover during the earthquake-induced (M7.5W) tsunami of 1692 CE that generated a 1.8m wave that devastated nearby Port Royal cannot be fully discounted. Analysis of macroscopic charcoal suggests hurricane-fire linkages within the lagoon watershed were likely associated with changes in available fuel. Synthesis of these data with existing paleotempestological and archaeological records suggests the combined impact of human and hurricane activity on long-term fire activity in the Hellshire Hills during Pre-Columbian, Colonial and Industrial times.

**P-1038**

## **Anthropogenic effect or natural limit? Shoreline changes of a delta from accretion to destruction: A case from the Eastern Mediterranean**

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### **Abstract**

The construction of dams on rivers feeding deltas has caused to the sinking of world deltas. Especially due to anthropogenic effects over the last half-century delta shoreline retreat has attracted much scientific attention. However, most studies focus on shoreline retreat after dams are constructed. To clearly show the retreat of shorelines has been due to anthropogenic effects, it is very important to observe the natural shoreline changes before the anthropogenic effects on the delta. This study observed shoreline changes in the Seyhan Delta in the Eastern Mediterranean from 1950 to 2018 employing long-term Landsat MSS, TM and OLI time-series and aerial photographs. To identify shoreline changes, aerial photographs from 1950 and 1956 together with Landsat satellite images from 1972, 1985, 1998, 2009 and 2018 were employed. After extracting shorelines with MNDWI and NDWI index, the statistical analysis of the shoreline changes found with the Digital Shoreline Analysis System tool (DSAS) for different periods was undertaken.

The results indicated that the shoreline accreted nearly 131 meters nearly the river mouth with a maximum rate of 22.9 m yr<sup>-1</sup> from 1950 to 1956. In this period an area of 322,071 m<sup>2</sup> was added to the delta. Contrary to this, following the construction of the Seyhan Dam in 1956, the Seyhan Delta lost a total area of 4,039,251 m<sup>2</sup> from 1956 to 2018. The shoreline retreated 2293 meters at the river mouth, with a maximum rate of retreat of 37 m yr<sup>-1</sup>. The major cause of this retreat is the trapping behind the Seyhan Dam of sediment brought down by the Seyhan River.

Comparing our data with different delta shorelines around the world showed the Seyhan Delta is the delta experiencing most rapid shoreline retreat in Turkey at a rate of 37 m yr<sup>-1</sup>. Additionally, it is the delta with the third most rapid shoreline retreat in the Mediterranean, after the Nile and Ebro deltas. In conclusion, accreting under natural conditions, the Seyhan Delta witnessed dramatic shoreline retreat due to the effect of the dams constructed on its course. In the future, it is to be expected that the shoreline will retreat even more rapidly from causes such as the construction of further planned dams, land subsidence and rising of global sea level. This situation will have a great impact upon wetland areas and upon agricultural and tourism areas and structures in the delta. This study was supported by HÜBAK #14162 project.

**Keywords:** Shoreline retreat, coastal erosion, anthropogenic effects, Mediterranean, Seyhan delta

P-1039

## Sea-land-man interactions revealed by the coastal vegetation history of the central Mediterranean during the Holocene

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### Abstract

Mediterranean coasts are projected as one of the most vulnerable areas to climate change and impact of human activities, mainly due to sea level rise and the ever-increasing of human population. This process is particularly worrying in some areas of the central Mediterranean, where the risk of natural ecosystem loss is extremely high. In this context, palynology represents a fundamental tool to detect the past climate-man-environment interplays and provides outstanding examples of long-lasting processes of natural ecosystems loss and recovery, related to the combined action of human activity, climate change, and geomorphic processes. Here, we present a review of pollen records from coastal areas of central Mediterranean regions (including Malta, Sardinia, Corsica, Italian Peninsula, Sicily, Croatia, and Greece), in order to describe the general processes characterizing the environmental evolution of this region and to detect the main causes producing landscape change during the last thousands of years. An overview of the main vegetation types reveals a rather diverse composition and structure of the vegetational landscape, mostly depending on the interaction of diversified environmental forcings from a local to global scale, which make it impossible to define a pollen stratigraphical scheme valid for the entire area during the last thousands of years. Climate and geomorphic processes played a major role in shaping the vegetation features of the central Mediterranean. In some case, only one sector of the central Mediterranean Basin was involved (e.g. Tyrrhenian expansion of *Alnus* around 5200 cal. BP), while in other cases extensive geographical processes occurred (e.g. development of coastal wetlands around 7000 cal. BP). Besides, coastal pollen records substantially contribute in defining the effects of the relative sea level changes in coastal ecosystems, during both the Pleistocene/Holocene transition and the Holocene, so providing paradigmatic examples of ecological dynamics associated with the sea level rise. Concerning human impact, a general and progressive anthropization trend in the vegetational landscape is observed since the Neolithic, evolving with different times and modes from site to site. In many cases, human populations adapted their activities to the locally existing natural resources, for example by exploiting native mediterranean plant taxa (e.g., *Olea*, *Vitis*, and *Quercus suber*) or transforming natural coastal wetlands in saltworks, always determining deep landscape changes and depletion of the native biodiversity. This long-term environmental perspective indicates that the current coastal ecosystems of the central Mediterranean Basin represent an ephemeral snap-shot, destined to new, abrupt and dramatic future changes. Thus, palaeoenvironmental studies may prove of fundamental importance in estimating both the environmental instability typical of each geographical context and the degree of vulnerability of coastal ecosystems, so providing suggestions for appropriate conservation actions in coastal environments.

**P-1040**

## **Using historical sources as proxies to study estuarine flood risk: the cases of Tagus (Portugal) and Shannon (Ireland) estuaries**

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### **Abstract**

Estuarine margins are complex areas where multiple flood triggers interact such as tides, fluvial discharges and storm surge along with human presence. Additionally, the expected sea level rise and increasing storminess poses new challenges on how to manage properly for the future in a scenery of increased uncertainty. Therefore, historical information on past flood events can be of great value to better understand estuarine flooding and the related societal effects.

The use of historical sources to extract information on flood events has been widely used to improve the flood frequency estimation through the maximum level extraction, as well as to support the reconstruction of geomorphological evolution. Instruments as databases of flooding events (at local, regional, national and international levels) have been compiled with the aim of create a congregated knowledge and enable a better understanding of these events and related damages in order to support prevention and proper land use planning.

In this work we present and compare two estuarine flood damage databases built on written historical sources such as newspapers, reports, photographs and letters. The Tagus estuary database congregates 235 entries between 1865 e 2013. The database uses mostly daily newspapers with a wide and continuous temporal coverage, one geodatabase from the Portuguese National Protection Authority and photographs from Lisbon Port Authority, comprising a total of 106 historical sources. The Shannon estuary database congregates 230 entries and comprises the period between 1927 e 2013, although with gaps in the temporal coverage. It was built based on the diverse typology of documents extracted from the Irish Flood Hazard Mapping Website [<http://www.floodmaps.ie/>] property of The Office of Public Works (OPW). At total, 106 documents were analysed including reports, letters, photographs, newspapers and minute meetings.

To allow a comparison both databases have a similar structure, founded on four groups of information, namely: Basic information; Type of impacts; Flood characteristics and Triggering factors. The historical sources were analysed using content analysis techniques in order to maintain coherence in the information extraction and statistical techniques were applied to analyse the data gathered. The results highlight the differences and the similarities on what concerns flood damages and triggers between the two estuarine systems. The results also point out the different capacity of each source type to inform about the triggers and damages.

This work demonstrates the usefulness of historical sources as a proxy to better understand the complexity of flooding in estuarine systems, the applicability of databases as instruments to collate different typologies of sources and finally, it also highlights the vast amount of information that can be extracted from these types of sources and their utility for estuarine flood risk management.

**P-1041**

## **LGM-to-recent sedimentary and high-resolution acoustic facies of a transgressed alluvial plain (Gulf of Trieste, northern Adriatic)**

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### **Abstract**

Post-LGM sea-level rise significantly affected sedimentary environments on low-gradient continental shelves. One such case is the present-day northern Adriatic where the vast LGM alluvial plain was rapidly transgressed and transformed into a shallow marine environment. One of the last areas which were affected by the Holocene transgression in the Adriatic Sea is the Gulf of Trieste located in its northeasternmost part. This area is particularly suited for investigations of the Late Pleistocene-Holocene transition due to its exceptionally well-preserved terrestrial record and shallow depths facilitating sediment sampling.

We used the Innomar SES-2000 sub-bottom sonar to acquire profiles from which we determine different acoustic facies units using the IHS Markit Kingdom software. We correlated the acoustic facies with sediment samples obtained with the Uwitek gravity corer. We performed granulometric analysis of the sediment samples with the Fritsch Analysette XX Laser Particle Sizer and the Gradistat software. AMS radiocarbon dating was used for absolute dating of the samples.

The sampled alluvial sediments were deposited between the onset of the LGM and the Early Holocene. Overlying Early Holocene transgressive sediments are buried by Early Holocene to recent shallow marine deposits. Our work provides a correlation of the high-resolution acoustic facies with the sedimentary facies on transgressed alluvial plains. The oldest sampled alluvial unit are cross-stratified sandy muds of fluvio-aeolian origin which show an acoustic facies with low-amplitude chaotic reflection geometries. This unit is topped by graded deposits (sandy mud and sandy clay grading into clay) expressed in the geophysical record by sub-horizontal high-amplitude and high-frequency reflections. These deposits are overlain by overbank fine-grained sediments which are expressed as a transparent acoustic facies containing individual discontinuous middle-to-low amplitude reflections. Transgressive deposits are represented by bioclastic sandy mud containing brackish mollusk assemblages and show middle-to-low amplitude reflections with onlapping and concordant reflection geometries. Marine sediment is composed of bioclastic sandy mud and silt with shallow marine mollusk assemblages and has a transparent acoustic facies.

**P-1042**

## **Spatial variation of concentration and chemical fractionation of sedimentary phosphorus in Guanabara Bay, Rio de Janeiro - Brazil.**

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### **Abstract**

The Anthropocene consists in the most recent period of the quaternary and the history of the Planet. It is at this time, that human activities begin to have a significant global impact on the Earth's climate and the functioning of its ecosystems. In this way, surface sediments absorb concentrations and chemical forms of pollutants caused by anthropic activities. Among the coastal aquatic ecosystems, the estuaries constitute a depositional environments and potencial reservoirs of several contaminants associated with recent sediments (Kucuksezgin et al., 2006). The Guanabara Bay system, located in Rio de Janeiro city, received a huge amount of untreated sewage produced by human activities. The aim of this study were, evaluate the seasonal variations of physic-chemical parameters and characterize the phosphorus fractionation in Guanabara Bay sediments ( Gachter et al., 1998). In order to identify and quantify the different forms of phosphorus was used a SEDEX sequential extraction of 23 sediments samples. The total phosphorus (TP) in the sediments ranged between 1.4 and 80,2  $\mu\text{mol.g}^{-1}$  respectively. The highest concentrations of TP in this area are attributed to the input of untreated domestic sewage. P-Exchangeable showed a variation in ranged between minimum and maximum 0 and 6,5  $\mu\text{mol.g}^{-1}$ , respectively. Through the obtained data in this study it is possible to observe in most of the stations, the significant occurrence of the P exchangeable fraction, which may also be associated with eutrophication existing in the system. The P-Fe fraction ranged between 0,22 and 19  $\mu\text{mol.g}^{-1}$ . Phosphorus bound to metal has ranged between 0,70 and 6.40  $\mu\text{mol.g}^{-1}$ . The eutrophication determines reducing environmental conditions, which are determinant in the predominance of the P-Fe and P-Me chemical fractions preferably linked to the organic phase. The P-Ca ranges from 0,21 to 12  $\mu\text{mol.g}^{-1}$ . The intense degradation of the natural system releases the stable phosphorous phases to other P-exchangeable fractions, that characterizes contaminated aquatic systems (Harahan et al., 2005). The concentrations of residual phosphorous are unimpressive in both seasons with minimum and maximum values of 0.5 to 7  $\mu\text{mol.g}^{-1}$ .

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**P-1043**

## **Seasonal distribution of organic matter in vertical and horizontal profiles of sheltered and exposed beaches on Polish coast**

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### **Abstract**

Sea coast is an extraordinary area which joins the elements of sea and land environment. It is an important zone both from environmental as well as economical point of view. Unique characteristics of sea coast cause that it is popular amongst of tourists and patients for recreational and rest purposes. Sea coasts are simultaneously very sensitive for any changes, both natural and anthropogenic. Many studies and observations indicate consecutive degradation of polish coast. It is caused by increased level of the sea and well as intensity and frequency of storms. Very often they are also modified by humans in an uncontrolled way in order to fulfill an increased economic expectations of tourists. Therefore, an important problem is the cleanliness and attractiveness of the beaches.

Sandy sediments coming from three beaches of the southern Baltic Sea were collected and analyzed. Investigated beaches were divided according to strength of anthropogenic impact and degree of sheltering. The first beach was situated in Ustka on the eastern side of the mouth of the Słupia River, second in Czołpino and the last one in Puck. Core sediment samples were collected seasonally, depending on the influence of the sea water on the examined sediments. At each station, surface sediments (0-5 cm) were collected as well as sediments at the depth of 10-15 cm. The general content of organic matter, proteins, lipids, carbohydrates, organic carbon and total bacterial number were determined.

The results of the conducted tests reveal, that anthropopressure, degree of sheltering, the depth where the collected sediments were taken and the direct influence of the sea water on the sediments have impact on the chemical composition of organic matter and bacterial number in beach sediments. Determination of the labile form of organic matter in the entire organic matter was a way of assessing the variability of the unformatted fraction of organic carbon. This fraction can not be used as a source of food for organisms living in the beach sediments. It is negative because the introduction of excessive organic matter causes the exploitation of oxygen resources in a given ecosystem. As a consequence, indigenous organisms can be replaced by allochthonous organisms, and even poisoning of existing organisms can occur.

**P-1044**

## **The rise and fall of Los Buchillones: a Taino village on the north coast of central Cuba**

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### **Abstract**

Los Buchillones is a Taino village located on the north coast of central Cuba. Several dozen AMS dates indicate that it was occupied from approximately 1220 to 1640 CE. It is one of the largest and best preserved prehistoric settlements in the Caribbean, and consists of approximately 40 collapsed houses made of wood and palm thatch. This high level of preservation is due in part to the fact that the site is submerged under 1 m of water, partly in a lagoon. Geoarchaeological investigations in the late 1990s suggested that Los Buchillones was built over water and that the prehistoric houses that are preserved at the site were constructed on piles. More recent archaeological investigations focusing on house architecture also supported the idea of pile dwellings, possibly as a strategy to cope with sea level rise, coastal erosion, and episodic storm surges. Recent paleoenvironmental investigations in the region provide important new data with which to understand the evolution of Los Buchillones. Preliminary sedimentological findings from a nearby sinkhole show that a severe drought occurred just prior to the beginning of occupation of the settlement, whereas drying associated with the Little Ice Age roughly coincided with the abandonment of the site. This would suggest possible close climatic control on settlement occupation, possibly through its impact on marine resources and agriculture. In addition, paleotempestological data from the Bahamas shows that the period from 1220 to 1640 CE represented a time of relatively active hurricane activity, which may partly explain the presence of a stilt village. The archaeological and paleoenvironmental data that have emerged from this region of Cuba permit hypotheses concerning vulnerability and resilience in coastal zones to be tested in a prehistoric context.

**P-1045**

## **Records of environmental change and sedimentation processes over the last century in a Baltic coastal inlet**

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### **Abstract**

The marine ecosystem in the Baltic Sea is affected by multiple stress factors, such as eutrophication and deoxygenation, overfishing and heavy metal pollution. Human-induced environmental changes may occur during a range of timescales and marine organisms must adapt to the new conditions, or they will be locally extinct. This project aims to reconstruct one Baltic coastal environment, SE Sweden, which has experienced an increasing human impact over the last century and identify trends of both human-induced pollution and large-scale environmental changes. The study area is affected by eutrophication due to nutrient load from surrounding farmlands and large-scale nutrient inputs. The inlet is deoxygenated due to organic substances in suspension and slow water exchange.

Four undisturbed laminated sediment cores were collected in the inner and outer part of the coastal inlet, dated using <sup>210</sup>Pb and <sup>137</sup>Cs. We are using grain-size analysis, organic carbon and nitrogen content, biogenic silica and elemental analysis to reconstruct the coastal environment over the last 100 years.

The results from our analysis of these four cores of near-coast sediments will contribute to increased understanding of past environmental changes and sedimentation processes in near-coast sediments of the Baltic Sea.

P-1046

## Holocene shoreline displacement and Stone Age palaeogeography of the Pärnu Bay area, eastern Baltic Sea

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### Abstract

The shore displacement and palaeogeography of the Pärnu Bay area, eastern Baltic Sea, during the Stone Age, were reconstructed using dated sedimentological and archaeological proxies and GIS-based landscape modelling. We discovered and studied buried palaeovalley sediments on the coastal lowland and in shallow offshore of the Pärnu Bay and interpreted these data together with previously published shore displacement evidence. The reconstructed shore displacement curve is based on 82 previously published and 7 new radiocarbon dates from sediment sequences and archaeological sites. The new shore displacement curve displays regressive water levels at -5.5 m and -4 m a.s.l before the Ancylus Lake and Litorina Sea transgressions, respectively. The total water level rise during the Ancylus Lake transgression (10.7–10.2 cal. ka BP) was around 17.5 m, with the average rate of rise about 35 mm per annum, whilst during the Litorina Sea transgression (8.5–7.3 cal. ka BP) the water level rose around 14 m, with average rate about 12 mm per annum. The relative sea level increase rates around 7.8–7.6 cal. ka BP clearly exceeds the concurrent rate of the eustatic sea level rise similarly to slowly uplifting areas in Samsø (Denmark), Blekinge (Sweden) and Narva-Luga (NE Estonia-NW Russia). The palaeogeographic reconstructions show the settlement patterns of the coastal landscape since the Mesolithic and provides new perspective for looking hunter-fisher-gatherer settlement sites on the shores of the ca. 9000 years old submerged river valley in the bottom of the present-day Pärnu Bay.

P-1047

## Reconstructing Estuarine Palaeo-Environments using 3D Ground Penetrating Radar Imaging

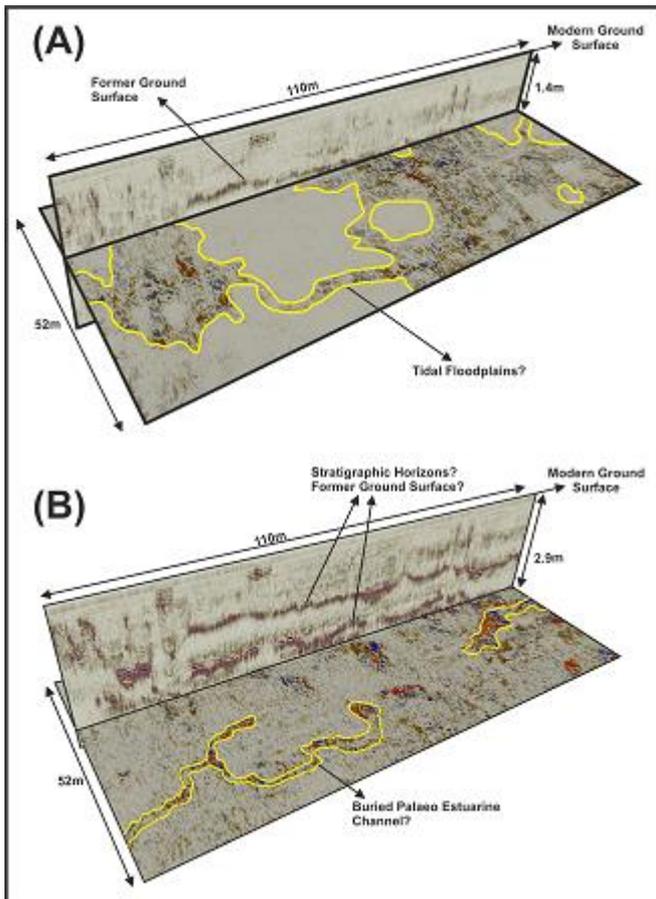
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### Abstract

During the last two decades, geophysical method, specifically Ground-Penetrating Radar (GPR) have grown in popularity for acquiring high-resolution images of the buried stratigraphy, internal structure and wider context of geomorphological landscapes. GPR provides a practical complement to established methods, including in-field mapping of exposures and sediment core-logging which typically provide sparse 2D insight into subsurface architecture and morphology. In geomorphological settings, GPR surveys typically complement core sampling by linking borehole data along 2D transects but cannot reveal full subsurface morphology. More comprehensive GPR surveys offer rapid, non-invasive 3D characterisation of the shallow sub-surface (~10 m maximum depth), with data interpretable in terms of the thickness, lithology, structure and extent of subsurface depositional environments (e.g. coastal, fluvial and alluvial deposits).

The wider uptake of 3D GPR is enabled by recent advances in GPR systems technology – the development of robust equipment and GPS-coupled antennas being particularly advantageous. 3D methodologies and their dedicated processing algorithms are now commonplace within the engineering and archaeological sectors, and are able to reveal the full structure of complex targets. Equivalent advantages can now be realised for geomorphological characterisation, for assessing the true size and extent of buried coastal landscapes.

This poster highlights the potential of 3D GPR methodologies using a 500 MHz GPR dataset collected over a buried Holocene estuarine environment in Llanbedr, Gwyendd, North Wales, which has since been reclaimed for use as an airport. The complexity of the buried estuarine structures, including small, meandering, salt-marsh channels, motivates a 3D GPR survey, given that i) the channel geometry is too complex to appreciate from individual 2D transects and ii) their narrow size suggests they could easily be missed in a core logging programme. When viewed in a top-down “depth-slice” view, the 3D architecture of the subsurface is easily appraised, and can furthermore be interpreted as a palaeo-record of the evolution of the site. The deepest palaeo channels (2.9 m depth) are small and sparsely distributed (*Fig. 1a*), but are both more densely spaced and complex at shallower depth (1.4 m) (*Fig. 1b*). When combined with regional models of sea-level change and associated sedimentation, these data provide a valuable model for the evolution of Holocene estuarine environments and present-day analogues.



**Figure 1:** (A) 3D depth slice at 1.4m of the more densely spaced and complex palaeo estuarine channels. (B) 3D depth slice at 2.4m of the small and sparsely distributed palaeo estuarine channels.

**P-1048**

## **Woodlands under the waves: Orcadian landscape change from the Mesolithic to Bronze Age**

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### **Abstract**

Coastal landscapes are vulnerable to both gradual and sudden, dramatic environmental change through the mechanisms of sea-level rise and extreme events such as storm surges and sand blow events. Coastal environments are also critical for resources, communication and living space, and arguably were even more important in prehistory. Here we present the results of a holistic investigation of coastal landscape change in Orkney over a 7000 year period, from the Mesolithic to Bronze Age; achieved by analysing a section of landscape incorporating dryland, intertidal and marine zones.

Offshore geophysical survey has provided information on seafloor sediments and inundated land surfaces; pollen, diatom, waterlogged plant remains, insect and sediment DNA analyses of radiocarbon dated sediment cores recovered from intertidal peats and freshwater lakes have enabled reconstruction of rising sea-levels, climate, and terrestrial landscape change including woodland decline and the introduction of agriculture. This study provides valuable contextual information for the periods before, during and after the use of the monuments making up the Heart of Neolithic Orkney World Heritage site, including the ongoing excavations at the Ness of Brodgar.

Pollen results show extensive woodland cover during the Mesolithic and into the Early Neolithic (c.7500-3800BC) that included pine, birch, hazel and to a lesser extent oak and alder. Submerged forest identified as largely willow with some birch has offered a glimpse into the character of wet woodland, dated to c. 4800-3350BC, with high levels of microscopic charcoal, including fragments of reed stomata and grasses provide evidence for wetland burning. While the discovery of a radially-split oak timber within the intertidal peat, (felling date of c.4200BC) demonstrates Later Mesolithic communities were not only present but manipulating the environment.

Woodland cover reduces significantly from c.4300-3800BC with evidence for agriculture beginning after this time; corresponding with the start of the Neolithic in Orkney. This landscape change occurs against a backdrop of sea-level rise, which in the intertidal zone led to the demise of carr-woodland and development of freshwater pools. Despite such extreme landscape change the occurrence of agriculture-related pollen and probable woodland clearance demonstrates that rather than abandoning these areas Neolithic people were actively modifying and monumentalising their landscape (e.g. the start of pier-architecture building at the Ness of Brodgar has been dated



to c.3000BC). A further extreme event (storm surge) is indicated by marine clays incorporated in intertidal peat between c.1600-1400BC. Pollen evidence suggests agricultural activity resumes immediately following this event showing continued resilience by Orcadian communities.

The results of this work have contributed significantly to our understanding of not only how this area of Orkney changed in prehistory as a response to wider environmental change but also more broadly as to how people adapted and reacted in the face of dramatic landscape change.

**P-1049**

## **Searching for fingerprints of early 20<sup>th</sup> century ice melt in Australian salt marshes**

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### **Abstract**

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Sea-level rise during the 20<sup>th</sup> century was faster than during any other century in the last 3000 years. Proxy evidence from salt marshes suggests that the magnitude of the sea-level acceleration from the 19<sup>th</sup> into the 20<sup>th</sup> century was greater in the Southern Hemisphere in comparison to the Northern. The cause of this sea-level acceleration remains unknown. Anthropogenic forcing was still weak; therefore, the rise must have been driven by natural processes. One potential source may have been melting of Arctic glaciers and the Greenland ice sheet (GrIS) during the Arctic Warm Period of the 1920s and 1930s. This melt produced a sea-level 'fingerprint', including high relative sea-level rise in far-field areas like South Africa, South America and the Pacific. In this study, we search for the fingerprint of ice melt in the salt marshes of southeastern Australia to test the hypothesis that Arctic and Greenland ice melt was responsible for the rapid rise in sea level in the early 20<sup>th</sup> century. Using microfossils, specifically benthic foraminifera preserved in sediment cores, changes in sea level will be reconstructed over the last ca. 500 years at cm-scale resolution at three sites in southeastern Australia including Bruny Island (Tasmania), Tarra River (Victoria) and Wapengo Lake (New South Wales). Core chronology will be established via a variety of dating tools including ITRAX-XRF, stable lead isotopes ( $^{206}\text{Pb}/^{207}\text{Pb}$ ,  $^{206}\text{Pb}/^{208}\text{Pb}$ ), radionuclides ( $^{137}\text{Cs}$  and  $^{210}\text{Pb}$ ), and AMS-bomb spike  $^{14}\text{C}$ . Reconstructions will be compared to the sea-level fingerprint of historical changes in Arctic ice mass.

**P-1050**

## **Reconstruction of post-glacial sea level fluctuations in the Baltic Sea: an integrated approach**

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### **Abstract**

There were many attempts to reconstruct the Baltic Sea water level changes by different investigators. As a result, several dozens of relative sea level (RSL) curves have been published; most of them are controversial to each other. Besides, a few others unsolved topics linked with the Baltic Sea development are still under discussion. The reason of such variety and incompatibility of RSL curves is that different authors were guided by different set of factual data, used different ways of data interpretation, etc. But the main problem is that separate parts of the Baltic Sea experience (or experienced before) different influence of glacioisostatic rebound: the absence of stable rafter ("zero" point) is the main obstacle for reliable reconstruction of sea level fluctuations starting from the Late Glacial until the present days.

The Lithuanian coast is the transit zone between the northern part of the Baltic Sea (that is still experiencing the glacioisostatic uplift), and the Southern Baltic (that is recently subsiding). Thus, it is the Lithuanian coast that could be the best "rafter" for the estimation of sea level fluctuations. The recent underwater archaeological investigations carried out by researches of Klaipėda University (V. Žulkus, A. Girininkas, etc.) show that large submerged landscapes with survived remnants of tree trunks and stumps, also sediments of relict lakes and bogs, are spread on the Lithuanian offshore. It serves as a good sea level indicator starting from the Yoldia Sea stage. A new reconstruction of sea level fluctuations at the Lithuanian coast is based on two principal moments: (1) strong selection of reliably dated objects indicating sea level position (key-indicators), and (2) an estimation of glacioisostatic rebound trend and amplitudes in the coastal zone. The rating of the latter factor allows to speak not only about RSL fluctuations, but also about eustatic sea level changes in the Baltic basin.

It is possible to conclude that the salinity of the different Baltic Sea basins (freshwater or brackish) and transitional situation between them (transgression or regression) depend on three main factors: (1) rate of the eustatic water level rise in the World Ocean (i.e. in the North Sea in our case), (2) water level in the Baltic Sea basin related to melting of the Scandinavian Ice Sheet and inflow of rivers, and (3) rate of glacioisostatic rebound in the Southern Sweden and in the region of the Danish Straits. The glacioisostatic model and eustatic curve of sea level fluctuations at the Lithuanian coastal zone, as well as integrated model of the Southern Baltic development during the entire post-glacial period are presented in the graphic form.

**P-1051**

## **Investigating the influence of the deglaciation of the Southern Alps icefield on Holocene sea-level change, South Island, New Zealand**

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### **Abstract**

During the Last Glacial Maximum (LGM) New Zealand's Southern Alps were covered by the Southern Alps icefield, a 800-km long mountain icefield spanning ~5° latitude, feeding outlet glaciers extending 70-100 km onto the adjacent forelands, sometimes to sea level. Large-scale glacial retreat commenced c. 17,000 years BP; today, only mountain glaciers remain. Glacial isostatic rebound of the Southern Alps has previously been hypothesised but has not been substantively investigated. This ongoing project aims to identify the potential effects of glacial isostatic adjustment (GIA) – particularly in response to retreat of the Southern Alps icefield – on Holocene sea-level (SL) changes around the coast of the South Island.

There are two ongoing avenues to this investigation. Firstly, production of a high resolution time-series of the deglaciation of the Southern Alps icefield from c.17,000 years BP to c. 6,000 years BP (when the minimum extent of the icefield was reached). This will be achieved by scaling an existing model of the extent of the Southern Alps icefield during the LGM (Golledge et al., 2012, QSR 46) using reconstructions of temperature and equilibrium line altitude. This local ice history will be merged with components of the global ice history to correctly model the GIA process. The global ice history will influence SL change around the South Island, but variability in our study area is likely to reflect melt of the Southern Alps icefield.

Secondly, production of new records of Holocene SL changes for key tectonically-stable regions around the South Island: Nelson-Tasman Bay; Otago; and Southland. Existing Holocene SL reconstructions from Otago show a misfit with current GIA model predictions (which do not consider the effect of deglaciation across the Southern Alps), and continuous GPS measurements from the region indicate subsidence. We hypothesise that these observations reflect regional subsidence associated with the collapse of a glacial forebulge throughout much of the Holocene. The new SL reconstructions – obtained over the Southern Hemisphere summer 2018-2019 field season – will be used to validate model predictions of South Island Holocene SL change derived using the approach described in the first part of this study.

**P-1052**

## **Sea-level rise in the Bristol Channel during the mid-late Holocene: new evidence from the Taw Estuary, southwest Britain.**

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### **Abstract**

This paper presents a new sea-level history for the Taw Estuary in southwest Britain. For the sea-level reconstruction, modern diatom samples were collected from two transects located across the intertidal marshes of the Taw Estuary, producing a local training set that related diatom species distribution to elevation in the tidal frame. A diatom-based transfer function was then developed and subsequently used to quantitatively reconstruct Holocene sea-level changes in two dated sediment cores, taken from the inner Taw Estuary. The transfer function model (WAPLS) indicates precise and accurate reconstructions are possible with an error estimate of  $\pm 0.18$  m, which is comparable to other diatom-based transfer functions.

11 sea-level index points (SLIP's) resulted from the reconstructions, producing a new mid-late Holocene sea-level record for south-west Britain, spanning the last -6,700 years. Importantly the new record includes 4 SLIP's from the last -2,300 years, a period where there is a paucity of SLIP's in this region, due to predominantly minerogenic deposition. The results show a history of steady sea-level rise from 6,700 cal. yr. BP to 2,300 cal. yr. BP. This is followed by a marked slow-down in sea-level rise and a subsequent highstand (close to modern elevation) that lasted from approx. 2,200 cal. yr. BP to 1,200 cal. yr. BP. The record then indicates a possible downward oscillation in sea level of c.0.5 m, followed by a rise of c.1.0 m since 800 cal. yr. BP. The reconstructed sea-level history is compared to the latest glacial isostatic adjustment models for the region, indicating some agreement.

One of the notable results of this reconstruction is the indication of a possible late Holocene sea-level highstand during the first millennia AD. This has not been shown in other reconstructions for the region (possibly due to a lack of SLIP's), but evidence for a Romano-British transgression and subsequent sea-level highstand has been indicated in the archaeological and historic record. Significantly, a separate comprehensive stratigraphic and palaeoecological investigation of the River Taw estuary and valley, that extends upstream of the current tidal limit, has revealed conclusive evidence of a major marine incursion that took place during the first half of the first millennia AD (the "Romano-British" period). Major valley incision took place at this time, followed by widespread deposition of shelly estuarine sands and silts upstream of the modern deposition of this facies. Fossil diatom assemblages from marsh sediments dated to the early centuries of the first millennia AD also contain significant numbers of brackish-marine mesohalobous and polyhalobous species upstream of their modern-day occurrence. In conclusion, this new evidence all points to a prolonged marine incursion into the estuaries of southwest Britain during the first millennia AD.

**P-1053**

## **Inception of the World Atlas of Last Interglacial Shorelines (WALIS) – advancing knowledge of sea level changes in past warmer worlds.**

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### **Abstract**

In the last century, nearly 1000 scientific papers have described the elevation, age or stratigraphic details of last interglacial shorelines (ca. 125 ka). This has resulted in thousands of sites reported globally, but with varying degrees of detail and scarce standardization between different datasets. In order to disentangle eustatic, isostatic, and other processes causing relative sea level changes in the Last Interglacial, the paleo sea level community is in need of a reliable global database of last interglacial sea-level proxies. Here, we present two tools designed to facilitate the compilation of the World Atlas of Last Interglacial Shorelines (WALIS). The first is a relational MySQL database, complete with a user-friendly interface of more than 100 different fields that allows the insertion of sea level data and metadata inclusive of sea level stratigraphy and multiple methods of radiometric age constraint. The second is a Wiki website designed to host the last interglacial sea-level information derived from the database and subdivided by national boundaries. The WALIS database and Wiki are being developed in the framework of the WARMCOASTS ERC Starting Grant, and will be improved and maintained in close collaboration with the PALSEA community (PAGES-INQUA).

P-1055

## Improving mangrove radiocarbon chronologies for reconstructing late Holocene sea-level changes

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### Abstract

Mangrove sediments are an important archive of past sea-level changes in relatively under-sampled, low-latitude locations. These locations are important because they are far from the former and present polar ice sheets, and therefore records of sea-level changes are less dominated by glacial isostatic adjustment signatures. However, the utility of mangrove sediment is currently limited due to problems with poor fossil preservation and the difficulty of establishing accurate and precise radiocarbon chronologies. Mangrove-based sea-level reconstructions depend upon radiocarbon chronologies but obtaining samples which faithfully record down-core ages can be problematic due to bioturbation by roots and crabs, and potential inputs from many carbon sources that do not reflect deposition age. To confidently interpret mangrove sea-level records, we need a better understanding of how to obtain accurate age estimates for mangrove sediments. In settings with slow sedimentation rates during the late Holocene, this means being able to create high resolution chronologies based on closely spaced radiocarbon dates in short cores (often less than one metre long).

Here, we address the question of which components of the fossil mangrove record are most reliable for radiocarbon dating. Many mangrove sea-level studies have reported problems with out-of-sequence ages when bulk sediment samples are used for measurement. Additionally, mangrove roots can penetrate as much as two metres into underlying sedimentary sequences, and therefore ages from large root material will not be the same as *in situ* material from an equivalent stratigraphic depth. Similarly, fine roots which branch off from the main larger roots at depth also introduce younger carbon into the sedimentary sequence, but decompose more rapidly than larger roots. Where identifiable and present, above ground macrofossils (e.g. leaves, seeds) can provide the most accurate ages. Such macrofossils are short-lived, discrete plant material that represent up to 18 months mangrove tree growth, or a single flowering season, which overcomes the problem of inbuilt carbon ages. Previous work has targeted a specific organic concentrate size fraction (10-63  $\mu\text{m}$ ) in Holocene mangrove cores from Tanzania.

Here we compare radiocarbon dates derived from bulk sediments, organic concentrates (size fraction 10-63  $\mu\text{m}$ ), pollen concentrates and surface macrofossils (leaves and seeds), from short cores (<1 m) collected in Seychelles mangroves. We aim to identify which organic components provide the most accurate ages for short sequences of late Holocene mangrove sediments. These results will inform future mangrove dating strategies and allow more accurate and precise sea-level reconstructions.

P-1056

## Pre-industrial Sea-level Rise Hotspots in the Northwest Atlantic Ocean

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### Abstract

The Northwest Atlantic is a region where hotspots of sea-level rise in the instrumental record have been linked to observed ocean-atmosphere climate variability. Here we test if these hotspots are present in pre-industrial sea-level records by reconstructing sea-level changes from three sites in the Northwest Atlantic (Nova Scotia, Maine, Connecticut) using foraminifera preserved in salt-marsh sediments as proxy indicators. We use training sets comprising contemporary foraminifera to develop transfer functions for sea-level reconstructions. The transfer functions quantify the vertical relationship between elevation and micro-biota and allow sea level to be expressed as a function of the microfossil assemblages preserved in sediments in cores. We collected the cores from the highest marsh zones, close to the upper limit of present tidal inundation and away from tidal creeks. We assess statistically the fit between modern and fossil foraminiferal datasets using the Modern Analogue Technique. We use a variety of dating methods, including AMS<sup>14</sup>C, <sup>210</sup>Pb, <sup>137</sup>Cs, <sup>206</sup>Pb/<sup>207</sup>Pb, pollen markers and trace metal markers to develop robust chronologies for our records. We apply a Gaussian process regression approach that models relative sea-level (RSL) at each site by taking the corresponding vertical and chronological uncertainties into account, and therefore provides probabilistic estimates of past rate changes. We test the assumption that sediment compaction errors are insignificant in our sites by comparing our reconstructed sea levels with sea-level data reconstructed from basal sediments that are unaffected by the effects of compaction.

In all three sites the 20<sup>th</sup> century rates are unambiguously high compared to rates in preceding centuries. However, we also document evidence for sea-level rise in the late 18<sup>th</sup> century that was only slightly slower than rates in the 20<sup>th</sup> century. To our knowledge this represents the first clear proxy evidence for episodes of pre-industrial rapid sea-level rise along the North American East Coast in, broadly, the same region where sea-level rise hotspots have been documented in 20<sup>th</sup> century tide-gauge records. A comparison with other North Atlantic salt-marsh records reveals that centennial periods of sea-level acceleration along the US east coast coincide with periods of deceleration in Iceland and vice versa. This anti-phase relationship correlates significantly with centennial swings in the North Atlantic Oscillation and is physically linked to changes in the prevailing wind and pressure conditions along the two coasts. We conclude that sea-level rise hotspots are a persistent feature along the North American East Coast and not unique to the 20<sup>th</sup> century. Predictions of future sea-level rise for New York City, Boston and other population centres in New England and Atlantic Canada should account for fluctuating rates of background natural sea-level rise.

P-1057

## Reconstructing holocene sea levels using rock-encrusting oysters: case examples from peninsular Malaysia

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### Abstract

We present a standardized methodology for using rock-encrusting oysters (REO) to reconstruct relative sea level (RSL) during the Holocene. REO are important sea-level indicators in tropical and subtropical areas where Holocene RSL was higher than present. Reconstruction of former sea-level is based on the altitudinal relationships between living and fossil REO at the same locality. We surveyed REO of *Saccostrea cucullata* from two Peninsular Malaysia field areas (Langkawi islands and NE Peninsular Malaysia) with differing glacial isostatic adjustment (GIA) histories. Living *S. cucullata* are confined to the intertidal zone between mean low water spring tide (MLWST) and mean high water spring tide (MHWST). We therefore are able for the first time to formally define the reference water level of *S. cucullata* as the mid-point of MHWST and MLWST and the indicative range as the altitudinal difference between MHWST and MLWST, which is ca. 1 m and 0.5 m for Langkawi and NE Peninsular Malaysia, respectively. The elevation of *S. cucullata* above their living counterparts represents the change in RSL between now and the time the fossil REO lived. We determine the chronology by radiocarbon dating the fossil *S. cucullata* and subsequently calibrate using marine reservoir effects of  $-121 \pm 60$  and  $-15 \pm 38$  for Langkawi and NE Peninsular Malaysia, respectively.

We reconstruct RSL at Langkawi and NE Peninsular Malaysia using 20 sea-level index points and radiocarbon dates for the fossil oysters. We compare these index points with site-specific RSL predictions based on GIA model ICE-7G\_NA (VM7). Our index points from both study areas indicate highstand-to-falling-stage RSL from mid-Holocene onward. The consistency supports the reliability of our method, and provides constraints on the performance of our GIA model. Thus, we are confident that this standardized methodology is effective for reconstructing RSL over millennial time scales with 0.5 to 1 m precision in tropical and subtropical areas where Holocene RSL was higher than present.

P-1058

## Reconstruction of Holocene environmental changes and neotectonic events in the North-Western Pacific

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### Abstract

Kurile-Kamchatka and Aleutian island-arc systems are located along a zone of intense seismic and volcanic activity in the northwestern Pacific (NWP). Neotectonic vertical movements and the superposed effects of climate-controlled sea-level changes play a decisive role in the evolution of the coastal sectors of this region. To highlight similarities and differences in the paleoenvironmental history of the southern Kuriles we analyzed sediment records from Shikotan Island and compared our results with the available information from the adjacent areas in the NWP.

7.9-6.4 cal ka BP. This period corresponds to the warm and dry Holocene Climate Optimum (HCO), which had a coeval impact on the neighbouring Kurile, Kamchatka and Japanese islands. During the Holocene transgression the sea-level rose up to 3 m above PSL.

6.4-5.8 cal ka BP. During this interval a trend toward wetter and cooler conditions occurred. The lower sea level corresponds to the end of the Holocene transgression.

5.8-5.0 cal ka BP. Neoglacial cooling coincided with the most significant Middle to Late Holocene (Jomon) regression when sea level was 4–5 m below PSL. Landslides at this time could have been caused by the higher precipitation and/or strong earthquakes.

5.0 – 3.5 cal ka BP. An onset of a low-amplitude Late Holocene transgression. The higher sea level corresponded to the Late Jomon transgression, with an amplitude of approximately 1.2–2.5 m above PSL. The presence of tsunamigenic sands corresponded to strong paleo-earthquakes around ca 4.43 and 3.89 cal ka BP.

3.5 – 2.0 cal ka BP. Cool climate. Tephra deposition (2.5 cal ka BP, Tarumai Volcano, Hokkaido) altered the lake chemistry. Two sand layers may correspond to small tsunamis preceding the eruption.

2.0 – 1.07 cal ka BP. Cool conditions and slight regression that were also identified on Kunashir Island and in Central Kuriles corresponded the beginning of the Kofun cold stage of Japan. Fragments of *Coscinodiscus sp.* in a sand layer at 2.0 cal ka BP indicated a tsunami event.

1.07 – 0.4 cal ka BP. Gradual climate warming and transitions to a MWP in this interval could be correlated with a Nara-Heian-Kamakura warm stage. The impact of the MWP was not prominent on the Bering Islands, Central Kamchatka, and Central Kurile islands apart from the Semushir.



After 0.4 cal ka BP. The deposits of this interval were formed during the LIA, which was distinctly pronounced across Kuriles, on Japanese islands, and in Kamchatka. Fragments of oceanic diatoms indicate several tsunami events.

In summary, the general chronology of major Holocene climatic events in the southern Kuriles is in accordance with the climate records from the NWP region. The recognized spatial differences in timing and magnitude of the Late Holocene climatic episodes (LIA, MWP) in the study region needs further investigations.

**P-1059**

## **Glacial Isostatic Adjustment of the British Isles and North West Europe.**

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### **Abstract**

The British and Irish Ice sheet (BIIS) was one of the smaller marine-based ice sheets that grew during the Last Glacial cycle, but it is by far the world's best empirically constrained with the completion of the BRITICE-CHRONO project. Despite its small size (contributing less than 2m to global sea level rise), the ongoing glacial-isostatic-adjustment- (GIA) driven crustal motion plays an important role in controlling rates of sea-level-rise across the North-West Coast of Europe. Unravelling this complex GIA signal is important not only for ongoing and future sea level projections, but also in understanding marine-based ice sheet dynamics.

The pattern of relative sea level (RSL) and GIA across this region is spatially variable and highly non-monotonic. This is due to the temporally varying interplay between the regional GIA signal, driven by the BIIS and the global signal which was driven by the deglaciation of the larger global ice sheets, such as Antarctica and Laurentide. Although many previous GIA modelling studies were relatively successful in capturing the broad pattern of regional RSL change, there are some major unresolved discrepancies and factors that were not considered, which this study will address. Firstly, the models were not able to capture both the elevated RSL during the Late Devensian and the timing and magnitude of the Holocene highstand. Secondly, new evidence shows that the BIIS is more dynamic and spatially extensive than previously thought. Finally, the deglaciation of the grounded ice sheet from the offshore continental shelf and resultant RSL was largely overlooked in previous studies, due to a lack of observational data.

In this study, we utilise the recently updated regional sea-level database, which contains over 2100 data points, recording relative sea level (RSL) from 86 unique regions in Great Britain (GB) and Ireland for the last 20 kyr. We will present an ensemble of simulations of the BIIS and Scandinavian ice sheet (SIS), constrained by the new geomorphological and geochronological data collated by the BRITICE-CHRONO consortium and the DATED -1 project, combined with different global GIA models. By comparing the predicted RSL with the updated sea-level database, we will outline the interplay between the regional (BIIS and SIS) and global ice sheets (Laurentide and Antarctica) in driving the pattern of RSL in GB and Ireland over the last 20 ka.

**P-1060**

## **Reconnaissance of Early-Middle Pleistocene Bridgewater Formation and implications for long-term landscape development of the northern Coorong Coastal Plain, South Australia**

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### **Abstract**

Located on the southern margin of Australia, the Coorong Coastal Plain retains one of the longest terrestrial records of Quaternary sea-level highstands recognized in the Bridgewater Formation carbonate aeolianites and associated lagoonal sediments. Quaternary uplift in the southern coastal plain has allowed the discernment of barriers of different ages through the generation of physical space resulting in the identification of thirteen 'dune ranges'. Additional ranges farther inland extend the record through the Middle Pleistocene Transition and into the Early Pleistocene. The northern coastal plain record is less well defined due to decreasing rates of uplift northward and eventually subsidence in the Murray Lakes region. However, this region remains important due to the presence of the River Murray, the largest exhoreic river of Australia, and for improving our understanding of the Quaternary development of the landscape. Investigation of the Bridgewater Formation in the northern part of the coastal plain has allowed the identification of Early and Middle Pleistocene beach barriers and assisted in the identification of multiple drivers of regional landscape evolution.

Other than the potential for paleomagnetic analysis, the ranges are beyond the current capabilities of other geochronological methods. The tentative ages were determined through correlation with the marine isotope record and their counterparts in the south using geographic and morphostratigraphic interpretations assisted by topographic transects derived from SRTM data. The deposition of the Bridgewater Formation in the northern coastal plain, and therefore, to some extent, the position and orientation of successive coastlines has been influenced since the Early Pleistocene by the Padthaway Ridge, a Late Cambrian-Ordovician basement feature. Ranges deposited upon and landward of the Padthaway Ridge have typically formed composite structures and form topographic highs in the landscape. The composite nature of these features may also be in part due to shorter cycles of sea-level change prior to establishment of eccentricity-dominated cyclicity. Preservation of these ranges indicates the River Murray has always discharged to the west, supporting not only the premise of long-term subsidence of the Murray Lakes region, but also suggesting dominant longshore drift northwest along the coastline during sea-level highstands throughout much of the Pleistocene. Ranges deposited seaward of the Padthaway Ridge have subsided and have been susceptible to erosion by the River Murray and sea-level transgressions and highstands. In summary, in addition to eustatic sea-level fluctuations, the distribution and preservation of the Pleistocene Bridgewater Formation within the Coorong Coastal Plain has been influenced by the presence of the Padthaway Ridge basement structure, differential rates of uplift experienced across and along the Coorong Coastal Plain, a dominant northwest direction of longshore drift during sea-level highstands, and susceptibility to erosion by the River Murray.

**P-1061**

## **Inception of a global atlas of Holocene sea levels**

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### **Abstract**

Determining the rates, mechanisms and geographic variability of sea-level change is a priority science question for the next decade of ocean research. The HOlocene SEA-level variability (HOLSEA) working group is developing the first standardized global synthesis of Holocene relative sea-level that incorporates full consideration of vertical and temporal uncertainty for each sea-level index point, including uncertainties associated with the relationship of each indicator to past sea level and the methods used to date each indicator. HOLSEA aims to: (1) estimate the magnitudes and rates of global mean sea-level change during the Holocene; and (2) identify trends in spatial variability and decipher the processes responsible for geographic differences in relative sea-level change.

The global atlas includes over 12,000 sea-level index points and limiting data from a range of different indicators across seven continents from the Last Glacial Maximum to present. The global atlas will be made available in a special issue of Quaternary Science Reviews and archived on NOAA's National Centers for Environmental Information (NCEI). The global atlas now includes sea-level data from:

1. Near-field regions (Atlantic Canada, Greenland, the British Isles, the Russian Arctic, Antarctica);
2. Intermediate-field regions (Pacific, Gulf, Atlantic and Caribbean coasts of North America, western Europe, the Mediterranean, New Zealand);
3. Far-field regions (Atlantic South America, South Africa, India, Sri Lanka, the Maldives, Southeast Asia, China, Australia)

Here we combine near-, intermediate-, and far-field data along a pole-to-pole transect (Greenland, North American Atlantic coast, Caribbean, South American Atlantic coast and Antarctica) to illustrate the advantages of applying a spatio-temporal empirical hierarchical statistical model to describe the spatial variability in relative sea level and its rates of change. By comparing these records across a transect that spans a range of 'fingerprints' from land-based ice sheets, we have the potential to isolate ice-sheet contributions to Holocene RSL changes.

P-1062

## Early to mid-Holocene relative sea-level changes in the Ningbo Plain, southern Yangtze River Delta, Eastern China

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### Abstract

Holocene relative sea-level (RSL) records from far-field locations provide important constraints on the timing of the deglaciation of the large northern hemisphere ice sheets and on the viscosity profile used in Glacial Isostatic Adjustment (GIA) model predictions. Here, we reconstruct RSL changes during the early to mid-Holocene in the Ningbo Plain, southern Yangtze River Delta (YRD), eastern China. Previously published RSL curves for the YRD were hampered by dating and vertical constraint uncertainties. Using 25 newly obtained boreholes, we provide a detailed RSL record using new radiocarbon ages coupled with multi-proxy lithological and sedimentary evidence that constrains the timing and position of past RSL. Furthermore, we applied an Errors-In-Variables Integrated Gaussian Process (EIV-IGP) model to assess magnitudes and rates of RSL change and compare the RSL reconstruction with GIA model predictions.

Our reconstruction provides 38 new sea-level index points and 5 limiting data points. During the early Holocene, RSL rose from  $\sim -34$  m at  $\sim 10$  ka BP to  $\sim -3$  m at 7 ka BP. The millennial-scale rate of RSL rise decreased during the early Holocene from 13.6 mm/yr (10 – 9 ka) to 10.9 mm/yr (9 – 8 ka) to 3.6 mm/yr (8 – 7 ka). During the mid-Holocene, RSL rose to  $\sim -1$  m at 5.5 ka BP at a rate of 1 mm/yr (6 – 5 ka). Comparison of GIA predictions with the new data show GIA is the main driving force of Holocene RSL change in southern Yangtze. However, obvious misfits exist in comparison to different GIA models. Our results demonstrate the need for new high-quality far-field RSL data to tune the next generation of GIA models.

P-1063

## A limpet's-eye view of post-glacial isostasy

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### Abstract

The altitude of intertidal marine platforms is determined by a combination of intrinsic and extrinsic factors of which mean sea level is just one. Hence it can be difficult to accurately determine relative sea level during formation of so-called 'raised beaches'. Many Sea Level Index Point (SLIPs) rely for dating on supratidal or subtidal organic material (terrestrial vegetation or marine shells) whose exact relationship to mean sea level is imprecise, and so it can also be difficult to establish an accurate chronology.

The '25 Foot Raised Beach' in Northern Ireland is a distinctive erosional feature formed during a brief period when Holocene eustasy and isostasy were rising at the same rate. The date and relative elevation of this 'mid-Holocene highstand' has been established as part of a broader Relative Sea Level (RSL) curve using conventional SLIPs which indicate a RSL in north-eastern Ireland of c.+6 metres at c.6 ka B.P.

Bioerosional marks of Limpets (*Patella*), and other intertidal and subtidal organisms, have been observed on limestone cliffs >10 metres above present LWM at a site in Co. Antrim, Northern Ireland. The vertical distribution of modern limpets relative to HWM and LWM is well documented and hence these sub-fossil limpet marks accurately constrain upper and lower tidal limits in this region at some point during the Holocene. Remarkably, sub-fossil shells of Limpets (*Patella*), with an associated fauna of Winkles (*Littorina*), Dog Whelks (*Nucellus*) and encrusting annelids (*Spirorbis*) have been recovered from the base of fissures around 1-2 metres directly below the limpet marks. C-14 analysis of this shell material gives various dates between 4ka and 6ka cal B.P., the oldest of which matches closely with previous dates for the mid-Holocene highstand and formation of the '25 Foot Raised Beach'. Marine shells have been used previously to date the raised beach, but never from a context where they can be tied in so precisely to tidal range.

These limpet marks represent a uniquely precise SLIP for the Holocene. Significantly, they indicate a vertical error of ~40% for previously published Holocene RSL curves for the region. Furthermore, the vertical distribution of associated bioerosional taxa at this site has implications for the rate of decoupling of isostasy and eustasy following the mid-Holocene highstand and, indeed, for the very nature (gradual vs. episodic) of isostatic uplift here.

P-1064

## Sea-level research on the North Sea and in Greater Rotterdam, The Netherlands

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### Abstract

The Netherlands has a long tradition of sea-level research from which vast amounts of data accumulated over the last 60 years. The results, however, are scattered across large numbers of papers and reports, were obtained using different sampling and dating techniques, have been in part revised, and as a whole had not been uniformly scrutinized on quality and usability today. We present new results for Greater Rotterdam (including record of the pre-8.2 sea-level jump) and from offshore regions within the southern and central North Sea (Rhine-Thames land, Doggerland).

For the Rhine-Meuse delta and transgressed palaeovalley below 'Greater Rotterdam' (RMD), we have recently re-assessed the sea-level reconstruction data. Following documented protocols, index points tied to radiocarbon dates from peat beds were selected (catalogued), then documented and screened individually in a database, and then further screened in ensemble on quantified age-depth position and inshore palaeotidal setting. The RMD database holds 50 sea-level index points (SLIPs) and 56 upper limiting data points. The SLIPs cover an age-range of 8.8-3.0 ka, beginning at -21 m O.D. in the RMD near offshore. For upper limiting data points, the coverage reaches further offshore tracing the Rhine palaeovalley, back to 11 ka BP and down to -34 m O.D.

Between 8.0 and 4.5 ka, relative sea-level rise gradually decelerated from 0.9 to 0.2 m/cy. Between 9.0 and 8.0 ka, rates of rise were much higher. They averaged 1 m/cy, and were briefly higher (~2m/cy) during a superimposed 'sea-level jump'. For this jump, the RMD resolves a magnitude of  $1.7 \pm 0.6$  m for the first phase (starting 8.45 ka), and a few more decimetres in a second phase (8.3-8.25 ka). This corresponds to globally-averaged jump components of  $2.5 \pm 0.9$  m ( $1\sigma$ ) and 0.1-0.4 m respectively, caused by drainage of Lake Agassiz-Ojibway also known from the 8.2-ka cold event.

For the pre-9 ka BP period, for which data is to be sampled offshore, SLIPs are rare and not currently available from the Rhine palaeovalley. More to the north (Oyster Grounds and Doggerbank regions), a few SLIPs exist, that have considerable uncertainties with respect to their sampled elevation, their indicative meaning and their age. Resampling for SLIPs, aiming to densify the vertical series from subregions offshore is an ongoing effort, with two cruises with the vessel Pelagia (NIOZ, Royal Netherlands Institute for Sea Research) completed in 2017 and 2018. These sampled peat beds between -60 and -25 m O.D. (completed) to obtain sea-level index points (in preparation).

In our presentation we will show both the results from the database effort in the Rotterdam area and the preliminary results from our North Sea palaeo sea-level campaigns.

P-1065

## A Holocene sea level record for the far-field region of Singapore

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### Abstract

The early Holocene (11.6 – 7.0 ka BP) was a period of dramatic environmental change coincident with rapid relative sea-level (RSL) rise that provides a valuable analogue for the future. However, this critical time period remains inadequately studied, especially in far-field regions that experience hydro-isostasy but minimal land-level change due to glacio-isostatic adjustment.

Singapore lies near within the tectonically stable Sundaland, and here we obtained new sea level index points (SLIPs) from a ~40 m sediment core in Singapore, that augment and extend existing records. We dated wood and charcoal samples from a basal mangrove peat unit to produce 4 new SLIPs spanning ~9.5 – 9.2 ka BP, which provide the earliest record of post-Last Glacial Maximum marine transgression in the region. Additionally, we recalibrated 57 published SLIPs and 20 marine-limiting points, and used a Bayesian modelling approach to produce a revised Holocene sea-level record for Singapore.

The new record reveals a period of rapid RSL rise in the early Holocene from -20.5 m at ~9.5 ka BP to -4.5 m at 8 ka with a rate of 10.9 mm/yr. The rate of RSL significantly slowed to ~4 mm/yr between 8 and 6 ka BP when RSL was ~2.5 m. The maximum RSL of 5 m was reached at ~5.1 ka BP. RSL sea-level fell from the highstand although there are only 2 index points both at ~2.3 ka BP to constrain the reconstruction. The resolution of the revised RSL record does not illustrate any inflections in the rate of sea-level rise during the Holocene. Our results provide new early Holocene data that may inform glacio-isostatic adjustment (GIA) models and projections of future sea level for Singapore and the region.

P-1066

## Leveraging preservation bias in Last Interglacial coral sea-level records to refine global ice volumes over the ice age

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### Abstract

Accurately reconstructing sea level during the Last Interglacial (~125 ka) will improve our understanding of how ice sheets have reacted to warm temperatures in the past, and this insight can aid in refining estimates of future sea level rise in a warming world. Past sea levels have been reconstructed using biologic and geologic shoreline features, such as fossil coral reefs, marine terraces, and erosional notches. Amongst these sea level indicators, fossil coral reefs are the most widely used, as their chronology can often be tightly constrained using U-Th dating. Today's record of existing sea-level markers are a result of systematic preservation biases, which to-date have not been directly considered in reconstructions of Last Interglacial global mean sea level. Tectonic uplift, sea level change, accretion rates, and erosion rates dictate whether a coral reef forms and its subsequent probability of preservation, resulting in preferential preservation of proxies reflecting relative sea level highstands.

We explore the observed distribution of Last Interglacial coral reef sea-level markers using a statistical model that accounts for the growth and destruction of coral reefs over the last glacial cycle. We force this model with sea-level predictions from a large ensemble of glacial isostatic adjustment simulations sampling a range of possible ice volume change scenarios across the last ice age, and identify spatial signatures in model-produced coral distributions, to show how regional sea level patterns produce distinct records of coral reef preservation. We show that predicted elevation distributions of preserved corals in the Bahamas and western Australia are strongly imprinted by local sea level histories. We find that this modeling yields an improved understanding of indicative meaning, which is essential in constraining global mean sea-level values across the Last Interglacial and the subsequent glacial cycle, because only a certain subset of ice histories predict a present-day distribution of sea-level markers consistent with the observed dataset of Last Interglacial coral reef records. This reveals the potential to leverage the observed elevation distribution of Last Interglacial corals to constrain past relative sea level, and thereby global ice volumes, across the last glacial cycle.

P-1067

## Drivers of sea-level changes in eastern Canada

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### Abstract

Coastal management and planning is needed for adaptation strategies against climate change risks associated with sea-level rise and storm surges. To be effective, policies rely on accurate forecasting of future sea-level changes at regional scales. Recent progress in climate modelling has closed the global sea-level budget for the twentieth century to within uncertainty and modelled sea-level estimates capture regional variability observed within instrumental datasets (tide gauge and satellite) since 1900 CE. Despite this good agreement, it can be argued that sea-level projections from climate models should be validated against datasets spanning beyond the twentieth century if they are to be considered robust estimators of long term (centennial to millennial) future sea-level changes. Natural variability remains a significant source of uncertainty in modelling sea-level change and proxy-based records of pre-industrial sea-level trends will be key for defining scales of multi-decadal to millennial variability prior to the onset of instrumental data collection and anthropogenic warming. Next-generation sea-level projection models that are capable of accurately hindcasting observed regional sea-level trends for recent centuries and millennia will be more robust at predicting sea-level changes further into the future.

Regional sea-level trends in eastern Canada differ significantly from the global mean due to, predominantly, gradients of vertical land motion that remain following the deglaciation of the former ice masses (the Laurentide Ice Sheet and the Appalachian Glacier Complex) that occupied this region during the Last Glacial Maximum. Areas undergoing glacio-isostatic subsidence along Atlantic Canada and within the Gulf of St. Lawrence currently experience rates of local relative sea-level rise that exceed the mean rate of global sea-level rise. We present an analysis of new and published high-resolution sea-level reconstructions from Quebec and eastern Canada that have been developed using foraminifera and testate amoebae from salt-marsh sediments. These records of Common Era sea-level changes reveal multidecadal variability that is superimposed upon the near-linear background trends of glacio-isostatic adjustment. This sea-level variability is attributable to mass flux between the cryosphere and the oceans during climatic shifts during the late Holocene (the Medieval Climate Anomaly and the Little Ice Age) and to dynamic ocean mass redistribution during phases of ocean-atmosphere modes. Distinguishing the roles of these different drivers and replicating their contributions in climate models is a necessary first step towards developing accurate long-term projections of future sea-level changes throughout eastern Canada.

**P-1068**

## **Mapping of tunnel valleys in the UK and Norwegian North Sea**

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### **Abstract**

The use of 3D-seismic reflection data sets with regional coverage (180 000 km<sup>2</sup>) has enabled the mapping of large complexes of buried tunnel valleys in the North Sea. In addition, high-resolution airborne magnetic data were applied to complement the mapping of tunnel valleys where 3D-seismic data were not on hand.

Here we present the results of a regional mapping study for tunnel valleys for large parts of the North Sea, north of 56°N. The mapping reveals thousands of buried tunnel valleys with at least four valley generations, probably linked to the last few glaciations during the last 500 000 years. The tunnel valleys can reach lengths of more than 150 km, can be up to 5 km wide and 500 m deep.

The Quaternary North Sea Basin comprises relatively soft and generally poorly consolidated, fine-grained sediments which have provided an ideal substrate for the development of tunnel valleys. A eustatic low sea level has been a prerequisite for developing of such valleys and led to dry land on the North Sea Plateau with a generally passive ice sheet during deglaciation periods. The tunnel valleys are formed on the North Sea Plateau areas west and south of the much deeper Norwegian Channel. They seem to be less common in the northern North Sea, probably related to generally deeper water. Reconstruction of the ice sheet configuration during the formation of the tunnel valley is challenging, but it is inferred from our results that the water draining under the ice sheet has been generally flowing towards the Norwegian Channel.

P-1069

## Glacitectonic evidence of ice lobe interaction across Dogger Bank (southern central North Sea) during the Last Glacial Maximum

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### Abstract

High-resolution seismic data from the Dogger Bank in the central southern North Sea has revealed that the Dogger Bank Formation records a complex history of sedimentation and penecontemporaneous, large-scale, ice-marginal to proglacial glacitectonic deformation. These processes led to the development of a complex assemblage of glacial landforms and sediments which record the interplay between two lobes of the Weichselian ice sheet which occupied the North Sea basin during the Late Glacial Maximum. The “Dogger Bank lobe” advanced from the N/NW with its subsequent active northward retreat resulting in the development of a complex assemblage of arcuate thrust-block moraines (“Dogger Bank moraine”) composed of highly folded and thrust lower Dogger Bank sediments (c. 40-50m thick). These large glacitectonic landforms (200m-15km across; >30km long) are separated by low-lying sedimentary basins and meltwater channels filled by upper Dogger Bank outwash sediments. The impact of the second lobe was restricted to the western margin of Dogger Bank where it led to the construction of a large (5-20km wide) thrust-complex (“western moraine”) composed of a thick sequence (c. 100-150m thick) of glacitectonised sediments. The geometry of the structures within this deep-seated moraine are consistent with ice-push driven by ice advancing from the west. The boundary zone between the two moraine systems is structurally complex and overlain by an elongate basin (up to 7-8km wide) filled by upper Dogger Bank sediments (10-40m thick) which were primarily derived from the northeast. This sedimentary basin formed as the two ice lobes unstitched and retreated from Dogger Bank. However the exact timing of the “decoupling” of the two ice masses remains uncertain. Initial results indicate that the two ice masses were still in close proximity resulting in the interleaving of the glacitectonised sediments within the moraines, with the unstitching of the two ice lobes occurring during the early stages of the deglaciation of Dogger Bank.

**Acknowledgements:** The authors thank the Forewind consortium for providing the seismic data

P-1070

## Deposition of proglacial sediments along an active ice margin during the Last Glacial Maximum, Dogger Bank, southern central North Sea

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### Abstract

High-resolution seismic data from the Dogger Bank in the southern central North Sea has revealed that the Dogger Bank Formation records a complex history of ice-marginal to proglacial sedimentation and penecontemporaneous, large-scale, glacitectonic deformation during the Last Glacial Maximum. The study site presented here is located along the margin of the Weichselian aged British and Irish Ice Sheet and Fennoscandian Ice Sheet, within the Dogger Bank area.

The resulting glacial system and sedimentary sequences reveal the presence of a number of sedimentological features including meltwater channels, outwash fans and plains, desiccation surfaces and lacustrine systems, as well as a plethora of glacitectonic arcuate thrust-block moraines.

Here we focus on the development of the meltwater channel systems, outwash flood sheets and fan systems which formed during the northward retreat of the ice sheet across Dogger Bank. The fans are up to 2.5km wide and comprise sediment packages (up to 50m thick) with inclined reflectors. They are interpreted as forming an ice marginal apron system occupying a low lying sedimentary basin formed between the larger, higher relief moraines located within the southern margin of the Dogger Bank. Large channels up to 1km wide and between 30m and 70m deep have been identified incised into a thick (up to 40m thick) sequence of outwash sediments. These sediments exhibit varying degrees of deformation, linked to a history of active retreat of the ice margin. The complex internal architecture of the channels indicate that they record several periods of sedimentation separated by prominent erosive surfaces. Desiccation surfaces are preserved within both the channels and laterally extensive outwash plains, indicating several periods of intense periglacial weathering (drying, alteration) occurred during deglaciation. This sedimentary assemblage therefore records a complex history of deposition, meltwater release and channel incision separated by phases of periglacial weathering and glacitectonic deformation during the deglaciation of the Dogger Bank towards the end of the Weichselian glaciation.

**Acknowledgements:** The authors thank the Forewind consortium for providing the seismic data

**P-1071**

## **Remains of arctic and boreal plants and animals from the Danish North Sea**

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### **Abstract**

The North Sea is a large shallow epicontinental sea dominated by sandy bottom that reflects a high energy environment. Little is known about the late Quaternary history of the Danish part that was probably dry land during long time periods of the last ice age.

In connection with mapping of raw material in the Danish part of the North Sea, a number of 6 m long vibro-cores were collected by the Geological Survey of Denmark and Greenland. During description of the sediment cores, remains of plants were noted, but most of them were early Holocene. However, a few samples from two sediment cores contained macrofossils of cold-adapted plants, such as the dwarf shrubs *Dryas octopetala*, *Salix herbecea* and *Betula nana*. Herbaceous plants were represented by *Carex* sp., *Ranunculus* sp. and *Juncus* sp. The samples also contained remains of plants and animals living in fresh water, such as *Potamogeton filiformis*, the bryozoan *Cristatella mucedo* and larvae of caddis flies.

Two samples were dated by AMS radiocarbon age determination. One sample gave an age of ca. 12.6 cal. ka BP, corresponding to the Younger Dryas cold period. The other sample was dated to ca. 35 cal. ka BP, corresponding to marine isotope stage 3, prior to the last glacial maximum. The floras and faunas are not rich in species, but they provide some of the first information about the biotas of the last glacial stage.

Previous remains of arctic species from the Danish North Sea are confined to a few records of walrus. One of these finds was also dated to ca. 35 cal. ka BP, whereas two others finds gave somewhat younger ages. In some areas of the Dutch sector of the North Sea, bones of arctic mammals are common. The fauna includes terrestrial species such as mammoth and reindeer and marine species such as walrus and white whale.

Pre-Holocene shells of marine molluscs have been reported from Jyske Rev and dating of three samples gave finite radiocarbon ages of 43–45 cal. ka BP. The fossil assemblages include warm-adapted bivalve species such as *Donax vittatus*, *Spisula subtruncata*, *Arctica islandica* and *Cerastoderma edule*. These species are well known from interglacial deposits in the region, but not from interstadial deposits and we suggest that the deposits are of Eemian age.

**P-1072**

## **Palaeoenvironmental change within the southern North Sea following the Last Glacial Maximum.**

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### **Abstract**

The Last Glacial Maximum (LGM) to Early Holocene period is characterised by considerable global climatic instability. During this time the landscape of the southern North Sea evolved from an aerially exposed periglacial environment to shallow marine conditions. The stratigraphic record for the period covering the LGM up to the onset of the marine transgression in the Holocene can be documented using recently acquired high resolution seismic, core and geotechnical data from the offshore renewable energy industry, offshore East Anglia, England. These integrated data form a valuable archive of mid-latitude palaeoenvironmental change and landscape evolution during marine inundation of low-lying coastal areas.

Overlying sediments of LGM age are extensive peats and fluvial channel-fills that have been mapped in seismic profiles and calibrated to borehole records. These peats record the establishment of terrestrial landscape, intersected by a network of fluvial channels, as climate warmed during the Early Holocene. The nature of the seismic facies and tributive channel-network pattern indicate a palaeoflow direction towards the southwest. Average channel widths are 150 m (maximum 1.4 km) and <3 m deep and have variable fill character, ranging from dipping foresets to draped to chaotic fill. In the north of the survey area, isolated incisional fills are common and display both dipping (foresets) and draped fill characters. These may represent previous channels that have subsequently been eroded leaving isolated, disconnected fills. The peats are highly amorphous in character, suggesting high levels of decay. Overlying the peats is a transgressive surface of marine sands. The top peat-contact shallows towards the northwest indicating an approximately NE-SW trending shoreline, with marine transgression from the southeast. The patchy, laterally discontinuous distribution of the peats suggest that much of the organic material was eroded and reworked during transgression. These erosive processes during marine transgression are further supported by the contact between peat and the overlying marine sediments, whereby peat fragments (rip-up) are often incorporated into the overlying marine sediments.

The interpretation of LGM to Early Holocene stratigraphy reveal palaeoenvironmental evolution under rising relative sea level on a much larger scale than previously recorded in onshore archives, allowing development of kilometre-scale landscape response models. The ability to map subsurface organic material allows us to calculate both the amount of carbon stored in offshore environments, as well as furthering understanding of the erosion of coastal and freshwater peatlands under models of sea level rise.

**P-1073**

## **Pockmarks within a stratigraphic framework from the Witch Ground Basin, central North Sea**

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### **Abstract**

One manifestation of focused fluid migration at the seafloor are circular to semi-circular depressions known as pockmarks, which form in response to vigorous venting of fluids from the seafloor. Here, we use 2-D and 3-D seismic reflection, multibeam bathymetric and sedimentological data to map and describe pockmarks in the Witch Ground Basin (central North Sea) and characterize associated sedimentological and fluid migration structures. More than 1500 pockmarks of two distinct morphological classes spread over an area of 225 km<sup>2</sup>. Large pockmarks (> 6 m deep, > 250 m long, and > 75 m wide), show active venting, and are located above vertical fluid conduits that hydraulically connect the seafloor with deep methane sources. Smaller pockmarks (0.9-3.1 m deep, 26-140 m long, and 14-57 m wide) are limited to the soft, fine-grained sediments of the Witch Ground Formation. The larger pockmarks are sourced by biogenic methane through seismic pipe structures which hydraulically connect deeper strata with the surface. The smaller pockmarks are independently formed by another source of fluids. Paleo-pockmarks within the Witch Ground Formation document distinct phases of pockmark formation, likely triggered by externally-induced pressure and temperature changes.

**P-1074**

## **Mid-Pleistocene thin-skinned glaciotectonic thrusting of the Aberdeen Ground Formation, Central Graben region, central North Sea**

David Vaughan<sup>1</sup>, Emrys Phillips<sup>2</sup>

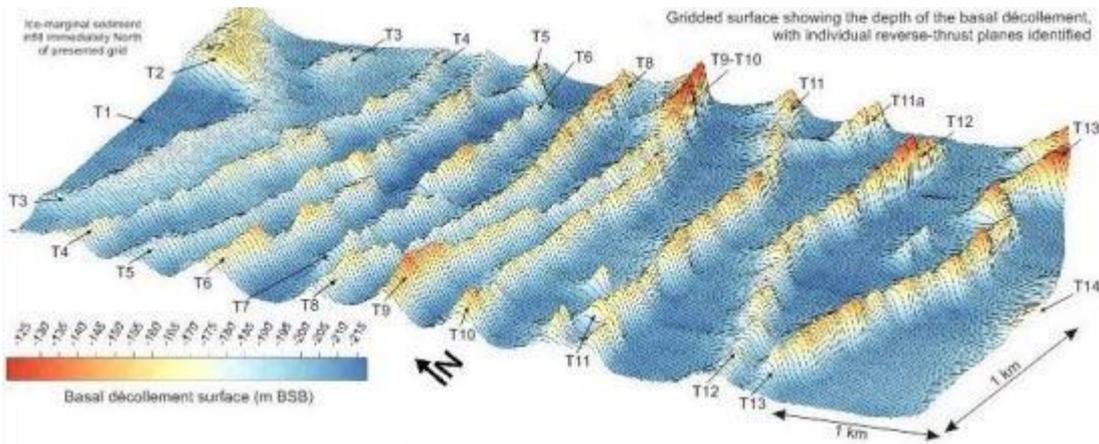
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### **Abstract**

This paper presents the results of a high-resolution 2D seismic survey of Mid-Pleistocene glaciogenic sediments in the Central Graben region of the central North Sea. The survey has revealed that these sediments, which were originally interpreted as possessing a simple layercake stratigraphy, have in fact undergone major glaciotectonic thrusting and folding associated with the repeated southerly advance of an ice sheet across the region during the Mid-Pleistocene.

The total observed length of the thrust-stacked section is approximately 5 to 6 km, comprising a series of discrete thrust slices, which range in length from < 300 m to > 700 m. The basal detachment of the thrust complex occurs at a depth of c. 220 m below sea bed within the upper Aberdeen Ground Formation. The ice-proximal limit of thrusting is marked by a large depression (>100 m deep, >1600 m wide) infilled by a sequence comprising at its base acoustically chaotic deposits, overlain by a well-bedded unit, passing upwards into tectonically deformed sediments.

A thin-skinned glaciotectonic model involving proglacial to ice-marginal glaciotectonic thrusting followed by post-tectonic deposition is proposed. Initial ice advance led to the over-pressurising of groundwater within a laterally extensive sand sheet in the upper Aberdeen Ground Formation, promoting the formation of a major décollement surface at the base of the developing thrust stack. Detachment and transport of the thrust sediments led to the contemporaneous formation of a “glaciotectonic hollow” beneath the ice margin. Dewatering of the basal décollement, possibly due to water escaping from the thrusts which propagated upwards through the Aberdeen Ground, led to the cessation of forward propagation of the leading-edge of the thrust stack accompanied by extensive shortening and deformation at its ice-proximal end. Subsequent retreat of the ice exposed the tectonic hollow which became infilled with glacial outwash. This glacial sequence was itself deformed during later readvance of the ice from the north. The proposed model provides clear evidence that Mid-Pleistocene ice sheet dynamics within the Central Graben of the North Sea was far more complex than previously thought.



3D visualisation of the glacetectonic decollement surface throughout the survey area. Thrust slices are labelled as individual T-numbers, and the depth scale is in meters below sea bed.

**P-1201**

## **Shotgun ancient DNA, pollen and macrofossil analysis of Lateglacial lake sediments from southern Sweden**

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### **Abstract**

We used shotgun DNA sequencing of the full metagenome preserved in an ancient lake sediment from southern Sweden to investigate the whole diversity of taxonomic groups present. We combine sedimentary aDNA, pollen and macrofossil studies and tested if it was possible to correlate the relative abundances of plant taxa to distinct climatic shifts that occurred between 14 and 10.5 ka BP.

Metagenomic DNA provides a stronger signal of plant community changes than plant micro- and plant macrofossil analyses alone and a larger number of new taxa were recorded in Younger Dryas samples. A comparison between the three proxies highlights differences and similarities and supports earlier findings that plants growing close to or within a lake are recorded by DNA. Plant macrofossil remains moreover show that tree birch was present close to the ancient lake since Allerød; together with the DNA results, this indicates that boreal to subarctic climatic conditions also prevailed during the cold Younger Dryas interval.

Increasing DNA reference libraries and enrichment strategies prior to sequencing are necessary to improve the potential and accuracy of plant identification using the metagenomic approach.

**P-1202**

## **Optimization of efficient ancient DNA extraction from lake sediment**

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### **Abstract**

Insights derived from ancient DNA are revolutionizing our knowledge of biotic dispersals and population histories. Ancient DNA from lake sediments (*sedaDNA*) has been shown to provide finer temporal resolution than the hard tissue record, and so has great potential to refine insights into the speed and dynamics of biotic changes, such as the appearance of agriculture or the immigration of key taxa to a region. However, unlike the mature methodologies for hard tissues, the extraction of *sedaDNA* can be problematic, due to the complex and variable geo- and biochemical composition of sediments, which currently constrain the type of sediments amenable to analysis. In this study, we compare *sedaDNA* extraction protocols across a variety of sediment types. Although protocol chemistry impacts metabarcoding-inferred plant taxonomic diversity, sediment types with high organic content often yielded near-unusable results regardless of the protocol used. However, slight modification of an existing protocol greatly improved the results for some of these problematic sediment types. Together with other *sedaDNA* methodologies currently in development, this work brings us closer to unlocking the full potential of this underexploited ancient DNA source.

P-1203

## Holocene vegetation changes in the Alps, as inferred from lake sedimentary ancient DNA

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### Abstract

Ongoing climate change is rapidly transforming ecosystems. Considering the range of projected climate change scenarios and the relatively short length of instrumental records, how species and ecosystems will respond to the effects of future human impact and climate changes is poorly understood. Palaeoecology can be used to better understand the dynamics of past ecosystem changes and composition of plant communities, allowing researchers to infer the extent of vegetation changes predicted by models of future climate.

High-mountain lakes of the Alps are suitable ecosystems for studying local environmental shifts driven by large-scale climate changes, giving a long-term perspective of environmental change. These mountain ecosystems are also expected to be severely affected by future changes in climate (prompting an upward shift in vegetation distribution, as well as elevated replacement rates and species losses).

Previous palaeobotanical studies in the Alps have used biotic proxies such as pollen or macrofossils to infer past vegetation dynamics. However, microscopic morphological determinations are time-consuming and, in some cases, they might be limited by low taxonomic resolution and the preservation of identifiable remains. However, ancient DNA from organisms is also preserved in the sediment (*sedDNA*), which can be detected and analysed through metabarcoding. By using the modern DNA sequence database PhyloAlps for the alpine flora of the Alps (4500 species and sub-species), we can bypass the morphological limitations and refine the taxonomic resolution, often to the species level. The *sedDNA* also reflects the local vegetation surrounding the lake compared to the regional vegetal information provided by long-distance transported pollen. This proxy will allow the inference of more complete species occurrences, and thus, better assessments of vegetation shifts in past ecosystems.

To investigate the origin and impact of past environmental changes in alpine ecosystems along the Holocene, we performed a multi-proxy reconstruction using sediment cores from lakes of the Western Alps with different anthropogenic pressures. Using *sedDNA*, elemental analysis, magnetic susceptibility, and loss-on-ignition data, we reconstructed the plant community composition and lacustrine dynamics during the Holocene.

We will present the major findings from these analysed records and the general trends inferred from them, and pay special attention to the anthropogenic pressure in lakes located close to archaeological settlements.

P-1204

## Late-Pleistocene vegetation in northeast Siberia inferred from sedaDNA records: detection of local-scale variation

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### Abstract

For paleosols and similar horizons, the provenance of ancient DNA retrieved directly from sediments (sedaDNA) is such that local floristics are accurate but under-represent taxonomic richness. Sediment samples function like 1-2m<sup>2</sup> quadrats regarding the spatial distributions of plant taxa they record. Frozen silt deposits in NE Siberia (yedoma) often provide taxonomically rich sedaDNA records, but most samples are restricted to vertical sequences with little horizontal coverage at any given site. To test for spatial variation in paleo-vegetation, we sampled a series of horizons (five within a 1-m height range) across ca. 35 m of the face of a large yedoma exposure at Duvanny Yar, Yakutia (DY). The samples fell into five physical clusters related to the sampling design; they were individually radiocarbon-dated. Dating and detailed stratigraphy revealed a gently dipping palaeosol across the deposit. Samples of the same height above datum were thus not contemporaneous, but some ages clustered quite tightly within a total age range ca. 30-39 cal ka BP. A metabarcoding approach identified plant taxa (molecular taxonomic units: MOTUs) in DNA extracts from frozen sediment samples. For the main primer set (chloroplast trnL intron, P6 loop) we used four amplifications per sample; singletons with low reads (<100) and taxa occurring at high values in negative controls were filtered out. This meant exclusion of two widespread taxa that should have occurred, based on ecological expectation: Salicaceae and *Equisetum*. The number of MOTUs per sample ranged from 4 to 23 (mean 13.4, total 101); virtually all MOTUs were biogeographically reasonable. Of the major functional types: grasses, sedges, forbs and woody taxa, forb DNA dominates (except in three samples dominated by bryophyte DNA). This matches patterns observed at other late-Pleistocene localities across the Eurasian North.

Log-transformed data were examined with ordination (DCA, NMDS). While sample composition varies considerably, differentiation that might relate to a local-scale vegetation mosaic or gradient is poorly defined. This result is not dissimilar from observations of sedaDNA taken from modern tundra soils; it probably reflects a small suite of dominant taxa masking more subtle indications of vegetation composition shown by minor taxa. Overall, the data indicate predominantly herbaceous vegetation adapted to cold, dry conditions (NB excluded Salicaceae has low importance). Assuming that the dominant taxa correctly characterize the zonal vegetation, regional environmental conditions are probably the major control of sedaDNA assemblages from deposits such as these, but local-scale environmental variation may be difficult to identify.

P-1205

## Extraction of ancient DNA from macrofossils of different tree species preserved in European Alpine lake sediments

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### Abstract

Lake sediment represent archives that capture the environmental history of their surroundings and provide ideal conditions for the preservation of ancient DNA (aDNA). The extraction and analysis of environmental aDNA directly from bulk sediment (i.e. exogenous aDNA, also known as sedimentary aDNA or *seDaDNA*) has recently been established as a new method in palaeoecology to infer past plant occurrences around these natural archives that can provide data complementary to traditional optical approaches such as pollen and macrofossil analysis. However, aDNA analysis has the potential to open up even more avenues of research in palaeoecology by directly studying population genetic processes through time. Endogenous aDNA from macrofossils preserved in lake sediments can be used to infer intra-specific changes in the genetic diversity and possibly adaptive potential of a species as well as tracking population dynamics in space and time. However, due to technical difficulties in sample preparation and aDNA extraction, only few studies have successfully extracted endogenous aDNA from macrofossils to answer population genetic research questions.

Here, we provide results of a pilot study that aimed to extract endogenous aDNA from different macroscopic plant remains of four conifer species from two lakes in the European Alps over the Holocene. We selected 25 macrofossils from *Picea abies*, *Pinus cembra*, *Abies alba* and *Larix decidua* that date to ca. 10 – 3.5 ka cal. BP. Most of the macrofossils are needles or needle fragments in various states of preservation, but we also used seeds, twigs and bud scales to test if successful aDNA extraction is dependent on the source material used.

We extracted aDNA from the samples in a dedicated aDNA facility under clean room conditions. To evaluate the identity of the species and estimate the proportion of endogenous aDNA and ancient and modern contaminants in each sample, we used an amplicon-sequencing approach (based on amplification of a short universal plant barcode, i.e. chloroplast *trnL* P6 loop) on a next generation sequencing platform. We also checked the amplicons for authenticity by analyzing diagnostic deamination patterns typical for post-mortem degradation of DNA: We considered the aDNA to be authentic if the PCR replicates contained sequence reads of the respective macrofossil species and if the cytosine to thymine and guanine to adenine misincorporation rates were significantly higher than a modern reference sample.

The results of our pilot study provide valuable information about the preservation and the potential for extraction and amplification of aDNA from a variety of source materials. Our results can be used to improve sampling strategies and extraction protocols to maximize genotyping success in future intra-specific aDNA studies.

P-1206

## Pleistocene extinction of megaherbivores from eastern Beringia using multiproxy palaeoenvironmental records from central Yukon lake sediments: first results

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### Abstract

Here we present preliminary multiproxy palaeoenvironmental records from Gravel Lake, central Yukon Territory, to investigate the environmental response associated with the disappearance of megaherbivores at the end of the Pleistocene. Lake sediment cores were recovered in 2017 then subsampled and stored at the University of Alberta. Chronology for the cores is based on radiocarbon and cryptotephra analyses and 1 cm loss-on-ignition record of the sediments spanning the Pleistocene-Holocene transition. High resolution loss-on-ignition, coupled with a basal radiocarbon date of ca. 14,000 cal yr BP, allows identification of Bølling-Allerød warming and the Pleistocene-Holocene transition, and has guided subsequent sampling near the expected timing of megaherbivore extinctions in eastern Beringia. Palynological analyses of pollen and coprophilous fungi are in progress at the Brock University Water and Environment Laboratory alongside magnetic susceptibility (MS). We have identified pollen in standardised counts of 300 per sample with further identification of pigmented fungal spores, particularly those known to be obligate coprophilous genera. Coprophilous fungal spores have become increasingly utilised as proxies for megaherbivore abundance in Late Quaternary samples and appear throughout the samples from Gravel Lake. *Sporormiella*, *Cercophora*, *Podospora* and *Sordaria* appear to be the most common taxa. We aim to combine results of abundance and disappearance of obligate coprophilous spores, sedimentary ancient DNA, and an established chronology to identify the timing of local megaherbivore extirpation. At the McMaster Ancient DNA Centre, we are extracting sedaDNA using a recently optimized approach to maximize DNA recovery from environmental samples prone to the carryover of prolific enzymatic inhibitors. These sedaDNA extracts are being analysed with an enrichment approach targeting diagnostic genetic loci from the plant chloroplast animal mitochondrial genomes. By enriching the ecologically informative fraction of these sedaDNA libraries, we can more efficiently high-throughput sequence taxonomically diagnostic biomolecules in order to reconstruct palaeoecological change through time in central Yukon with our complementary set of environmental proxy data. Core chronology and LOI are being established at the University of Alberta allowing the sedaDNA, palynological data and MS to firstly be compared temporally, but similarly against previous studies from the region. The Arctic is currently undergoing dramatic changes that directly impact the stability of ecosystems and northern landscapes. Rapid climate change during the Late Quaternary caused numerous ecosystem responses, including altering vegetation assemblages and possibly contributing to the mass extinction of numerous megaherbivore taxa. This study aims to highlight the direct impact of climatic amelioration on megaherbivore populations with intentions to provide another dataset of biodiversity alteration from which analogues of modern ecological responses to current and future anthropogenic warming can be based.

P-1207

## Bacterial palEnDNA of Pleistocene sediments reveal paleoclimate changes

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### Abstract

*The palEnDNA based reconstruction of bacterial community structure of three sediment layers from the Vettaikaraniruppu paleo-beach ridge core, clearly indicated that sediment bacterial communities reflected the depositional environment. Reconstruction of bacterial community structure was possible even from 146,000-year-old samples using V3 hypervariable region of bacterial 16S rDNA targeted Illumina sequencing. The bacterial community dynamics between and among the sediment layers showed that marine transgression caused a mix up of environments and resulted in the increase of taxonomical diversity and altered the functional diversity of the native community. After marine transgression, the bacterial communities had attempted to regain its original structure. These attempts erased the changes in biogeographic patterns, although the bacterial communities contained the impressions of marine transgression even after 3000 years. The difference in the recovery of palEnDNA from the three sediment layers reflected stratigraphic reliability. The taxonomic diversity observed in three samples revealed no intermixing of modern and ancient genetic signals and DNA leaching/migration through water, active bacteria, bioturbation or during the act of coring sampling itself. All these append the value to bacterial palEnDNA to be employed as a tool for paleoenvironmental reconstruction.*

P-1208

## Sedimentary ancient DNA of rotifers reveal responses to 200 years of climate change in two Kenyan crater lakes

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### Abstract

Sedimentary ancient DNA (*sedaDNA*) has been proven to be a useful tool for paleoenvironmental studies, but only a handful exist for tropical regions. We here present *sedaDNA* analyses dating back to 1800 AD on two sediment cores from two crater lakes from the Kenyan Rift Valley. These alkaline-saline lakes have experienced different climatic and anthropogenic influences. New data were retrieved from a sediment core from Lake Kageinya (formerly known as Lake Eight), located in the remote, non-influenced anthropogenically, hot and hyper-arid Suguta Valley. In this study we used *sedaDNA* to study the temporal succession of *Brachionus* spp. rotifer haplotypes. The results are compared to previously published data from Lake Sonachi, a well-studied lake in the humid and colder mountainous region of Kenya near Naivasha town, now supported by a <sup>210</sup>Pb age chronology. Both records expand well beyond the onset of substantial anthropogenic impact on the regions. The results revealed that climate is the main driver for haplotype changes in both lakes rather than an anthropogenic impact. During prolonged dry periods haplotype composition remained constant and at low diversity such as from 1910 to the late 1960s. Sudden changes and the emergence of new haplotypes are observed when climate became more humid, but also more variable (before 1910 and from 1960s onwards). Progressive changes in haplotype composition during such variable climates could reflect local adaptation and/or is the result of immigration of new haplotypes after the eradication of previous populations during extreme environmental conditions. These results imply that *sedaDNA* in tropical lake sediments, despite of adverse chemical conditions, is preserved at least back to 1800 AD and its analysis provides a good complementary paleoenvironmental proxy for paleo-limnological reconstructions.

P-1209

## Comparing sedimentary environmental DNA-based vegetation to current vegetation composition around lakes

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### Abstract

Past changes in vegetation have typically been assessed using pollen and macrofossils as proxies. In recent years, these proxies have been supplemented by lake sedimentary DNA (*sedDNA*), which has a higher taxonomic resolution. However, the degree to which metabarcoding-derived *sedDNA* data quantitatively reflects actual species abundance in the vegetation surrounding lakes, is less clear due to various potential biological and technical biases. A large-scale direct comparison of contemporary vegetation data to that of *sedDNA* is therefore required, to determine if any correlation exists between these quantitative measures in spite of these biases. In this study, we assess how the vegetation in the catchment area of a lake predicts contemporary lake *sedDNA*. More specifically, we hypothesized that the dominant taxa of the most abundant habitat types in the catchment area of a lake will be the most abundant taxa, in terms of amplicon representation, in the *sedDNA* data. Furthermore, we hypothesized that species abundance distribution in the contributing area will be reflected in the *sedDNA*. In addition, we also considered distance from the lakeshore as one of the determinants of *sedDNA* deposition in a lake. To test this, we hypothesized that the vegetation in the area in closest proximity to the lake has the most resemblance to that inferred from *sedDNA*. To address these hypotheses, we described the catchment area of 23 lakes in Northern Norway, mapping vegetation types and performing point-intercept surveys to quantify the biomass of common species and functional groups. Then, also for each lake, we extracted *sedDNA* from top sediments, performed metabarcoding, and identified taxa based on available reference databases, to provide the number and proportion of reads as abundance estimates of common species and functional groups in the *sedDNA* data. Results from comparisons of species dominance and abundance relations between vegetation and *sedDNA* has the potential for opening avenues to more quantitative palaeoecological inference from ancient *sedDNA*, which is essential for a more nuanced understanding of past ecology.

**P-1210**

## **Ancient DNA in unfrozen archaeological sediments from interior Alaska**

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### **Abstract**

Between 14,000 and 5,000 years ago, on the cusp of major environmental shifts that affected the distribution of animals, vegetation cover and hydrology, humans entered interior Alaska and presumably witnessed these changes. Analysis of sedimentary ancient DNA (*sedaDNA*) from loess deposits that contain archaeological remains has the potential to revolutionise our understanding of how these early people responded to this changing environment and adapted their use of natural resources. Loessic sediments at these archaeological sites present particular challenges to *sedaDNA* studies, including anthropogenic disturbance of the matrix by ancient humans and unfrozen conditions for around four months of the year that may accelerate bacterial degradation and fragmentation of DNA.

Our objectives are i) to extract *sedaDNA* derived from vascular plant, mammal and fish taxa, from both cultural and non-cultural layers of two archaeological sites with well-preserved animal bones in interior Alaska and ii) compare the results with contemporaneous samples from a nearby lake, which will provide baseline data on the local biota spanning over 15,000 years.

Universal primers were used to amplify a short locus of the plant chloroplast genome. Species-specific primers were designed to amplify a short locus of the mitochondrial genome of key mammal and fish taxa species and were first tested on modern tissue samples from a museum collection prior to use on ancient material. Preliminary results from a series of pilot samples indicate good *sedaDNA* preservation and high taxonomic resolution of plant identifications with 121 plant taxa identified, of which 44 % were identified to species level, 42 % to genus and 14 % to family level.

**P-1211**

## **eDNA analysis of mid-latitude sites for paleoenvironmental reconstruction**

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### **Abstract**

Recovery of ancient nucleic acids has been successful at identifying taxa in samples derived from permafrost, lake cores, cave sediments, and other protected and climatically stable environments (eDNA). The greatest success has been in high latitudes or at high elevations. There have been few reports of ancient eDNA analyses from open air, mid-latitude contexts. To evaluate the feasibility of routine use of eDNA approaches to paleoenvironmental reconstruction in mid-latitudes, we selected three stratified, well-dated archaeological sites on an east-west transect across Kansas, USA. Cultural deposits at the three sites are associated with buried soils.

The study sites occur in three different bioclimatic zones, and vary in age from ca. 13,000 to 1 ka. The Kanorado site is on the High Plains of western Kansas, a semi-arid region with short-grass prairie, low annual precipitation and humidity, and seasonal extremes of temperature. Stratified cultural deposits at Kanorado are in a well-developed buried soil and yielded radiocarbon ages ranging from ca. 13,000 to 10,400 ka. The Alum Creek site is in the dry sub-humid mixed-grass prairie of north-central Kansas and has cultural deposits dating to ca. 1000 ka in an overthickened A horizon of a buried soil. The Claussen site is in the moist sub-humid tallgrass prairie of northeastern Kansas and has stratified cultural deposits dating from ca. 10,400 to 10,000 ka in a deeply buried soil. We expected that ancient nucleic acids would yield different profiles of microbial, plant and/or animal species present in the buried soils at the three sites. The goal was to see if methodological resolution was adequate to test this assumption in semi-arid to moist sub-humid mid-latitude environmental contexts. For comparison, we also analyzed eDNA recovered from a ~1000 year-old archaeological site in subarctic coastal Alaska.

At all three sites, soil samples were taken from the surface of the buried soil, 5-10 cm above and below the soil surface, and from the modern surface in order to test for movement of nucleic acids through the stratigraphic column. We also tested several extraction and sequencing protocols to identify an optimal method for DNA recovery from these contexts. A subset of samples was shotgun sequenced on an Illumina MiSeq platform to ensure viability. After initial sequencing success, all samples were prepared for metagenomic sequencing and shotgun sequenced on an Illumina NextSeq to generate more reads for greater taxonomic resolution. Ancient nucleic acids were distinguished from modern DNA by the presence of distinctive damage patterns associated with degraded DNA. Preliminary analyses indicate that even at Kanorado, the oldest of the three sites, ancient nucleic acids were recovered from the soil surface. Bioinformatic analyses are ongoing to identify species present and to distinguish them, if possible, from modern forms.

P-1212

## Aquatic plant dynamic and fishes over the last 1800 years in the Lake Aiguebelette (Northern French Alps)

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### Abstract

Watersheds of large peri-alpine lakes have undergone substantial demographic and urban developments (leading to the release of waste waters, containing nitrates and phosphates), as well as agricultural activities intensification (use of fertilizers) during the 20th century. The seasonal fluctuations of their water levels is often reduced and controlled to generate hydroelectric power or to reduce flooded areas. Furthermore, these lakes host fishing activities, often for commercial purpose. These pressures, combined with global warming, significantly impacted the aquatic ecosystems especially through the eutrophication process and modifications of the trophic web.

In order to understand such limnological changes, several peri-alpine lakes are monitored for several decades. However, this instrumental monitoring does not allow the assessment of the ecosystem state before the anthropisation acceleration. Lake sediment cores represent relevant archives to fill this gap. Geochemical analyses and biotic remains preserved in lake sediments can be used to reconstruct the past long-term trajectories of aquatic ecosystems.

However, up to now, palaeoecological studies undertaken on lake sediments were only focused on phytoplankton, zooplankton, chironomids or microbial communities, but nor on aquatic plant community, nor on fishes. For fishes, this lack is explained by the absence (or rare presence) of fossils preserved in the sediments and for aquatic plants by a limited detection by pollen analyses. Environmental DNA preserved in the sediment offers a unique opportunity to address these challenges.

In this paper, the DNA metabarcoding approach is used to identify past aquatic plants and fishes living over the last 1800 years in the Lake Aiguebelette (390 m a.s.l., 5.45 km<sup>2</sup> lake surface area, 70 km<sup>2</sup> catchment area, 73m deep). The most significant result is the evidence of interactions between aquatic plants and fishes. Roach, a fish species which has a preference for aquatic grass habitats, appears from 1000 years AD, i.e. when the diversity and biomass of aquatic plants highly increase. This change also corresponds to the development of mesotrophic conditions due to the intensification of the livestock farming.

P-1213

## Ancient DNA (aDNA) of bacteria from 146,000 year Late Quaternary sediments: a potential proxy for unearthing the “paleo sea-level reconstruction”

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### Abstract

Ancient DNA (aDNA) is prudent in unearthing the paleoenvironments. A Geobiotechnological approach to unearth aDNA of bacteria for paleo sea-level reconstruction had been attempted. A 25m sediment core had been excavated from the two beach ridges Vettaikaraniruppu (VKI: 10.572514 N, 79.835111 E) and Korukkai (KUI: 10.535717 N, 79.711936 E) located 2.6Km and 16.6Km inland respectively, along the Cauvery Delta, Tamil Nadu, South East Coast of India. aDNA isolated from four sediment samples from each core VKI-2 (2.8m), VKI-5 (7.2m), VKI-12 (21.0m) and VKI-14 (24.5m); KUI-3 (3.2m), KUI-7 (9.0m), KUI-11 (14.5m) and KUI-16 (24.2m) revealed highest aDNA yield in VKI-12 and KUI-16 paleosols and were least in VKI-5 and KUI-11 paleosols among their respective core samples. V3 hypervariable region targeted 16S rDNA metabarcoding and the taxonomic annotation revealed highest species richness and species evenness in VKI-5 and KUI-16 samples. Marine bacterial signatures at each taxonomic level viz., the marine signature phyla *AC1*, *Aminicenants Chlorobi*, *Lentisphaerae*, *Tenericutes*, and *WS3* were abundant in VKI-5 sample. At class level, *Deltaproteobacteria* with sulphate reducers *Desulfotomaculum* and *Desulfovibrio* were present in VKI-5, VKI-12 and KUI-11 proving that these sediments were formed under marine environment. At genus level, *Prevotella copri* which is an inhabitant of coastal environments was present in all four VKI paleosols, yet was abundant in VKI-5 sample. *Pseudomonas alcaligenes* was present in all the samples of KUI core, yet was abundant in KUI-7 and KUI-11 samples. Further, terrestrial and aerobic bacterial proxies were found to be the highest in VKI-2, VKI-14, KUI-3 and KUI-16 paleosols. Micropaleontological studies in VKI core revealed highest benthic and planktic foraminiferal species at 7.2m; least planktic to benthic foraminiferal ratio at 21.0m. In KUI core, abundant benthic foraminiferal species was observed at both 9.0m and 14.5m. Optically Stimulated Luminescence (OSL) dating revealed the age of VKI-2, VKI-5, VKI-12 and VKI-14 to be  $3.36 \pm 0.42$ ,  $6.04 \pm 1.25$ ,  $122.10 \pm 39.00$  and  $146.64 \pm 36.81$  kaBP respectively. KUI-3, KUI-7, KUI-11, and KUI-16 were dated to  $19.22 \pm 8.65$ ,  $42.30 \pm 14.67$ ,  $67.63 \pm 44.25$  and  $145.51 \pm 27.92$  kaBP respectively. The aDNA metabarcoding analysis of bacteria of VKI and KUI paleosols alongside the conventional foraminiferal proxies and OSL dating revealed marine environments at VKI-5 and VKI-12 which coincided with Mid Holocene Transgression and Last Interglacial Transgression respectively; KUI-7 and KUI-11 were formed under marine environment which was confirmed by the presence of foraminifers. The diversity of both marine and terrestrial bacterial proxies at various depths of both VKI and KUI paleorecords confirmed marine transgressions and regressions. The Geobiotechnological study revealed that bacterial DNA sustain activity even 146,000 years after burial and also reflected stratigraphic reliability and proved aDNA of bacteria to be an efficient proxy for paleo sea-level reconstruction.

P-1214

## 1800 years of vegetation and land use trajectories in the French Prealps: the Lake Aiguebelette sediment record

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### Abstract

Along the last two millennia, peri-alpine lakes have been subject to complex human impacts, mixing agriculture, pastoralism, urban development... The current mosaic landscape of their watershed is the result of the long-term interactions between vegetation and the socio-economic history. In this paper, we propose to focus on one of the main peri-alpine lakes: Aiguebelette (373 m a.s.l., 5.45 km<sup>2</sup> area, 70 km<sup>2</sup> catchment area, 70 m max depth).

By crossing environmental DNA with pollen and coprophilous fungi analyses, we propose to address a more detailed reconstruction of past vegetation dynamic and land use history.

In this region, several pollen records already exist. They provide similar vegetation histories than Aiguebelette for the last millennia. Is that the result of a regional pollen rain, or a regional trend of the evolution of the socio-ecosystems? Because the plant DNA in lake sediments has a local origin (i.e. the watershed or less), it represents a key proxy to decipher the different pollen origins (regional / local) and to better reconstruct the spatial vegetation distribution in the Aiguebelette watershed.

The past vegetation dynamic and land use history can be summed up as follows:

- Along the 1850 years spanned by the sequence, pollen well-reflects the two main deforestation phases associated with crop increasing ([500-700], [1000-1850] cal. AD).
- From 500 AD, pollen and DNA evidence the onset of fruit tree cultivation (vines, chestnuts and walnuts).
- From 1000 to 1850 AD, pollen, DNA and coprophilous fungi spores, indicate an expansion of crop, fruit trees, hemp and pastoral activities. The DNA highlight the importance of orchards (plums or cherries, apples) in that economy.
- The last century is characterised by the decline of most of agricultural activities, except the development of vegetable gardens, similar to the ones that we can see today, with for instance celery, green beans or beetroots.

P-1215

## Past treeline dynamics at Bol'shoy Lyakhovsky Island (New Siberian Archipelago) since the last interglacial inferred from sedimentary ancient DNA

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### Abstract

Permafrost deposits at Bol'shoy Lyakhovsky Island are natural archives dating back to the Eemian (Krest Yuryakh Suite, ~125 kyr BP) with excellent conditions to preserve ancient DNA. The today treeless island is located between the Laptev and East Siberian Seas, but during the last glacial it was part of the Western Beringian landmass due to the marine regression, which exposed the shallow Siberian shelf. Our aim was to reconstruct vegetation changes driven by the strong climatic oscillations from the last interglacial until today. Permafrost coring took place west of the Zimov'e River where four terrestrial permafrost cores were drilled. In total we collected 72 sediment samples and combined pollen analysis with sedimentary ancient DNA metabarcoding for which we amplified the short vascular plant specific P6-loop of the plastid trnL (UAA) intron. Furthermore, we applied two newly developed larch-specific chloroplast SNP markers to assess their suitability in identifying past population dynamics from environmental samples. The new markers were re-sequenced and displayed both SNP variants of each marker in last interglacial samples. Highest diversity and a vegetation containing trees (*Picea*, *Larix*, *Populus*) were inferred covering the island during the last interglacial. During the Mid Weichselian interstadial and the Bølling-Allerød interstadial complex only *Larix* was detected among trees but disappeared along with most shrub taxa during the Holocene. This suggests that the northern extent of the Siberian treeline was further north than previously inferred from pollen analyses, and that modern larch taiga is differently composed than the taiga during the last interglacial.

P-1216

## Survival profiles from linear models versus Weibull models: Estimating stable and stationary population structures for Pleistocene large mammals

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### Abstract

Survival and mortality profiles of mammalian species can provide information on the environmental context of Pleistocene archaeopaleontological localities as well as on the agents involved in the site formation process (e.g., the role played by the bone-accumulating agents, including their patterns of food procurement and carcass consumption, or the strategies of space use by carnivores and humans). Environmental context (i.e., climate and vegetational cover) and meat availability were both relevant factors for determining human settlements in Europe during the Pleistocene. For this reason, to gain deeper insights on the paleoecology of the large mammals communities can provide key information on human evolution and dispersal patterns. In this study we compare two mathematical approaches that allow reconstructing survival and mortality profiles of large mammals and their age-structured populations: the linear model and the Weibull model. Both approaches provide similar results for all species of large mammals analyzed. The lowest correlation coefficient was for *Bison bison* (0.789), but the difference in biomass estimates between the models decreases to <2%. When both methodologies were compared at the community level in the Orce sites, the ecological indexes used to compare paleocommunities showed also differences of <2%. Given the similarities in the output data derived from both models, we suggest a preferential use of the Weibull model due to its strength of results and easier computation compared to the linear model. Moreover, the  $\lambda$  and  $k$  parameters of the Weibull model supply information on the fertility and maturity of the age-structured populations, which are useful for differentiating among the reproductive strategies of the species compared. Therefore, our results suggest that the Weibull model is a valuable tool for investigating the availability of meat resources and the level of competition among carnivores in the Pleistocene communities of large mammals that inhabited Europe during the Pleistocene.

P-1218

**The vulnerable giant; establishing a window of extinction for the ultimate non-adapting - *Gigantopithecus blacki***

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**Abstract**

The infamous giant ape *Gigantopithecus blacki*, the king of all Asian megafauna, was the largest ever primate and the only ape to go extinct in the Quaternary. Its abrupt disappearance from the fossil record is significant and has implications for other extinct megafauna and for understanding the adaptation and survival capabilities of the surviving species, including humans. This ape is shrouded in mystery as it is only known by teeth and mandibles and the cause of its extinction has remained elusive since its discovery in a Hong Kong drugstore in the 1930's. Some have argued that Giganto was vulnerable to changing climates and environments as it could not adapt when its preferred forested habitat deteriorated. But before the true cause of this giant's demise can be determined an accurate window of extinction must be established to pinpoint exactly when this ape dropped out of the fossil record. The precision in this timeline is essential as it will represent a vital tipping point on which palaeoenvironmental combined with palaeobehavioural evidence can be interpreted. This will allow an assessment of the vulnerability of the giant ape within the prevailing environmental conditions.

In this talk we will outline a new Bayesian modelling approach to establishing the extinction window of Giganto using luminescence, U-series, ESR and cosmogenic dating techniques applied to 19 caves sites in southern China. Using both a fossil and sedimentary context for dating and sampling both Giganto-bearing and non-Giganto bearing caves we have reconstructed a point in time when giants ceased to roam this region.

P-1219

## Rise of the giant deers in China and the related palaeoenvironmental issues

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### Abstract

One million years ago, the giant ruminant guilds of continental Eurasia were dominated by cervids rather than by bovids as that of today. The Villafranchian giant deer taxa include *Arvernoceros*, *Eucladoceros*, *Libralces*, *Cervalces*, *Sinomegaceros*, *Praemegaceros* and *Megaloceros*, all of which have body weights over 300 kg, and some of them even reached 870 kg. In East Asia, the pre-Villafranchian cervid guilds were usually dominated by small- to medium-sized three-tined deers of Cervinae and Muntiacinae. How the giant deers rose so abruptly and how they spread so quickly are still unsolved scientific questions. Among the Villafranchian giant deers, the comb-antlered deer *Eucladoceros* is the most peculiar taxon, which inhabited Eurasia in the middle and high latitudes during most part of the Villafranchian, and the most striking evidence is that it appeared in East Asia and West Europe almost at the same time. Although the species of *Eucladoceros* in China is prominently different from the co-generic species in Europe in morphology, the recent recoveries support a close relationship between them. The quick communications or migrations of mammalian fauna can be attributed to the spreading of the open habitats in Eurasia.

P-1220

## Woody ecosystems in the Galician Rias Baixas at the end of the last glacial cycle: regional biodiversity, biotopes and mesoclimates

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### Abstract

Multiproxy data obtained from lakes and shallow marine sediments in NW Iberia allowed a more complete approach to the climate and the ecosystems dynamics in this region during the Late Pleistocene. Pollen evidence reveals that several types of coniferous, heath communities and broadleaved forests persisted between ca. 60-10 kcal. yr BP in different coastal valleys of NW Iberia. Particularly, the Galician *Rías Baixas* hosted quite different types of cryoxeric vegetation, among them: a) xerophilous communities with pine and juniper that likely inhabited coastal dunes; b) coastal wet/dry heathlands and c) cryophilous birch forests on coastal lowlands that were directly affected by the frontal systems and the coastal upwelling. Besides, we also found evidence of more mesic vegetation like: c) beech forests existing on oceanic slopes of some coastal highlands, where they probably found a humid atmosphere, with precipitation well distributed throughout the year, and a well-drained soil; and d) different mesophytic deciduous forests including hornbeam that might be comparable to the oak-ash, ravine and hardwood floodplain forests currently existing in other Atlantic and Continental regions of Europe. Therefore, a complex mosaic of woody habitats existed in this relatively small area, formed by species able to adapt and take advantage of different types of mesoclimates derived from the interaction between the regional climate, the upwelling cells and the coastal morphology. At the end of the Lateglacial period the climate become more oceanic in this region and the sea-level rose. Thus, at the beginning of the Holocene large areas of these coastal ecosystems were submerged by the sea and disappeared, while other upland zones were transformed, firstly covered by saltmarshes and then replaced by heathlands and oak deciduous forests.

P-1221

## A palaeoecological investigation of Scots pine (*Pinus sylvestris*) refugia in north-east Wales and Shropshire.

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### Abstract

Since its arrival in the British Isles around 10,000 cal yr BP, native *Pinus sylvestris* was widely distributed throughout the region and reached its maximum extent ~4500 cal yr BP. Around 4000 cal yr BP, it suffered a widespread and sudden demise, which is attributed to various factors such as climatic deterioration, competition with other tree species, anthropogenic effects, pathogens and volcanic activity. Currently, populations of native Scots pine are geographically isolated to the Scottish Highlands, while in the rest of the British Isles they exist only as plantations after being re-introduced as non-natives in the 1800s. This has caused significant debate regarding the presence of native Scots pine outside this recognised range. This study, undertaken in the framework of an MSc dissertation submitted to the University of Manchester, and in collaboration with the Woodland Trust for Wales, aims to understand the ecological history of present-day Scots pine populations found on the steep crags of Nesscliffe Hill, Shropshire. A 3m sediment record dating from 7000 cal yrs BP was extracted from Lin Can Moss (LM18), a small raised ombrotrophic bog adjacent to Nesscliffe hill. A basal radiocarbon date and palynological evidence of the elm (*Ulmus*) decline and the arrival of beech (*Fagus sylvatica*) help constrain the timeframe of the record. The record reveals a pine decline around ~3500 cal yr BP, but also suggests that Scots pine may have survived and persisted locally until at least ~2000 cal yr BP. This suggests that the area may have acted as a refugium, protecting Scots pine from climatic deterioration and human pressures. A novel approach using morphological analysis traced the size of fossil *Pinus* pollen grains throughout the LM18 record, and compared with fossil material of comparable age from Bennachie (BEN), Scotland, for both Mid-Holocene and sub-recent samples. For both age ranges, LM18 pine grains are significantly larger than in the BEN samples. This analysis supports that pollen at LM18 was deposited locally and was not derived from populations further north. The difference in grain size between LM18 and BEN may be caused by the different prevailing temperatures at the sites. Overall, the pollen record and morphological analysis point towards the persistence of small locally native Scots pine populations on the steep crags of Nesscliffe Hill, although the search for “smoking-gun” macrofossil, stomatal and DNA evidence continues. The findings have significant implications for the restoration of ancient woodlands and suggest that more focus should be directed towards the conservation of potentially native Scots pine in this area. Protecting locally native Scots pine will help mitigate the effects of climate change and promote adaptation of the species.

P-1222

## Last deglacial warming improving snail species diversity in fragile ecological region of East Asia

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### Abstract

Global warming poses increasing threats to terrestrial ecosystems, the recognition of which is leading to concerns that a wave of species extinctions may be imminent. Understanding how organisms adapt to past climatic warming is important for assessing potential biotic responses to future climate change. Terrestrial mollusks are an important component of terrestrial ecosystems mainly because of their key role as a trophic link between animals and plants. However, our knowledge how the structure and diversity of mollusk communities respond to past climate warming in fragile ecosystems is limited. Here, we present three well-dated high-resolution terrestrial mollusk records spanning the last 25,000 years from the Chinese Loess Plateau (CLP) and examine their past response to natural climatic warming since the last deglacial. Our fossil records show a low-diversity mollusk fauna in the Last Glacial Maximum, a significantly more diverse early to middle Holocene fauna exceeding today levels, and a decline in diversity in the late Holocene. The net gain in species diversity during the last deglaciation, consistent with the rise in northern hemisphere temperature, is more significant in northerwestern sites than in southeastern sites. However, in spatial no matter what the substages, the species diversity in southern sites (~10 species) is always higher than that in the northern sites (~4 species). These results suggest that the natural warming of ~2°C higher than today is beneficial for the increase of mollusk species diversity, particularly in the species-poor communities of fragile ecological region in East Asian monsoon.

**P-1223**

## **Holocene paleoenvironmental changes in Upo Wetland of Korea and their link to flooding event**

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### **Abstract**

Upo Wetland is the largest riverine wetland in Korea which has been inscribed on the Ramsar List of Wetlands of International Importance in 1998. In this study, sedimentological study was carried out in order to understand the environmental changes in Upo Wetland during the Holocene. The drilling work for recovering the Quaternary sediments was conducted on the inner part (UPW01, UPW02, UPW03) and the outer part (UPL01, UPL02) of the present Upo Wetland. The recovered sediments are commonly characterized by gravel-dominated deposits in the lower part and silty clay-dominated deposits in the middle to upper parts respectively, which are seemed to be changed from fluvial to palustrine/lacustrine environments around 4,000 cal yr BP. The abundant benthic and epipelagic diatom species are interpreted this area lasted for 4,000 years as a low flow velocity and water discharge. In particular, while the palustrine/lacustrine environments were maintained, the increasing diatom abundance, organic matters and high sedimentation rate in the sand-dominated deposits at the altitude of about 6-7 m are likely to be associated with flooding event around 1,300 cal yr BP. The commonly change from clay-dominated deposit to sand-dominated deposit since 1,500 years in the cores DSR09 and STP18-05 around the Nakdong River indicates the flooding event of the Nakdong River affected to Upo Wetland.

P-1224

## Can we infer humidity gradients across the Ural Mountains during the Late Quaternary using arvicoline rodents as a paleoclimate proxy?

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### Abstract

Nowadays, the large-scale humidity gradients in the central part of Northern Eurasia are primarily determined by the latitudinal insolation gradient inducing the southward increase of evaporation, and the barrier role of the Ural Mountains against the Atlantic warm and humid air masses. The present-day climatic gradients are clearly reflected in the spatial spread of natural landscape zones and in the distribution patterns of particular plant and animal species. Here, we consider arvicoline rodents, the most widespread and abundant mammalian group in the Quaternary paleo-archives of the Northern Eurasia, as direct indicators of particular habitat characteristics, and as indirect proxies for climatic reconstructions. We classify 15 native arvicoline species known in the central part of Northern Eurasia since the Late Pleistocene into 5 groups based on the vegetation type and moisture balance of the breeding and survival habitats of their extant representatives. We identify the species groups of the hygro-, mesohygro-, meso-, mesoxero-, and xerophytic habitats and calculate the occurrence of each group in the micromammal assemblages from 32 multi-layer localities situated on the western and eastern macroslopes of the Northern, Middle, and Southern Urals. Based on the absolute and relative dating methods, the dataset is divided into the Late Pleistocene, Early, Mid-, and Late Holocene subsets. An analysis over the large-scale latitude-longitude grid reveals the significant southeastward increase in the frequency of occurrence of the species confined to xerophytic habitats in each of the temporal subsets. This result indirectly confirms the stable role of the Ural Mountains in shaping the west-east precipitation gradient during the Late Pleistocene – Holocene. However, the biogeographic barrier role of the Ural Mountains was changeable. In the Late Pleistocene, the environmental gradients favored 1) the uniformity of the arvicoline faunas on both western and eastern slopes of the Northern Urals, and 2) the distinctiveness between the faunas on the opposite slopes of the Southern Urals. During the Holocene, the differences between the slopes of the Southern Urals were leveled off whereas the faunas of the Northern Urals acquired significant differences between the slopes. The results suggest that arvicoline rodents may be successfully used for reconstruction of the environmental gradients across large spatial scales. The approach based on arvicolines appears to be especially important for the paleo-archives comprising no reliable paleobotanic data (e.g., the numerous karst caves of the Ural Mountains). When considering responses by individual species to climate change, all types of response might be referred to as 'species-specific habitat-related movements'. Two patterns of range contraction leading to the degradation of the Late Pleistocene non-analogous arvicoline communities are identified, including 1) gradual species declines, and 2) patchy extinctions. The study is supported by RFBR, grant № 19-04-00966.

P-1225

## The fight for survival; Pleistocene faunal contexts before, during, and after *Gigantopithecus blacki*'s extinction

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### Abstract

*Gigantopithecus blacki* is the largest hominoid that ever lived. It is known primarily from Early and Middle Pleistocene cave sites in southern China, dating from 2.0 Ma to ~300 ka, when it drops out of the fossil record. The cause of its extinction in the late Middle Pleistocene is unknown. Ecological change may have been the contributing factor. There was a progressive increase in dental size from the Early Pleistocene to the Middle Pleistocene, and possibly a shift towards greater complexity of the cheek teeth. These microevolutionary morphological changes may be evidence of adaptations to survive.

Here we report chronologically successive Pleistocene mammalian faunas from four cave sites in Chongzuo, Guangxi ZAR, China to establish the faunal contexts before, during and after *Gigantopithecus blacki*'s extinction. The four cave sites are Early Pleistocene Baikong Cave, Middle Pleistocene Yixiantian Cave and Hejiang Cave, and late Middle Pleistocene Baxian Cave. The faunas from these caves are represented mainly by dental remains of the *Stegodon-Ailuropoda* fauna (*sensu lato*), which set the stage for the rise and fall of *Gigantopithecus blacki*. In an attempt to establish the role played by *Gigantopithecus blacki* in this faunal assemblage the cause of its extinction, the compositional dynamics and chronological transitions of the *Stegodon-Ailuropoda* fauna are analyzed based solely on the taxonomic and morphological studies of the newly found dental remains.

P-1226

## Long-term treeline dynamics in the Central Pyrenees revealed from an ice cave

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### Abstract

An increasing number of studies are evidencing the significant changes that mountain ecosystems are experiencing in relation to global change. For instance, changes in plant communities occurring across altitudinal gradients are affecting biodiversity. Palaeoenvironmental approaches may provide significant insights into long-term vegetation changes to manage these new scenarios in a proper spatio-temporal context. Lacustrine sequences are the most common deposits recording vegetation change on long timescales but other archives, such as sub-superficial ice, can be key for accurate reconstructions in mountain landscapes.

We present here a pioneer study from the Armeña-A294 Ice Cave (2238 m a.s.l.), located in the Cotiella massif (Spanish Central Pyrenees) with the first pollen and plant macrofossil record from an ice cave ever studied in the Iberian Peninsula.

The ice deposit contains several detrital layers with plenty of plant remains, which provide detailed palaeoecological information and allow obtaining an accurate chronology based on replicated <sup>14</sup>C dates on terrestrial plant macrofossils. The period recorded spans the mid to late Holocene, with ages ranging from 5700 to 2200 cal yr BP, making it the oldest known firn ice cave worldwide.

This extraordinary archive preserves frozen pollen and plant macrofossils and is therefore ideal to assess the processes that controlled both local and extra-local plant species dynamics over time, and to infer the long-term vegetation and treeline fluctuations in the area (DOI:10.1111/1365-2745.13077).

The ice record shows that altitudinal treeline changes were closely linked to summer temperature changes. Thus, 5700 years ago mountain pines (*Pinus uncinata*) were dominating with birches (*Betula* spp.) in the surroundings of the ice cave at ca. 2250 m a.s.l., significantly higher up than today's maximum altitude reached by trees (2000 m a.s.l.). Approximately 4600 years ago, a progressive lowering of the treeline occurred together with the establishment of alpine meadows dominated by *Dryas octopetala* in response to the Neoglacial cooling trend. The treeline shifted upwards again ca. 3200 years ago, but did not reach its uppermost positions (before 4600 cal. BP), as documented by the persistence of alpine meadows. This treeline ecotone persisted near the cave until the end of the record 2200 years ago, when the ice sequence ends. The current landscape is very different to that of 2000 years



ago as currently only alpine meadows are present, suggesting that during the last two millennia large disturbances, either climatic or human, might have led to a depression of both treeline and timberline resulting in their current positions in the Armeña cirque.

The long-term sensitivity detected in these subalpine Pyrenean ecosystems is essential to assess future ecosystem dynamics under global change conditions. Ice archives are, however, severely endangered by rising temperatures and more scientific attention is needed in order to rescue their untapped information.

P-1227

## Reconstructing Pleistocene plant community shifts from the La Brea Tar Pits, and implications for regional plant response to climate change

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### Abstract

Today, generalized patterns in the shift of plant species' distributions can be observed, or are anticipated, across the globe in response anthropogenic climate change. While similar larger-scale shifts are also observed in the Quaternary palaeobotanical record, evidence can be found for diverging patterns of individual species' responses on smaller spatial scales. How such individualist responses play out at regional scales is an important question. Understanding how and why these spatial dissimilarities in the response of terrestrial life occur is necessary to the management of changing terrestrial ecosystems in the future. This study uses plant macrofossils excavated from the La Brea Tar Pits in Los Angeles California to reconstruct past plant communities from the past 55,000 years - ranging from the Late Pleistocene and into the Holocene. Macrofossils are identified to species or genus using morphological traits and comparative modern specimens. Identified fossils are then radiocarbon dated using accelerator mass spectrometry. Thus far a total of 136 macrofossils have been identified and dated. Preliminary findings indicate significant range extensions southward and westward by genera such as *Pinus* and *Juniperus* during MIS 2 and 3. The macrofossils also suggest development of communities with no clear analogue today. The replacement of cypress and pine species with juniper and oak during MIS 3 is a possible indication of a drier climate during this mild interglacial than previously thought.

P-1228

## Palynological record for Holocene vegetation and environmental history on the southern coast of South Korea

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### Abstract

Age-constrained high resolution palynomorph analysis of the STP16-20 sediment core obtained from the southern coastal region of the Korean Peninsula (KP) was carried out to clarify paleoclimate history during the Holocene. Palynological record shows the obvious environmental and vegetation changes against the relative sea level change and East Asian summer monsoon (EASM) oscillation, respectively. Our multi-proxy data (palynomorph, mean grain size, TOC, TS, C/N ratios, and  $\delta^{13}\text{C}_{\text{TOC}}$ ) indicate that the depositional environment has changed at about 7500 cal yr BP from fluvio-coast to subtidal zone by sea level rise. At that time, sudden increasing of AP (arboreal pollen) and *Alnus* pollen profiles may reflect the abrupt depositional environmental change and local humid conditions near the coast environment, respectively. In addition, the critical pollen taxa suggest a significant shift in vegetation community at about 8000 cal yr BP; sharp decline in cold taxa (*Abies*, *Betula*, *Picea*, and *Pinus-Haploxyton*) and, in contrast, predominance of *Quercus-Lepidobalanus* and *Pinus-Diploxyton* (= Japanese black pine) together with the high proportion of freshwater discharge indicators (fern spores and *Pseudoschizaea*). These pollen assemblages refer that a mixed of deciduous and conifer forest flourished under the warm and humid conditions by enhanced EASM and sea level rise during about 8000-5900 cal yr BP. Since about 5900 cal yr BP, *Pinus* (*Haploxyton* and *Diploxyton*) were predominant, whereas *Quercus* was in decline due to weakened EASM. Our pollen record is well accordance with previous pollen studies of the other coast area in the KP. The Holocene climate changes on the southern coast of the KP might be controlled by activity of the East Asian monsoon. Noteworthy, the two dominant taxa of *Quercus* and *Pinus* display the opposite spectrum in their occurrence, and also it markedly has quasi-Periodicity at Centennial timescale during the early- to mid-Holocene (between approximately 7500 and 4000 cal yr BP). The mutual work with other cores in future is required to interpret more detailed the Holocene paleoclimate and paleoenvironment.

P-1229

## The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ record of the world's last woolly mammoths (*Mammuthus primigenius*): thriving or surviving?

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### Abstract

The last woolly mammoths (*Mammuthus primigenius*) persisted on arctic islands several thousands of years into the Holocene, and finally became extinct at ca. 4,000 cal BP following a dramatic contraction of range size during a period of major climatic changes. Mammoths had survived similar climatic changes in earlier Pleistocene, reducing and confining their range to the north during warming episodes and expanding again during colder times.

To examine the level of ecological flexibility of woolly mammoths and their response to regional climatic warming, we analyzed collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in subfossil bones and teeth of the last population of woolly mammoths on Wrangel Island, and

specimens collected from the Bykovsky peninsula in Siberia. These new records were compared to a compilation of corresponding previously published data from the last representatives of the species in Europe, Siberia and northwestern North America. Altogether, we present new data for > 70 mammoth specimens on Wrangel Island and Siberia, most of them directly radiocarbon dated.

During their peak occurrence times, woolly mammoths all over northern Eurasia showed a consistent pattern of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values compared to sympatric large herbivores, with relatively low  $\delta^{13}\text{C}$  values and conspicuously high  $\delta^{15}\text{N}$  values reflecting a specific dietary niche. The gathered isotopic data for Europe and Siberia suggest alteration or disappearance of this niche towards the end of the record. Some populations maintained their accustomed specific isotopic niche, but were overlapping with coeval horses, a situation suggesting a reduction of mammoth population. In contrast, the mammoth population from Wrangel Island does not exhibit any clear ecological change from 10 to 4 kyr BP as judged by their  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values, and are comparable to their earlier, "full ice-age" counterparts in mainland Siberia. Compared with sympatric ungulates, it appears that the Wrangel Island mammoths were able to maintain a position in the  $\delta^{13}\text{C}$ - $\delta^{15}\text{N}$  isospace similar to that of the late Pleistocene populations in continental Eurasia.

Most likely a combination of cold high arctic conditions, low competition and predation, as well as the impact of the mammoths themselves on maintaining the plant community, allowed this insular population to survive despite climatic change. The final extinction of the Wrangel Island woolly mammoths is not reflected in their  $\delta^{13}\text{C}$ - $\delta^{15}\text{N}$  values, and appears to have caught the population at a time of stable climate, range size and dietary status. There is no evidence of mammoth hunting by modern humans on the island, but it is conceivable that their actions probably increased the stress level of the population to a level beyond survival capabilities and contributed to the final extinction.

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**P-1230**

## **Un-extirpating pine in western Ireland – it didn't die, it was just hiding.**

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### **Abstract**

*Pinus sylvestris* was a dominant tree across northwest Europe during the early Holocene. Competition from other tree species, habitat loss and human exploitation all contributed to its asynchronous decline and apparent extirpation across much of its former range, including in Ireland, England, Wales, the Netherlands, Belgium and Denmark. *Pinus sylvestris* has been widely planted over recent centuries and now forms semi-natural forest stands across most of its former range. Palaeoecological analyses in western Ireland have identified a putative native stand of *Pinus sylvestris* that has continuity with prehistoric populations. The environmental setting and history of this site provides guides for exploring the continuity of *Pinus sylvestris* elsewhere in its former European range.

P-1231

## Amino acid nitrogen isotope analysis suggests herbivory for Romanian cave bears (*Ursus ingressus*)

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### Abstract

The feeding habit of cave bear complex that went extinct around the Last Glacial Maximum (LGM), the period with the coolest and harsh climate condition during the late Pleistocene, has been intensely debated based on tooth and jaw morphologies, stable isotope analysis, etc. While many cave bears in Europe exhibit relatively low  $\delta^{15}\text{N}$  values of bulk bone collagen that suggest dominant if not exclusive herbivory, some specimens from Romanian sites exhibit relatively high  $\delta^{15}\text{N}$  values. Such values have been interpreted by some authors as reflecting omnivory or carnivory for these cave bear populations. However, without knowing the isotopic baseline represented in plants at the start of food-webs, a value that can be spatiotemporally variable, a herbivorous diet based on plants with high  $\delta^{15}\text{N}$  values cannot be ruled out. Here we use a new approach based on  $\delta^{15}\text{N}$  values of individual amino acids from collagen that offset the baseline  $\delta^{15}\text{N}$  variation among environments. Our analysis performed on cave bears with high variability of  $\delta^{15}\text{N}$  in their bulk collagen, from the Romanian sites of Măgura, Cioclovina and Răsuflătoarei caves, yielded strongly herbivorous signals that can be seen especially in the  $\delta^{15}\text{N}$  values of glutamate and phenylalanine. Therefore, these results support the claim that the high  $\delta^{15}\text{N}$  value of collagen observed for cave bears in Romanian region were most likely caused by their local plant diets with high  $\delta^{15}\text{N}$  values, rather than by an omnivorous feeding behaviour of this species. Since both types of herbivorous cave bears inhabited the same caves at the same time or over a relatively short time span of about 2,000 years, some with low collagen  $\delta^{15}\text{N}$  values and others with high  $\delta^{15}\text{N}$  values, further research is needed to understand which types of plants with high  $\delta^{15}\text{N}$  values were involved in this dietary difference and which factors drove the niche partitioning among coeval cave bears in Romania, but not in other areas of Europe.

P-1232

## Pre- and postcolonial vegetation and settlement history in the North Pare Mountains derived from the Umbwane swamp pollen record

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### Abstract

Umbwane swamp is located at 1300 m in the North Pare Mts., Tanzania. The pollen archive spans the past ca. 1120 to 1960 yr AD/BC and allows the detailed reconstruction of the progressive human settlement of the area.

The first 200 yrs until ~ 1350 yr AD/BC abundant Cyperaceae and montane forest suggest that the Umbwane swamp was a small, more closed forest swamp surrounded by dense montane forest with a diverse understory dominated by Poaceae and ferns. Dry woodland was probably present at the lower slopes in the transition to savanna in the colline zone as where it can also be found today. After 1350 yr AD/BC, the strong reduction of montane forest indicates the begin of deforestation, most likely due to the need for firewood for iron smelting activities which are known to have taken place in the Ugweno area since that time (12). 1440 yr AD/BC marks a first opening of the swamp area as indicated by the increase of the fern *Cyclosorus interruptus*. Simultaneously, the forest abundance reaches a minimum suggesting intensified iron smelting and related activities took place close to the study site. After 1640 yr AD/BC, the pollen record shows an opening and expansion of the swamp area most likely due to permanent settlements. The first local maize cultivation around 1820 yr AD/BC precedes the first silviculture of exotic tree taxa (*Eucalyptus*, *Cupressus*, *Pinus*) roughly 50 yrs later introduced as part of the German colonialism (1881-1963). Simultaneously to the silvi- and agricultural activities, the swamp area becomes very open. The abundance of woodland and montane forest remains low as the largely opened area is heavily used for agricultural. The sudden decline in anthropogenic indicators and swamp vegetation at the end of the 19th century might represent the beginning of the climatic drought, causing a devastating famine in the North Pare which resulted in the collapse of the political and economic system debilitated by epidemics and warfare. After about 1940 yr AD/BC the swamp area is strongly reduced again due to drainage for the creation of arable land. This trend seems to have continued until today. This unique late Holocene pollen record gives detailed insight into the pre- and postcolonial vegetation and settlement history of the North Pare and complements very well the numerous archaeological sites - mostly associated with iron smelting – that were recorded throughout North and South Pare as well as in the Usambara Mountains.

P-1233

## Assessing the significance of testate amoeba shell morphology as an indicator of nutrient status in lakes

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### Abstract

There has been an unprecedented growth in recent years in the measurement of functional traits (FT) in many biological groups, particularly plants. These are measured characteristics that define species in terms of their ecological roles, i.e. how they interact with the environment and with other species. Traits have been used, for example, to study the fundamental constraints on plant evolution, to explain community assembly and to understand ecosystem function. Traits-based approaches have, however, been used comparatively rarely in Quaternary palaeoecological studies, as many biological groups are limited by issues of poor preservation and incomplete records. Traits-based approaches have nevertheless been applied to some fossil groups, e.g. Pleistocene mammal remains, which in turn have been compared with other palaeoecological datasets (e.g. pollen) to examine trait-environment relationships.

There is considerable potential to apply traits-based approaches to the subfossil remains of shell-forming micro-organisms like testate amoebae that are abundant and diverse, and whose short generation times make it possible to achieve high temporal resolution in palaeoecological studies. This has been highlighted in recent work with peatland testate amoebae that showed that traits can be used to reconstruct water table depth changes independently of species data (e.g. Lamentowicz et al., 2015). In this paper we review the potential for applying traits-based approaches to arcellinid testate amoebae (Arcellinida), a diverse group that dominate testate amoeba communities in lakes. In particular, we describe results from the 'ECOTRAIT' project, which is employing interdisciplinary methodologies to examine the utility of trait-based approaches for lacustrine Arcellinida. Specific project objectives include: to examine the character and causes of FT variability in modern and palaeo-limnological settings; to develop novel biometric approaches to aid in trait delimitation; and to evaluate the significance of trait-based approaches for understanding temporal changes in species composition. In this paper we describe the methodologies that can be applied to delimit traits, review some of the challenges associated with trait characterisation and measurement, and present traits-based data from sediment cores from lakes in Scotland and Norfolk. These both have a history of eutrophication related to catchment disturbance that has been inferred from other fossil groups (including plant macrofossils, diatoms, invertebrates). They thus form important test sites to examine the relationship between arcellinid test morphologies and trophic status.

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**P-1234**

## **Deconstructing biodiversity and ecosystem loss in Southern Europe during the Pleistocene**

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### **Abstract**

The multifaceted evolutionary history of fauna and flora leading to the modern biodiversity and biogeographical setting mingles with palaeogeographical, climatic and environmental changes. However, the actual role of climate in driving flora and fauna dynamics, geographical range dispersal, configuration, originations and extinctions along geographical gradients is a still highly debated topic in palaeobiology and palaeoecology.

The biotic response of individuals, species and communities to climate change, including warming and cooling events/periods, as well as changes in seasonality and precipitation regime, and occurring on different time scales, from glacial/interglacial cycles to a few decades, is a decidedly complex phenomenon. For example, an unexpected result is that some organisms seem to have remained “unchanged” over thousands to perhaps millions of years in the face of environmental perturbations and species invasions. The Quaternary period, recording the most dramatic change in the Earth climate system, is of particular interest for deciphering the actual relationships between climate changes and ecosystem evolution.

With the aim of scrutinizing the causal factors leading to the progressive changes in biodiversity, species demise, and reconstruction of plant and mammalian communities during the Pleistocene, we have analysed and compared the trends shown by South European plants and large mammals at local (Spain, France, Italy, and Greece) and regional (North Mediterranean) scale. Evidence from past vegetation shows a Quaternary-long persistence of some tree taxa. Other taxa undergo a progressive disappearance that in some cases may be related to long-term climate changes, for example at the transition Gelasian/Calabrian and Early/Middle Pleistocene, and in other cases may reflect long-term tree population dynamics. Evidence resulting from the analysis of SE mammalian fauna strongly supports the hypothesis of a climatic driven displacement of a number of taxa. Each species enlarged, displaced or contracted its geographic range as the environmental conditions were suitable or not for it. Other biotic and abiotic factors contribute to differentiate time and mode of dispersion from species to species, merging new species in the previously existing communities, leading to new competition dynamics that contribute to shape the progressive change of SE Pleistocene fauna at a different pace and rate in different territories.

All in all, the comparison among the general trends of vegetation and large mammal fauna in SW Europe during the Pleistocene shows that the dynamics of plant and animal communities significantly varied during time at a different pace and extent. Plant communities, for instance show a remarkable persistence, while a number of new and last appearances are found in mammals, so that there is no substantial loss of richness. Some hypotheses are discussed to explain this complex, intriguing pattern.

P-1235

## Palynological evidence of *Picea omorika*-type dominated forests in the classical interglacial site of the Hötting Breccia (Northern Calcareous Alps, Austria)

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### Abstract

While deposits of the Last Glacial Maximum are widespread in the Alps, sediments pre-dating the Last Glacial Maximum are rare, mainly due to repeated overprint by glacial ice streams. An exception is the Hötting Breccia, a thick and complex succession of Pleistocene slope- and alluvial fan deposits preserved on the south-facing slope of the Nordkette range near Innsbruck (Austria). Since the 19<sup>th</sup> century, geologists and botanists have been fascinated by this site, famed for its spectacular record of macrofossil imprints including woody taxa extinct from the Alps today (e.g. leaf imprints identified as *Rhododendron ponticum* var. *sebinense* Sordelli).

We carried out a re-appraisal of this classical interglacial alpine site focussing on the fossiliferous lacustrine sediments in the basal part of the Hötting Breccia at Rossfall-Lahner and using the slabs that bear fossil plant imprints. All studied samples (calclutites, calcisiltites, calcilithic arenites) contain fossil palynomorphs and, to our surprise, some of them provide palynological evidence of *Picea omorika*-type dominated forests, with minor contributions of *Picea abies*-type and by other evergreen and deciduous trees. The taxonomical assessment of fossil pollen of spruce was analyzed at the population level by comparing fossil pollen grain populations of 11 samples from the Hötting Breccia with 18 living populations of several W-European, Asian and Canadian spruces. We set up practical criteria for the specific diagnosis for light- and scanning electron microscope, and evaluated their functional and phylogenetic value. The recent discovery of functional traits in *Picea* pollen morphology allowed to define new pollen types of phylogenetic importance in Eurasian *Picea*.

The results support the presence of a spruce forest – at times dominated by Serbian spruce – in the upper montane to subalpine belt of the Northern Calcareous Alps during an interglacial younger than Marine Isotope Stage 22. Geochronological age constraints of the Rossfall-Lahner interval using optical dating techniques suggest that this site, whose flora has been traditionally considered as typical of the Riss-Würm interglacial, is early Middle Pleistocene in age, consistent with U-Th-dated (minimum) age constraints provided by vein-filling calcite.

P-1236

## Did brown bear expanded from Iberia to Scandinavia after the LGM? A cryptic Atlantic refugium out of the Iberian Peninsula

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### Abstract

During Pleistocene glacial phases, southern European peninsulas were the refugia for temperate species that followed a model of contraction-expansion forced by climatic oscillations. The European brown bear (*Ursus arctos* L.) phylogeography was used to illustrate this model because of the relationship between modern Iberian and Southern Scandinavian populations.

Recent studies indicate that this generally accepted paradigm of the southern peninsulas as glacial refugia has exceptions that indicate an existence of cryptic refugia for some species further north. After an exhaustive compilation of available genetic and radiometric data from Western European brown bears, and adding new sequences of current bears from the Iberian Peninsula, we try to reconstruct the postglacial dynamics of this species in West Europe, mainly in the Iberian Peninsula.

For the model of the Iberian Peninsula as a refugium to be fulfilled, the Iberian Pleistocene brown bears, glacial and pre-glacial, would have to be the direct ancestors of the rest of the Atlantic post-glacial bears. Both data, genetics and chronology, show that the Iberian Pleistocene lineages were not the direct ancestors of the Holocene brown bears of western Europe. However, there is no continuity in any of the Pleistocene lineages in the Holocene of the Iberian Peninsula. All defined haplotypes were extirpated during the LGM at least in the North. After a gap in the record that coincides with the LGM, radiometric dating shows a sudden abundance of Cantabrian bears that we interpret as a late recolonization of the Peninsula. In Britain the same pattern of sudden abundance is observed coinciding with the melting of the glacier caps, about 15,000 years BP. In Iberia, this expansion occurred after the Younger Dryas.

So, the first area of Atlantic Europe to be recolonized after the ice retreatment was the British Isles. Brown bears entered Iberian Peninsula belatedly (around 10,000 years BP), and finally Southern Scandinavia was the last place to be colonized (9,500 – 7,500 years BP) when a land bridge were suitable. We therefore propose the existence of a cryptic refugium in continental Atlantic Europe, from where the bears would expand as the ice receded. The delay in the recolonization of the Iberian Peninsula could be due to the orographic characteristics of the Pyrenean-Cantabrian region and to the abundant presence of humans in the natural entrance to the Peninsula.

The Iberian Peninsula was considered traditionally as a glacial refugium for large mammals and humans, but with the available data, neither the 14C ages nor the mtDNA data support an Iberian refugium for the brown bears during the LGM, at least for those that recolonized the British Isles and the south of Scandinavia.

**P-1237**

## **The late Pleistocene and Holocene Thecamoebians from lake Stará Jímka in the Šumava Mts.**

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### **Abstract**

At the end of the last glacial period after glacier retreat the today defunct lake Stará Jímka was created (Břízová et Mentlík, 2005a; Mentlík et al. 2010). Its sedimentary record captures the climate changes in the last 15 000 years (periods bøling, allerød, younger dryas and early holocene), during recent it was buried (Mentlík et Břízová, 2005). For the study of the paleoenvironment of Šumava lake we can use testate amoebae alternatively Thecamoebians (Arcellinida), whose species composition is preserved in the sediment of the defunct Šumava lake Stará Jímka (Břízová et Mentlík, 2005a; Mentlík et al. 2010).

In the past few years, dr. Lorencová and doc. Holcová were studying Thecamoebians from Šumava Mts. in the Czech Republic. Within the project GA AVČR „Actuoeecology of freshwater Thecamoebians from the Šumava Mts“ they observed hydrological changes in the recent sediment of Lipno Dam. (Holcová et Lorencová, 2004b). After that Lorencová (2009) studied Thecamoebians from the Šumava Mts.

A sedimentary well (profile thickness of 1.5 m, thickness of 3 cm, 36 selected layers) was taken from Stará Jímka Lake and provided by the Institute for the Environment. Communities of Thecamoebians were described from the collected samples. Most of the communities consists mainly of species with the agglutinated type of the test, because the sediment is composed mainly of particles of sand and sandy gravel. The individual samples differ not only in frequency and size, but also in species diversity, which includes only a few species, especially genus *Diffflugia*. For some selected samples, higher tests damage can be observed.

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**P-1238**

## **An american brown bear clade in the Late Pleistocene of the NW Iberia? A new model for brown bear expansion**

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### **Abstract**

Of a total of 77 mitochondrial DNA sequences of brown bear from the Iberian Peninsula from literature, both fossil and modern, only 2 (2.6%) aren't from clade 1, the typical clade of Western Europe.

One of those individuals is a  $27178 \pm 433$  years BP ( $31879 \pm 349$ calBP) male bear from Arlanpe cave (north central Iberian Peninsula) and belongs to clade 3c, and the other one is a female from Sumio de Casares cave (NW of the Iberian Peninsula),  $25780 \pm 220$  years BP ( $30833 \pm 381$  calBP) from clade 4. For this work, the complete mitochondrial DNA of the Sumio de Casares bear has been sequenced. Both of those brown bears are from the final phase of MIS 3, which is characterized by a gradual cooling of the climate. Clade 4, is currently only found in North America, and the bear from Sumio de Casares is so far the only Western European individual from this group. Clade 3c is an extinct clade present on both sides of Beringia strait.

This work presents a hypothesis that explains how the Sumio de Casares bear has reached a place so far from its current geographic range, and serves as the basis for a model to explain the distribution of all modern and fossil brown bear clades. For this purpose, we combined data from the literature of modern and ancient DNA, radiocarbon dating and modern distributions of the different clades. The divergences between clades have been calculated using BEAST and comparing it with other published data.

This model proposes the existence of a cryptic core or cores located in central Asia from where the bears expanded again and again in all possible directions, but in a way conditioned to the orography and the different glacial and interglacial periods. The new expansions superimposed and erased the ancient ones, leaving the bears that expanded first relegated to the most peripheral areas of Eurasia and North America. So, subclade 3a is located from Eastern Europe to Alaska, making this clade one of the most recent and with less variability, whereas clade 1 or 4, are on the extremes of the distribution. The presence of a clade 4 bear in NW Spain, plus the presence of this clade in Contiguous United States and SW Hokkaido make this clade the one with the widest and most peripheral geographic distribution.

In addition, the  $\delta^{18}\text{O}$  of the carbonates of the enamel of a molar and bone of Sumio de Casares bear has been analyzed and comparing it with other contemporary fauna of the zone, to know if this animal was a recent immigrant or if, on the contrary, it belonged to a clade settled extensively in the zone in that specific period

P-1239

## The Late Pleistocene reindeer (*Rangifer tarandus*, Linnaeus, 1758) of Britain and Western Europe: past migrations and seasonality

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### Abstract

During the last glaciation, reindeer (*Rangifer tarandus*, Linnaeus, 1758), a highly specialised cold adapted ungulate, was extremely common throughout Britain and Western Europe in marked contrast to the Arctic and Sub-Arctic distribution of the species today. Such high densities of herbivores would have had significant impacts on ecosystem processes and subsistence patterns for predators including early hominins. By reconstructing the palaeobiogeography (migrations and seasonality) of reindeer over the Late Pleistocene (125,000-11,700 years BP), the impacts of climatic, environmental and anthropogenic changes on reindeer ecology can be more tightly constrained. This is particularly important given the recent global declines in both the body masses and population sizes of reindeer.

As bi-annual migrators, reconstructions of reindeer palaeobiogeography are achieved by examining the seasonality of site occupations through the recognition of seasonal aggregations, primarily using the ageing and sexing of individual reindeer specimens. From the British Late Pleistocene, reconstructions of seasonality primarily imply that migratory reindeer followed a north-south trajectory between summer and winter grazing grounds. However, while these movements appear constrained to within Britain during MIS 5a and MIS 2, multiple signals of seasonality have been recognised from MIS 3 reindeer, particularly in the south of Britain. This has significant implications for reindeer palaeobiogeography under varying climatic and environmental conditions, especially given the fluctuating terrestrial connection between Britain and continental Europe during the Late Pleistocene and the potential, therefore, for east-west movement. In addition to the impacts of palaeoenvironmental and palaeoclimatic changes on fossil reindeer, the influence of herd-specific factors such as density dependence in this species are similarly important. This is evident from reconstructions of body mass from British specimens, which reveal further differences between the reindeer of MIS 5a, MIS 3 and MIS 2. Recent variations in reindeer body size demonstrate that the integration of both fossil and historical specimens is essential to constrain both past and ongoing impacts of climatic and anthropogenic changes on this ecologically vulnerable species.

P-1240

## How the Pleistocene morphogenesis of central Europe reflect genetic structure of small mammals: the case of the root vole (Rodentia)

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### Abstract

The aim of the research was to find out whether and how the landscape of eastern Poland, formed as a result of subsequent Pleistocene glaciations: Sanian 1 (MIS 16), Sanian 2 (MIS 12), Odranian (MIS 6) and Vistulian (MIS 2-5b), affects genetic differentiation of a species. The research was carried out on the root vole *Microtus oeconomus* (Arvicolinae, Rodentia), a model, boreal and hygrophilous species. Samples were collected from 439 vole individuals at 33 locations in different post-glacial landscape zones. Based on analysis of 12 microsatellite loci and the 908 bp of cytochrome b sequences (mtDNA), the genetic structure of *M. oeconomus* in the landscape zones of Polish Lowlands was determined. Longitudinal variability of the relief in the area of eastern Poland (resulting from different limits of Pleistocene glaciations) and the related specific configuration of hydrogenic habitats are reflected in the genetic differentiation of the root vole. All genetic parameters such as average allelic size range, average heterogeneity, the haplotype diversity and nucleotide diversity were very variable within the zones. Results were confirmed by PCA analysis which show population grouping based on  $F_{st}$  among populations and divided them into groups largely depending on the division of the landscape into zones. This division is especially very well visible in analyses of microsatellite DNA. Very similar results from STRUCTURE analysis were found (Bayesian clustering). The results show that the best living conditions for this species persist in large habitats with a high degree of connectivity - in swampy river valley systems of central eastern Poland. The relief of these areas was shaped mainly during the Odranian Glaciation (Wartanian Stadial). The lowest genetic variability indicates that the most difficult conditions for the tundra vole occur in the most mature, southern zone, the original relief of which was formed during the oldest glaciations (Sanian 1 and Sanian 2). It offers a completely different arrangement of habitats preferred by this species. The found relationships may also become, to some extent, an indicator useful in explaining the geological history of the region.

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**P-1241**

## **The effects of urbanization on four major rivers in the Gulf Coast region of the United States.**

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### **Abstract**

From 1997-2012, the population of Texas grew 15 times faster than the United States' national average, with much of this growth centered around the Dallas-Fort Worth Metroplex (DFWM) and in the Austin area, both of which are centered around major rivers. Studies of the effects of urbanization on rivers are numerous. Unfortunately, few have been conducted in areas with the climate (warm temperate, fully humid, hot summer) geology (predominantly limestone and shale) and relatively flat topography of the Gulf Coast region of the United States. Further, the effects of land cover change, such as that which occurs with urbanization, have not been studied at a large scale. Although humans have learned to adapt to long-term river adjustment, drastic anthropogenic changes can reduce time scales for geomorphic change to decades or centuries. Given the current population growth and projections for the region, we must understand the effects of urbanization on the major rivers in the Gulf Coast to prepare for fluvial adjustments induced by the rapid expansion of urban centers.

This study assesses the effects of urbanization on three major rivers in the Gulf Coast region of the United States: the Brazos River, Colorado River, and Trinity River in Texas. Objectives for this study are: (1) Determine the effects of urbanization on overall geomorphic channel stability of rivers in the Gulf Coast region, (2) Determine the effects of land use/land cover (LULC) on sediment size range of select rivers in the Gulf Coast region, and (3) Establish a channel stability assessment system for low-gradient rivers typical of those in the Gulf-Coast region. Qualitative assessment of channel stability is based upon the Modified Johnson et al. (1999) Method for Assessing Channel Stability, developed by Doyle and others in 2000. Local stream power and unit stream power were used as a quantitative indicator of stream stability. Effects of LULC were assessed by analysis of the HUC-12 sub-watershed using ArcGIS. Each sub-watershed was divided into constituent land-cover types, and sediment size range for each reach was compared to the proportions of each land-cover type at the specific as well as from upstream reaches.

Preliminary assessments show that although heavily urbanized stretches of the four rivers in this study are well protected and stabilized, a wide range of adjustments may occur downstream. Degraded channels immediately downstream of urbanized reaches can undergo rapid recovery if the river is protected from further alteration. In areas experiencing poorly-managed suburbanization, however, channel degradation continues even beyond the boundaries of heavily urbanized reaches. Protected public forests or land preserves on a watershed are thus particularly important downstream of heavily urbanized areas.

**P-1242**

## **The Future Floodplains project: ecosystem services of floodplains under socio-ecological change**

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### **Abstract**

Rivers and alluvial floodplains represent many ecosystem services (ESS) such as biodiversity, carbon storage, groundwater storage, agriculture, water buffering and recreation. Many of these ESS are, however, conflicting for involved social users and policy makers. A thorough understanding of the functioning of floodplains and the sensitivity of the floodplain ecosystem services to (future) changes to internal and external driving forces is needed, to develop a sustainable management policy that suits the needs of as many stakeholders as possible. This requires a multidisciplinary approach in which scientists from different fields cooperate, and which forms the core of the currently running Future Floodplains project (2017-2021). This project is an interdisciplinary strategic basic research project funded by the Fund for Scientific Research – Flanders (Belgium) with the aim to focus on innovative research that can create prospects for societal applications.

To understand the functioning of floodplains, the Future Floodplains project does not only take into account the present changes river and floodplain in geomorphology, ecology and hydrology (geoecohydrology) but also the past changes at mid- to longer timescales. This long-term data is in turn used for scenario-based modelling of future changes in floodplain geoecohydrology and floodplain ecosystems services. This scientific knowledge will be relevant for all governmental and non-governmental institutes and organisations that are dealing with the development and implementation of sustainable management policies related to rivers and floodplains. This includes nature and environmental policies, nature conservation and management, floodwater management, cultural and natural heritage, and agricultural, hunting and recreation policies. Therefore, it is important that the gap between fundamental research on the one hand and the implementation of the project results on the other hand is bridged.

The Future Floodplains project provides this bridge through the use of participative approaches. Stakeholders are involved in the project from the preparatory phase all the way to the end of the project. Through a co-learning and co-design approach, stakeholders are provided with the necessary insights into floodplain dynamics, in order to allow evaluation of the sustainability of present-day integrated management and policies in river floodplains. In this way, it provides a framework to revise environmental decision support systems for the future that takes into account the dynamic nature of floodplain systems, for lowland rivers in general, and rivers in Flanders (Belgium) in particular.

**P-1243**

## **Paleoenvironmental context of prehistoric human activity in the foreland of Polish loess uplands - case study: Sandomierz Upland and Iłża Foreland**

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### **Abstract**

The contact zone of the South Polish Uplands with the Central Polish Lowlands is a fragment of the intersection of two major important Pan-European belts - loess and sandy. According to geomorphological criteria, these belts clearly differ in the dominant landscapes. This is mainly due to the different lithology of age-varying geomorphic forms dominating there. An example of a pair of such different geomorphological regions are: the Sandomierz Upland and the Iłża Foothills. The first of them, with an extremely erosive-denudative relief, covers a continuous loess, and the second - karstified Mesozoic rocks with a mosaic cover of glacial tills and aeolian sands. Geomorphological diversity is reflected in the development of different soil types and in the plant cover, and thus their radically different values and perspectives for potential settlement and economic activity of humans.

The different ecological and landscape conditions of both mentioned regions had a particularly significant impact on the nature and intensity of settlement processes occurring within them in the prehistoric times. This is particularly clear since the middle stratigraphic unit of Holocene (the Atlantic period), and especially the settlement of early agricultural communities existing in the 6th and 5th millennium BC. Until recently, the state of archaeological research pointed to the high contrast of settlement activity within the loess Sandomierz Upland and the sandy areas of the Iłża Foothills. It justified the unambiguous linking of the basic settlement preferences of these communities with the first of these regions, and at the same time the assessment of the latter as a zone associated only with occasional penetration, and not permanent settlement. It corresponded very well with the situation recognized in other areas of central and western Europe. A similar situation can be observed also in the case of the settlement of multicultural communities of the Bronze Age and the early Iron Age. In the light of the current state of research their most important settlement ecumene was the area of loess Sandomierz Upland. Only a few and very poor traces of human groups penetration in these periods were documented within the sandy areas of Iłża Foothills.

The results of our latest geoarcheological studies allow for a significant verification of current views on the actual settlement intensity of prehistoric agricultural communities in areas located beyond the edge of the continuous loess cover. Obtained data clearly indicate the existence of extensive and permanent settlement centers within them from the oldest phase of Neolithic to the early Iron Age. Their creation and functioning were undoubtedly connected with the breakdown by the multicultural agrarian communities of the significant ecological barriers and the adaptation to different (more severe) environmental conditions.

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**P-1244**

## **Economic activity of the population in the territory of Southern Georgia in the Early Bronze Age**

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### **Abstract**

The Early Bronze Age is the longest period in the territory of Georgia. It started in the second half of the 4<sup>th</sup> millennium BC and lasted nearly 1200 years. The strongest warming took place at this time. In Georgia and Transcaucasia, the peak of this warming was 6000 years ago.

A new, Kura-Araxes, culture was originated and developed at this period. The number of settlements increased. Population mastered the highlands. In present day landscapes, where high subalpine and alpine meadows are common, there were broadleaved forests in the Kura-Araxes period. The results of a palynological study of the material of the Kodiani burial mound are a good example of it. This burial mound is located at the height of 2289 m a. s. l. and according to the archaeological data is dated to the 27-25 centuries BC. Palynological spectra show that given region was covered with forest at that time, where lime, beech and chestnut were mostly spread. Anthropologic indicators of pollen spectra show that human was mainly engaged in agriculture. Apiculture was also developed well.

The results of a palynological study of the Paravani burial mound (2000 m a. s. l.), the Chobareti settlement and the Tkemlara burial mound also point at the powerful development of agriculture in the highlands in the Early Bronze Age. While cattle-breeding prevails today in the region under discussion, in the Early Bronze Age wheat and other cereals were sown here, as well as flax. Because of warm climate conditions, viticulture and horticulture were also developed.

In the middle of the 3<sup>rd</sup> millennia the Kura-Araxes culture was replaced by the Bedeni culture. At that time, due to warm climate, zelkova and chestnut forests were spread on the high (1800-1600 m) plateaus of South Georgia. *Pterocarya* was observed in floodplain forests. Human cultivated even fig along with vine at this height. These plants do not grow in the mountains above 600-800 m at present.

Ethnopharmacology reached a higher level during the Bedeni period. While 48 species of medicinal plants were found in the burials and vessels of the Kura-Araxes period, this number increased significantly and reached 61 in the burial mounds of the Bedeni culture. A new tradition of burial appeared in the same culture, according to which the deceased person was accompanied with baskets and wooden boxes full of medicinal plants for the afterlife. Exactly such a four-sectioned "first aid kit" was found in the Bedeni burial mound № 10

P-1245

## Environment and Human Activity of the Classical Period of Georgia According to Palynological Data

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### Abstract

The sites of the Classical Period in Western Georgia - Vani, Nokalakevi, Pichvnari, and Tskheta - are palynologically investigated. Organic remains obtained from cultural layers (6<sup>th</sup>-5<sup>th</sup> century BC), burials (4<sup>th</sup> century BC), and a hoard (1<sup>st</sup> century BC), as well as modern samples were studied. The Khovle (3<sup>th</sup> century BC) and Mtskheta necropoleis (5<sup>th</sup> century BC), discovered in Eastern Georgia, were also investigated by means of the palynological method. Relying upon the palynological data, we could conclude that at various stages of the Classical Period paleoecological conditions were not homogenous in the central part of Georgia. According to the palynologica spectra, the climate in the 5<sup>th</sup> century became wet, causing swamping of the area. In the first half of the 4<sup>th</sup> century the climatic conditions seem to be the warmest since chestnut, zelkova and oak woods grew there. Wing-nut trees and royal ferns were spreading on the riverbanks and near lakes. Climatic xerophytic (decrease of the annual rainfalls) of the climatic conditions occurred in the second half of the 4<sup>th</sup> century. The 3<sup>rd</sup> century BC was especially distinguishable for worsening of the climatic conditions. It was marked with decrease of the mean annual temperature, while the volume of precipitation was increasing. Fall in temperature is clearly observed on the whole territory of Georgia. Worsening of climatic conditions supposedly began in the first half of the 1<sup>st</sup> century BC. Farming was well-developed in Vani, Pichvnari and Noqalakevi in the Early Classical Period, which was characterized with warm climatic conditions. The population was growing wheat, Italian millet, barley, millet, a lot of cultivated pulses, and flax. Horticulture and viticulture were well-developed. Olives, that need warm climatic conditions, were also grown. Apiculture was also advanced. According to the tradition, which is evidenced by the palynological data, in the Classical Period honey and wine was interred into burials for the deceased's needs in the next world. In the Late Classical Period because of the worsening of climatic conditions farming diminished, especially markers of arable farming were falling down. Cattle-breeding occupied advanced position. On the basis of palynological studies it was proved that forest ranges were drastically destroyed at the end of the 2<sup>nd</sup> century BC and the beginning of the 1<sup>st</sup> century BC.

P-1246

## Neanderthal mobility patterns in view of seasonally variable resource availability

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### Abstract

Seasonal changes in resource availability are expected to have an impact on subsistence strategies of humans and thus on patterns of landuse and mobility. According to a basic scheme, patchy distribution of resources promotes a logistical movement pattern, while rather evenly distributed resources allow for residential camps and their movement. In order to test this hypothesis we compare occupation times at Neanderthal sites across Europe in a glacial (MIS 6) and an interglacial (MIS 5e) episode. Here we present first results of this study.

Length of stay is inferred from tool diversity in the assemblages expressed by a specialization index. The specialization index  $S_i$  correlates inversely with the diversity of an assemblage and the specific use of the camp. The shorter the duration of stay, the higher the specialization index, for instance at a specialized task camp. In residential camps, tool diversity is expected to be higher resulting in lower specialization indices and longer duration of stays.

In our present study, we assessed two types of food resources and their respective shifts in seasonal availabilities, in particular edible plants as well as large mammal herbivores, to monitor resource distribution. Although other types of food resources are available too, plants and large animals contribute a considerable proportion to the Neanderthal diet. Plant communities in MIS 5e and MIS 6 are assigned to comparable modern vegetation units and assessed for the seasonal availability of edible plant parts. The availability of herbivores in particular seasons is assessed by means of a model which links herbivore diet to migration potential on a quantitative basis.

Both types of resources experience fluctuations throughout the year, irrespective of a glacial and/or an interglacial background. Neanderthal mobility patterns reflect seasonally changing resource spectra in rather complex ways. On a regional and/or local scale, however, correlations can be observed. Despite consistently changing environments Neanderthals display considerable conservatism with respect to their material culture. This conservatism must not be considered as a disadvantage finally driving Neanderthals to their extinction. Instead remarkably flexible patterns of subsistence and mobility rest on the firm base of cultural continuity.

P-1247

## Long-term land-use, archaeological and environmental changes in Holyrood Park, Edinburgh

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### Abstract

Situated in central Edinburgh and covering an area of 259 ha, Holyrood Park is home to geologically important evidence of volcanic activity which took place 350 million years ago such as Arthur's Seat and Salisbury Crags. With the earliest evidence of human presence dating back to the 5th millennium BC, the continuous human occupation makes Holyrood Park ideally suited to reconstruct the local evolution of vegetation, land-use and human settlement from the late Mesolithic to the 19th century AD. The decision to undertake a study focusing on the evolution of the immediate surrounding landscape meant the sampling had to be conducted as close as possible to the study area, which posed particular challenges. The available sampling sites were not the "classical" palaeoenvironmental archives and factors such as sedimentation and post depositional processes were to be examined very closely.

Dunsapie Loch is located just to the East of Arthur's Seat and sits at the base of the Dunsapie Crag hillfort. The Loch directly faces some of the best preserved cultivation terraces in the wider region. Its privileged location makes the site particularly suited to obtain a high quality, high resolution pollen, Non Pollen Palynomorphs (NPP) and soil erosion record which can contribute to the understanding of the nature and chronology of the immediate archaeological features. For the Dunsapie sequence geochemical and data were compared with pollen and archaeological records to help inform the construction of the age-depth model and of a long-term sedimentation sequence, defining periods of natural and anthropic-led erosion. Multi-element analysis indicates that an erosion event occurring *circa* 4000 BC was preceded by a decline in *Ulmus* and other woodland taxa. The pollen record suggests a landscape dominated by grassland by *circa* 2700 BC with no significant woodland recovery throughout the remaining sequence. Grazing and cultivation, as suggested by the presence of NPP and cereal-type pollen, were first recorded during the 4th millennium BC and intermittently present until the close of the sequence.

The Dunsapie Loch pollen sequence is unique in the Scottish context and could be argued that the essentially local nature of the analysed proxies contributed to mute a wider regional signal. The findings from this study will assist future projects undertaking the interpretation of complex archaeological landscapes from the sediment and pollen records by highlighting the important contribution of local and, often overlooked, palaeoenvironmental archives. By understanding the convoluted relationship between the different archives, and through the use of a multiproxy approach, it was possible to obtain an essentially local, high resolution palaeoenvironmental record of the changes that took place within the Park area over the last 7000 years.

P-1248

## A Holocene Pollen Record from the Western Qilian Mountains and Its Implication for Regional Climate Change in Northwest China

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### Abstract

The sparsity of long-term reliable climatic records hampers our understanding of both vegetation ecological feedbacks and human-environment interactions in the semi-arid Hexi Corridor, northwest China. This study analyzed a pollen sequence from a small lake, the Tian'E Lake, in the western Qilian Mountains covering the past 10 ka (1 ka=1000 cal yr BP). The chronology is provided by reliable accelerator mass spectrometry (AMS) C-14 dates from nine terrestrial plant materials and one organic material in the sediment. The fossil pollen spectra suggested that the Tian'E Lake region vegetation were dominated by Amaranthaceae (=Chenopodiaceae), *Artemisia*, Poaceae and Cyperaceae. From 10 ka to 3.6 ka, the local vegetation was steppe dominated by *Artemisia*, Poaceae and Amaranthaceae with some sparse trees, indicating stronger Asian monsoon. After ~3.6 ka, a decrease of tree pollen suggests that forest vegetation disappeared from this region, and the local vegetation was desert steppe dominated by Amaranthaceae, *Artemisia* and Poaceae with the weakening of Asian monsoon. The ratio of *Artemisia* and Chenopodiaceae (A/C) could represent the regional humidity variations, and there was relatively dry period from 1.3 to 0.8 ka. The A/C ratio indicates that regional humidity decreasing significantly after ~3.6 ka. The regional humidity was overall increased during the Little Ice Age (LIA) and Century Warming Period (CWP), which might be caused by depressed the evaporation during the LIA and monsoon enhancement during the CWP. Comparison with tree-ring data indicates that some archaeological site and ancient cities of the Hexi Corridor were abandoned corresponding to continuous droughts.

P-1249

## Multi-proxy evidence for population dynamics in the Neolithic and Bronze Age of north-western Central Europe

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### Abstract

Population dynamics are regarded to be crucial for understanding social change and cultural organisation in prehistoric societies. Hereby summed probability distributions (SPD) of archaeological radiocarbon dates have been increasingly used as a palaeodemographic proxy during the last decades of archaeological research. This approach, however, is controversially discussed as several methodological uncertainties and biases are involved. In order to mitigate such proxy related uncertainties we use a multi-proxy approach. Hereby the comparative interpretation of several independent proxies allows the identification of demographic patterns with greater confidence. We use palaeoenvironmental data from northern Germany and southern-western Denmark, to reconstruct independent proxies of human impact during the Neolithic and Bronze Age. This involves, beside sum calibration of archaeological <sup>14</sup>C dates, the quantification of human impact on the vegetation from pollen analysis using multivariate statistics as well as soil erosion history from stacked colluvial records. We postulate that the assumed relationship of human activity and population density in the SPD approach is also true for the other palaeoenvironmental proxies and use them accordingly as additional proxies for population dynamics.

Based on the comparison of the three proxies we define phases of growing (boom) and decreasing (bust) population in northern Germany. The boom phases date to ca. 4000–3500, 3000–2900, 2200–2100, 1450–1300 and 1000–750 cal. BC. The bust phases to ca. 3200–3000, 2400–2300, 1650–1500 and 1200–1100 cal. BC.

P-1250

## Anthropogenic alternation of natural vegetation process began 6,000 years ago in southern China

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### Abstract

Vegetation dynamics during previous warm interglacial periods shed light on human impacts on natural ecosystem trends during the Holocene. But only a few terrestrial records span such periods with a reliable chronology. Here we present a high-resolution marine pollen record from the northern South China Sea. We find that during five peak interglacial periods, MIS 13a, 11c, 9c, 5e and 1 (the Holocene), the vegetation successions in southern China were similar. At the beginning of each interglacial period, tropical rainforest conifers including *Dacrydium*, *Dacrycarpus* and *Podocarpus* and associated broadleaved taxa such as *Altingia*, expanded quickly at the expense of the subtropical/temperate montane conifer *Pinus*. Near the end of the previous warm periods, *Pinus* recovered and tropical taxa retreated. However, the Holocene process displays subtle but significant differences in which the species turnover was interrupted and the rainforest conifers never fully expanded. The Mg/Ca-based sea surface temperature record from the same site reveals that temperature was the major control on the rise and fall of the peak interglacial vegetation. However, exceptionally high charcoal fluxes during the Holocene suggests that human activities have completely, and possibly permanently, altered the natural vegetation trend five to six thousand years ago through forest clearance and burning.

P-1251

## Trajectories of Oyster Paleobiology and Human Exploitation (ca 5000 to 3100 BP) along the South Atlantic Coast USA

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### Abstract

The South Atlantic Coast of the United States is known for its impressive shell middens, especially its shell ring sites, which are arcuate to circular deposits of shell, bone, ceramics, and other artifacts. Many of these rings are of massive proportions and in excess of over 100 meters in diameter with elevations of over three meters above the surrounding topography. In addition to possessing some of the earliest ceramics in North America, these sites are thought to represent, in part, a shift to sedentary village life along the coast. Besides shape, one of the commonalities that shell rings have is that the primary shellfish exploited by the inhabitants was the eastern oyster (*Crassostrea virginica*). Most interestingly, shell rings become largely abandoned by around cal. 3800 years ago. Recently, we began a project to explore oyster paleobiology on a large scale along both the Gulf and Atlantic coasts of eastern North America. The work presented here is a subset of this research. Here we explore patterns in oyster size from South Carolina and Georgia during the Late Archaic period. In total, we measured left valve height (LVH) and left valve length (LVL) of over 30,000 oysters from 14 sites. We observed statistically significant differences in the size of oysters collected across sites. Further, significant differences exist at an intra-site level, with oysters from the lowest, and hence, earliest deposits being larger than those exploited later in time at some sites. Regionally, there appears to be a non-random pattern in the mean oyster size exploited moving from sites situated from north to south. We interpret the observed variation at both the site and regional level to processes related to territoriality, fishing rights, and coastal environmental variability. We also place these oyster paleobiological data within the context of larger temporal trends of climate and environmental latitudinal gradients.

**P-1252**

## **Using multiproxy analysis to identify the impacts of social transitions and crisis: Iona during the pre-Monastic to post-Viking era**

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### **Abstract**

The island of Iona in western Scotland has undergone numerous social transformations since prehistoric times. The island is well renowned for its early monastery constructed, in ~AD 563, where it quickly became an important centre for learning, agricultural innovation, and the spread of Christianity. Our knowledge for this period is improved by the availability of written records produced during the first 200 years of monastic life; however, between the 8<sup>th</sup>-12<sup>th</sup> centuries, Scotland experienced severe political and social upheavals, which ultimately saw the drying up of written records. This includes several Viking raids, which had a drastic impact on the monastic community; the waning of ecclesiastical power with the transfer of St. Columba's relics; and the restructuring of political borders - with Scandinavian settlement, the disappearance of Dal Riata and Pictland, and the gradual formation of Alba (Scotland).

Following on from a Historic Environment funded project to bring Charles Thomas' excavations (1956-1958) at Iona to publication, in 2017, a series of new excavations and environmental analysis took place at sites around Iona Abbey, directed by Ewan Campbell, university of Glasgow. By presenting the palaeoecological results of this investigation, this paper aims to provide additional information on the historical and archaeological resources, regarding the social transformations influencing Iona between the prehistoric and historic periods.

**P-1253**

## **An integrated palaeoenvironmental record of land use and industrial pollution within Angkor Thom, Angkor.**

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### **Abstract**

Here we present a multi-proxy record of environmental change from the administrative and ceremonial core of Angkor, within the urban enclosure of the 12<sup>th</sup> century citadel of Angkor Thom. Analysis of proxy data, including geochemistry, palynology, sedimentology and fire history, reveal a distinct period of elevated metal pollution between c. 1300 and 1600 C.E., demarcated particularly by elevated concentrations of lead and copper in the sediment archive. These results reveal periods of artisanal activity within the ceremonial core of Angkor Thom that can be linked to known sites of copper-based metallurgy adjacent to the Royal Palace in Angkor Thom. These results link palaeoenvironmental signals of changing land use with evidence for peaks in industrial metal pollution, and imply that activity in these ateliers continued uninterrupted throughout the supposed decline and demise of Angkor, in keeping with industrial metal working in other Khmer centres during this period.

**P-1254**

## **Ancient cisterns as a palaeoenvironmental archive: A case study from the Negev Highlands (Israel)**

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### **Abstract**

Drylands are characterised by a scarcity of sedimentary archives suitable for palaeoenvironmental reconstructions. This absence of established archives leads to the introduction of a novel sedimentary archive: ancient cisterns, with new possibilities and challenges. In this study, the ancient subterranean cistern system Borot Ramaliya (Negev Highlands, Israel) is evaluated for its potential to be utilized as a novel paleoenvironmental archive.

Ancient cisterns are frequently-occurring archaeological installations in the Negev Highlands. These installations collect and store water and can sustain settlements, agriculture and nomadic pastoralism under dry conditions. Despite the large number of cisterns in the arid Negev, these installations have not been systematically studied as sedimentary archives.

During precipitation events, surface runoff from adjoining slopes erodes and transports sediments, which are then deposited in the cisterns. Therefore, these archaeological installations serve as sediment traps, representing fluvial processes in their catchments. Additionally, the structures are usually constructed to prevent any water outlet, resulting in an undisturbed, often continuous sediment record of the infilling after their abandonment.

Crucial for the establishment of a palaeoenvironmental record are robust chronologies. Due to the removal of sediments during construction and maintenance of the installations, optical stimulated luminescence (OSL) dating proves to be the preferred dating method. The sediment record within the installations includes numerous environmental proxies (e.g., grain size, geochemical properties, botanical microremains, pollen, phytoliths), which can be used for palaeoenvironmental reconstruction, serving as an important archive in dryland areas.

P-1255

## Holocene history of Aleppo pine (*Pinus halepensis* Mill.) woodlands in the Central Ebro Basin: climate-biased or human-induced?

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### Abstract

The past distribution of key tree and shrub taxa at European scale has increased noticeably during the last decades as consequence of the accumulated data production effort carried out by many palaeobotanical research groups. The number of chronologically well-constrained available pollen and anthracological data have allowed defining not only the location of both deciduous and evergreen species during the Last Glacial Maximum, but also characterizing the pattern of postglacial recolonization of central and northern European regions.

One of the widespread trees in the semiarid Mediterranean Iberia is the Aleppo pine (*Pinus halepensis* Mill.) whose distribution is confined to the thermo- and meso-Mediterranean biogeographic belts. However, the chronological timing and the drivers explaining the long-term presence of Mediterranean pinewoods across the Central Ebro Basin and borderlands are far from being fully understood. The available anthracological data support the early spread of *Pinus halepensis* during the Mesolithic (ca. 9700 cal BP) accompanied by Mediterranean trees and shrubs like evergreen *Quercus*, *Juniperus* sp., *Arbutus unedo*, *Pistacia lentiscus*, *Rhamnus/Phillyrea*, Cistaceae or *Rosmarinus officinalis*, probably, as a local response to global climate change in the early Holocene. During the arrival of the Neolithic, pollen and charcoal records demonstrate the progressive substitution of open thermophilous landscape by both evergreen and deciduous *Quercus* in response to the Mid Holocene rise in temperatures and humid conditions. This evidence, however, converges with the general idea that the presence and the concomitant spread of *Pinus halepensis* and associated thermophilous scrubland have usually been attributed to the onset of landscape anthropization in the literature. The frequency of xero-thermophilous open scrubland and the use of Aleppo pine for fuel progressively acquired more visibility during the Bronze and Iron Age periods, and especially in Roman and Medieval times, where the vegetation landscape in the Central Ebro was practically deforested as consequence of increasing demographic pressure and the establishment of proto-urban centers.

The reviewed palaeobotanical data reveal that the modern distribution of *Pinus halepensis* in the Central Ebro Basin is the consequence of a combination of factors, including long-term ecological responses to climate changes and the human-induced shaping of the landscape. Overall, the anthracological data support the spread of Aleppo pine woodlands during the Mesolithic and therefore the primary role in the vegetation landscape prior to the arrival of Neolithic socioeconomic transformations.

P-1256

## Last millennium of the forest history and lake-peatland development along with economic and ecological transitions of Greater Poland (western Poland)

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### Abstract

Multi-proxy high-resolution palaeoecological studies on peatlands enable detailed reconstruction of forest development under variable human impact. In this study, we focus on the Kazanie fen, located in Greater Poland near Poznań. The aims of our studies were to (i) reconstruct the vegetation changes along with the progressing human impact related to the Polish state development, (ii) identify intrinsic and extrinsic factors in the peatland development, and (iii) extract the role of economic and historical turnovers for ecosystems' changes. We carried out pollen, plant macrofossil, charcoal, testate amoeba, and selected non-pollen palynomorph (NPP) analyses, supplemented by <sup>14</sup>C AMS dates (each 10-20 cm) and historical sources. Results show a strong link between human impact and vegetation changes in the past. Palaeoecological research has enabled the detection of well-documented historical events. Among them was a rapid decline in the population of the Swedish Deluge in 1655-1660, which was followed by spontaneous reforestation. Oak-hornbeam forest that dominated in the vicinity of the site between ca. AD 900 and 1610 was replaced by forest dominated by *Pinus sylvestris*. The area of the coring spot before AD 1520 was functioning as an overgrowing lake. Then brown mosses spread, among which *Scorpidium cossoni* and *Pseudocalliergon trifarium* dominated, indicating the presence of calcareous rich fen. The transition from vegetation typical of a rich fen to a poor fen took place ca. AD 1984, when *S. cossoni* was replaced mainly by i.e. *Sphagnum fallax*, *S. teres*, and *S. fimbriatum*, indicating more acidic habitats. This transition was also recorded by testate amoebae among which *Microchlamys patella*, *Centropyxis aculeata*, *Pyxidicula* ssp. and *Diffflugia* ssp. were replaced by *Assulina muscorum*, *Nebela tincta* and the representatives of the *Euglypha* spp. Simultaneously to this transition *Alnus* and *Betula* became more frequent in the vicinity of the site. We believe that the results of our research, confronted with historical sources, will contribute to a better quantitative understanding of the impact of land use changes during the historical period on the functioning of terrestrial and peatland ecosystems. Research financially supported from the funds of National Programme for the Development of Humanities (Project: NPH012; PI: Piotr Guzowski).

P-1257

## Centennial fluctuations of climate wetness in southern Siberia and ancient human cultures of Eurasian Great steppe belt

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### Abstract

Spore-pollen, testate amoeba and macrofossil analysis were performed for peat-lake sediment core from Bezrybnoye mire (52° 48' 36.29"N, 93° 30' 47.14"E, 1395 m.a.s.l.) located in Ergaki nature reserve (Western Sayan Mountains in the south of Central Siberia). Sediments of 600 cm thickness were accumulated during 3200 cal years. Dating is based on four radiocarbon dates. Resolution of palaeoecological series is 90-45 years per sample. The dynamic of the vegetation cover and humidity of climate together with wetness of mire surface were reconstructed based on palaeoecological data with appropriate transfer functions. By change in the assemblages of testate amoebae, 11 periods of lowering the mire water level and 9 periods of increased mire water levels were revealed.

Although the dynamics of the vegetation cover recorded in changes of the pollen zones reflected only long-term climatic trends, it turned out that the centennial and multi-decadal fluctuations in the abundance of the Scot's pine pollen (*Pinus sylvestris*) correlate positively with lowering of mire waters reconstructed by testate amoebas. Possibly pine reacted on the climate aridization either by increasing of its area at the expense of moisture-loving tree species – fir (*Abies sibirica*) and cedar (*Pinus sibirica*), or more mobile - by increasing its pollen productivity during dry time periods. In general during 3370 years we revealed 12 episodes of dry climate fixed both by testate amoeba complexes and by Scot's pine pollen - 77, 540, 897, 1152, 1526, 1753, 2023, 2313, 2503, 2879, 3114, 3302 cal yr BP. Comparison of these drought events with the historical data about desiccation of the steppes, cited in works of Russian ethnographer and historian Lev N. Gumilev, revealed a very good correlation between them. Our multi-proxy palaeoecological data confirm the hypothesis of strong influence of the centennial fluctuations in climate moistening on the history of ancient people in southern Siberia and in general in the Great Steppe Belt of Eurasia. We find confirmation of the identified periods of climate desiccation and humidification also in the data of dendrochronology. Both our palaeoecological data and published dendrochronological data evidence about better wetting of Great steppe belt during the heyday of the Mongolian empire and in Scythian times with two dry episodes at about 2500 and 2300 cal yr BP. We suppose that the revealed centennial fluctuations of climate humidity are related to the dynamics of solar activity.

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P-1258

## The olive groves landscape of Kournas lake (Crete, Greece) from the Late Neolithic to the Present Day

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### Abstract

The opportunities to follow the Holocene evolution through sedimentary archives are not numerous in south-eastern Mediterranean, and especially in the Aegean. In Crete, the largest Greek island, Kournas lake is the only natural lake and its sedimentary record offers the opportunity to study 10 millennia of environmental changes. On the 14 meters long core we extracted from the lake, multiproxy studies of sediments, pollen and non-pollen palynomorphs, and charcoals, were undertaken in order to document: 1) lake formation and evolution, 2) floods and slumps events, 3) land cover and biodiversity changes, 4) human agro-pastoral activities and 4) fire history.

The results highlight the Holocene environmental trajectory as well as key socio-cultural phases in the eastern Mediterranean basin. For example, early Neolithization, the development of Minoan civilization, Greek and Roman Antiquity and Venetian rule over Crete. The south-eastern Mediterranean is an area sensitive to climate change and/or rapid climate change events. In addition, the region is exposed to natural hazards such as volcanism and earthquakes, the most famous being Santorini eruption. This research allows us to assess and compare socio-cultural and natural process that shaped this typical Mediterranean landscape and the processes linking causes and effect in these changes.

At Kournas, considering changes in the vegetation cover, pollen biodiversity and fire regimes, our perception is that human disturbances are the main cause of changes. So are the different phases of olive cultivation that have succeeded one another since 6000 BP. From the Late Neolithic to the Present Day, the main stages comprise a sharp decrease at the end of Minoan civilization, a significant and sustained cultivation during Hellenistic and Roman periods, a decrease under the Venetian rule that favoured wine, and then, new growth from the Ottoman period onwards. Disturbances as an effect are more obvious on the hydrology of the watershed, including floods and changes in lake productivity. However, the major changes are often linked to multifactor causes. As an example, around 3600 BP, the Santorini eruption is not a disruption in the palaeoecological history in this area. But, at that time, seismic activities that caused several slumps in the lake, together with socio-political perturbations of the Late Minoan, and changes in agro-pastoral activities resulted in a significant environmental change.

Obviously, around the Cretan lake of Kournas, the main feature of the current landscape is a legacy of a 6 millennia-long olive cultivation, and the socio-cultural evolutions drove the rhythm of this major land-use. Nevertheless, only complex interrelations between natural and cultural changes led to ecosystems changes as may also succeed in the future.

P-1259

## Human Organizational Change and Climate Variability in Northwest Patagonia: the last 1000 years BP using a multi-proxy approach

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### Abstract

Although Northwest Patagonia was inhabited by hunter gatherer until historic times with evidence of “farming islands” in the north sector (mostly Diamante and Atuel River). Until recent time the human evolutionary trajectory had been focused in a coarse grained temporal resolution, using multi millennial units. This presentation explores the archaeological record in relation with climate variation during the last 1000 years. Using a paleoclimatic reconstruction of SAM (Southern Annular Mode) we compare human demography, diet, and technological organization. Different proxies indicate two different scenarios. First, between 1000 to 1300 years AD, dominated by SAM positive, hotter and driest summers were associated with stable human population, low use of high rank resources, like guanaco, and low frequency of non local rock and ceramics. Around 1400 years AD, start to dominate SAM negative, that implied cooler summer associated with an increase in precipitation. An abrupt increase on human population was observed in a period of ca. 200 years (ca. 1400 to 1600 AD). In addition, a notable increase in guanaco exploitation and significant change on stable isotopes trend on human bone (13C and 15N) indicate change in diet. An increase in a non-local rock like obsidian and non-local ceramic are recorded too. Clearly, these changes were operating before LIA and before the Hispanic domination (recorded ca. 1800/1880 AD in the area, ca. 1550 in a macro region). All these findings point out that the last millennium, in Northwest Patagonia was not a stable socio-ecological system. Contrarily, we detect abrupt changes associated with an increase in human demography and a significant increase in primary productivity as consequence of SAM negative modulation that generated summers with more precipitation and cooler than normal. This scenario of population growth in Patagonian hunter gatherers could cause their expansion to the North, retracting the limits of prehispanic farming, just a few centuries before the Spanish arrived.

**P-1260**

## **A millennium of landownership, land use and environmental change in Iceland**

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### **Abstract**

The present landscape of Iceland is marred by erosion scars and discontinuous vegetation cover having lost almost all natural woodland, and up to 50% of its soils, during the course of the last 1000 years. Palaeoecological studies show that woodland clearance followed by soil erosion, in both inhabited areas and upland range, has been underway since Iceland's initial settlement (Landnám) in the late 9<sup>th</sup> century. Ongoing discourse as to how such landscape degradation arose on such a scale, how it developed temporally and spatially, and what the nature of the underlying mechanisms responsible for these developments are, continues. Rarely do such studies explore social and/or economic variables influencing such environmental disturbance and nor do they situate them within theoretical models for environmental change (e.g. gradual or step-like etc.). Do particular instances of environmental change reflect changes in society or vice versa? This paper considers parity between palaeoecological data, bioarchaeological material, and historical sources. Three steps of environmental decline may be apparent in Iceland, all of which may be linked to socio-economic events: 1) Landnám and woodland clearance that triggers soil erosion during a period of relatively mild climate. 2) The replacement of a community comprised of independent farmsteads to one dominated by a manorial system and associated tenancies. This corresponds with a shift toward sheep farming at the expense of dairy cows, further woodland decline and an intensification of soil erosion between AD 1200 and AD 1400. 3) Environmental degradation is further amplified during the late 19<sup>th</sup> century in hand with an increase in sheep numbers in response to European markets for meat and wool, as well as agricultural improvement.

**P-1261**

**How geoarchaeological and paleoenvironmental approach can be useful to provides new insight about archaeological issue. Case study from southeastern Balkans.**

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**Abstract**

The contribution aims to present first results of a multiscale and geoarchaeological approach to Human-Environment relationships into Maritsa-Iztok area (Bulgaria) and particularly nearby the tell of Sokol (Late Chalcolithic – Bronze Age). Our goal is analyze the role of agropastoral practices and climate events on the dynamics of mosaic landscapes for this time interval.

Up to that time the investigations were limited to on-site sequence study and palaeoenvironmental research was lacking. In order to overcome the taphonomic issue in some cultural layers, we attempt to use local sedimentary archives to identify periods of landscapes and socio-cultural changes around the closer inhabited areas. The presentation is based on preliminary results which combine geomorphological and palynological analyses (including Non Pollen Palynomorphs), from about six cores carried out into an alluvial context. Beyond the limits of interpretation linked to the quality of sedimentary archives studied, the analysis shows that the question of the effects of human activity on the landscape cannot be addressed without an accurate analysis of local and off-site contexts. Even, it remains difficult to identify cultivated or harvested plant species from pollen taxa recovered, the results obtained can be accurately compared with other palaeobotanical dataset from the tell. This long term analysis about vegetation cover dynamics provides food for thought to fill the archaeological shortcoming for this period, guiding the future investigations.

Finally, the results obtained around Sokol invite us to expand our study area, putting this methodological approach into practice to some of other multiperiod and discontinuous occupation sites in the densely settled lowland areas such as Upper Thracian. In fact, in order to fill a gap of our understanding of the Human-Environment-Climate relationships during these cultural periods, we need to renew and update the palaeoenvironmental dataset for regions where archaeological data are already significant and still ongoing.

P-1262

## **Cultural and social trajectories of human occupation of the Chiloé Archipelago, Patagonia-Chile: change and interaction among marine-hunter-gatherer and agro-ceramic societies**

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### **Abstract**

The northern Patagonian archipelago is an extended geographical area (600km) that breaks the continuity of the Pacific coast and it projects into an insular system with notable biogeographical discontinuities, such as channels, fiords, mountain chains and icefields that portrays the southern extreme of the western side of South America (Figure 1). This oceanic environment, modeled mainly by important tectonic activity, volcanic and glacial action, registers the first signs of human occupation dated at 5500 years BP by marine hunter-gatherer groups that have navigation technologies.

However, the southern zone of Chile and the Chiloé archipelago (41°-43°S), present an important change in the trajectories towards the last millennium, represented by the emergence of cultural traditions that have ceramic technology, horticulture and -probably- domestic animals. This new social and cultural scenario contrasts with what occurs in the adjacent regions south of the Corcovado gulf (43° S), where the subsistence systems continued based on marine hunting and gathering and fishing until historic epochs (S. XVI-XX), endorsed by the presence of groups historically known as Chonos, Kawésqar and Yámana, in the Patagonian archipelago. This setting is of crucial importance to understand the processes of change and social interaction between societies that produce food and marine hunter-gatherers.

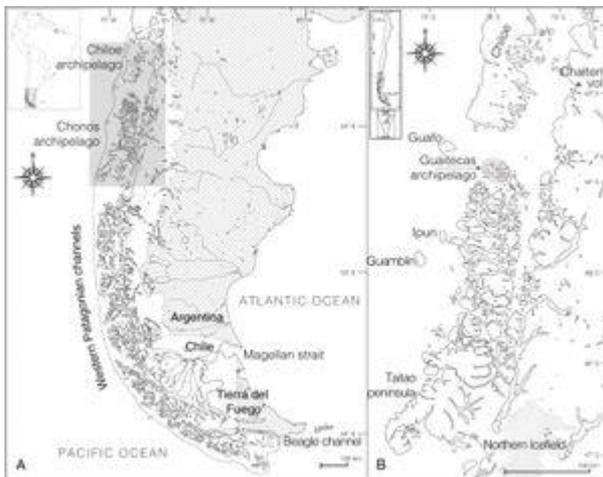
The island of Chiloé and its surrounding continental and insular sectors can be conceived as a border territory, a place of contact and interaction between different social and cultural systems. From the archaeological, bioanthropological, isotopic and historical records, we evaluated these cultural trajectories and interactions between human groups with different lifestyles and technological traditions in the northern area of the western Patagonian channels.

In our recent studies, we have detected the occasional consumption of domesticated plants -bean, potato, and corn - present in the dental calculus of individuals of these marine hunter-gatherer societies around 1000 years BP. Microfossil studies will also be applied to ceramic and lithic use residues to evaluate the presence of these domesticated plants that function as a marker of this moment of contact between both groups. Ceramic and lithic studies are oriented to detect continuities and changes in the production of these types of technologies. The faunal assemblage is also integrated to evaluate possible variations in the procurement of this type of resource. Finally,

isotopic analysis of human remains from the late Holocene sequence will allow to precise the diet these groups had and the changes occurred through time, all of this evidence is dated as to understand the chronology of the continuities and changes among these marine hunter-gathering groups.

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Figure 1. Location of Western Patagonian channels and Chiloé archipelago.



P-1263

## People, not climate, structured past fire regimes in south-central Utah

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### Abstract

Typically, climate is considered to be the dominant driver of fire regimes. However humans have been shown to influence fire regimes and override climate in the past. North American anthropogenic burning has been a controversial issue due to the widely perceived notion that low-density human populations had minimal impact on ecosystems. Recent research has illustrated that humans have had profound impacts on vegetation structure and fire regimes within fire-prone ecosystems for millennia. Understanding the successful coexistence between past human societies, especially from those societies living within lightning-fire-prone ecosystems, and fire can help provide insight into sustainable fire management; a topic of critical importance among many western North American land managers. Here, we investigate how humans may have influenced fire regimes over the past 1,300 years. We used a multi-proxy approach utilizing sediments collected from Fish Lake, Utah, a tree-ring-based record of drought, archaeological evidence, and Generalized Additive Models (GAMS) to model the relationship between fire, human occupation and climate. Fish Lake was seasonally used by the Fremont archaeological complex; a small farming and foraging group which inhabited an area roughly congruent with the modern borders of the state of Utah between 0-1400 CE, with a peak in site frequency occurring at ca. 1000 CE. Our results demonstrate that during the time of peak Fremont occupation, biomass burning was high, as were ethnobotanical herb pollen percentages. Despite the height of Fremont occupation occurring concurrent with the Medieval Climate Anomaly, our GAMS model found no significant correlation among charcoal influx and drought. Rather, our model demonstrates a significant correlation among charcoal influx and Fremont population densities. When Fremont populations densities declined beginning ~1400 CE, biomass burning and ethnobotanical herb pollen percentages simultaneously declined, while tree and shrub pollen percentages increased. It was not until Euro-American settlement ~1800 CE when biomass burning increased, despite the drastic change in vegetation composition associated with intensive grazing and ranching. Our results demonstrate how the Fremont potentially used sustainable fire practices for improving food-resource security.

P-1264

## Assessing climate change impacts on coastal and marine cultural heritage across the Middle East and North Africa: the MarEAMENA project

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### Abstract

There is growing awareness of the impact of climate change on cultural heritage and an expectation that impacts will be exacerbated in the future. Effective management strategies are needed to meet this threat and minimize the loss of valuable scientific information and irreplaceable cultural resources. However, understanding threat and managing climate change impacts (both direct and indirect) can be hindered by a lack of baseline data, both on cultural heritage (e.g. site locations, condition, extent) and the impacts themselves (e.g. severity, spatio-temporal variability). This is the case across large parts of the coastal and maritime environment of the Middle East and North Africa (MENA). Its maritime cultural resource is currently little understood. There has only been limited and fragmented archaeological research, mostly undertaken by researchers from outside the region, while national governments have frequently overlooked its protection and management due to a lack of local knowledge and expertise. Although conflict is often regarded as the main adverse impact on the heritage of the MENA region, direct climate change impacts (e.g. coastal erosion) and indirect effects (e.g. urban expansion, offshore infrastructure) are also present and starting to take their toll. Consequently, the archaeology of the coastal and nearshore underwater zone is being destroyed or damaged at an alarming rate and there is a critical need to document it before it is lost. This has led to initiation of the Maritime Endangered Archaeology of the Middle East and North Africa (MarEAMENA) project, an offshoot of the ongoing terrestrially-focussed EAMENA documentation and risk assessment programme. MarEAMENA aims to comprehensively document the entire coastal and nearshore zone of the MENA region both on land and underwater, building on the extant dispersed coastal documentation, and ensuring the accurate identification, interpretation and risk assessment of maritime archaeological sites. To do so, it will adopt EAMENA's established documentation and monitoring strategy based on systematic analysis of historic (e.g. Corona) and recent (e.g. Google Earth, Landsat, Sentinel-2) satellite imagery, aerial photographic archives and archival sources. Where possible, this will be supplemented by ground-checking using conventional maritime archaeological methods (e.g. acoustic surveys, dive surveys). Additionally, since the relationship of maritime sites to the sea is changeable over time and space owing to sea level change and coastal sedimentary processes, MarEAMENA will also analyse Quaternary patterns of coastal change to better understand the nature and condition of maritime archaeological sites and be better placed to make an assessment of the particular threats which they face. This poster will introduce the MarEAMENA project, outline its aims, objectives and methodology, and report on interim results which demonstrate the impact of climate change on cultural heritage in the coastal and nearshore MENA region.

P-1265

## People and peatlands in the Peruvian Amazon

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### Abstract

Interdisciplinary research by Quaternary palaeoecologists, ecologists, and social scientists has the potential to deepen our understanding of ecosystem function, stability and vulnerability in ways which are not possible for any one of these disciplines alone. This presentation will review the experiences and findings of the interdisciplinary work carried out recently by our research group to date, as we work on understanding the processes, dynamics and functioning of peatlands in Amazonia and attempt to ensure that our future research agenda on Amazon peatlands is useful, appropriate and culturally sensitive.

The peatlands of western Amazonia store a globally significant quantity of carbon and, in contrast to those of SE Asia, remain hydrologically intact. They harbour low, but unique, biodiversity and, like peatlands everywhere, preserve a palaeoecological archive of their own environmental history. Our palaeoecological work has shown that the peatlands are dynamic on centennial to millennial timescales and that the present day vegetation often only developed relatively recently. Our ecological research has demonstrated their importance as contributors to regional diversity and as stepping stones for dispersal between other biologically important habitats. We have shown that these peatlands are under threat from development of commercial agriculture and transport infrastructure, and from local resource exploitation. However, part of the picture has been missing from this research: the people who live in and around the peatlands.

The “Valuing intact tropical peatlands” project was a pilot study on the social, economic, and cultural values of peatlands in the Peruvian Amazon to complement existing scientific research on the carbon content, ecology, and formation of peatlands in the Pastaza-Marañón Foreland Basin, northern Peru. We worked closely with social scientists at the Instituto de Investigaciones de la Amazonia Peruana (IIAP) to conduct qualitative fieldwork in two Amazonian communities (one indigenous and one mestizo), which provided the first insights on people’s relationships with peatlands in the study area. The team conducted 51 interviews with local community members, two community-level participatory mapping workshops, and six site visits to peatlands guided by local people. The project successfully achieved its objective of cataloguing and mapping human activities in, and value of, peatlands in the region for the first time.

For the scientific research to contribute any positive impact to the region, the environment and its people, and in order to fully understand the functioning of these important ecosystems then future work must continue to incorporate people into the picture. Future projects will knit the social science and Quaternary palaeoecological and other scientific methods more closely together, for example, in establishing the extent and nature of peatland palm swamp degradation and engaging peatland communities in knowledge production.

P-1266

## Bringing art and science together: body painting for a more understandable palaeoscience.

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### Abstract

Society demands sound science communication schemes, as scientific concepts need to be informed to the general public in the most objective, evidence-based way possible. Communicating science should be indeed a corner-stone of Academia, as long as these publicly funded institutions have a compromise with society making findings available to tax payers.

However we, as researchers, often fail to communicate our findings probably due to several reasons: lacking the proper training as communicators; outreach is often not considered a milestone by science evaluators and, most often, because explaining complex concepts for non-academics is a difficult task. The case of palaeosciences is paramount of the latter, where even basic principles are sometimes difficult to communicate. While palaeosciences are essential to understand current Global Change, transmitting their findings and the scope of its evidences becomes challenging. Palaeosciences operate at multiple spatio-temporal scales, often connecting interpretative principles from current day processes and mechanisms with those of the past.

On a different realm of human cognition, frequently taken far from science, we find art. Art, especially painting and drawing, has the power of reconciling us with our reality, reawakening the essence of the easily forgotten value of our own lives by making ordinary occasions or items enticing. This is even more seductive when different media are used in the artistic process, pulling observers attention in a faster way, besides accomplishing a pedagogic function. Such is the case of body painting, that has rarely been used as a didactic tool but that it offers endless opportunities given the flexible, mobile and versatile nature of the media used.

Intending to communicate to the wider public why palaeosciences are critical to tackle current day problems, we present a dynamic video performance using body painting to explain landscape evolution, proxy production and deposition, patterns and processes at long-term scales and the interpretative principles featuring palaeoscientific knowledge.

P-1267

## Assessing the effects of the Pompeii urbanization on the Sarno river (Campania, Italy) between the Bronze Age and 79 AD

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### Abstract

The Mediterranean basin is one of the key regions for the evaluation of changes of fluvial environments under anthropogenic impacts. During the Holocene, the river response to human forcing resulted into different processes in both sedimentation and vegetation dynamics (Hooke 2006, *Geomorphology* 79, 3–4: 311-335). Especially the Roman colonization affected the fluvial and coastal landscapes through the development of settlements and land use strategies (Pepe et al. 2016, *Journal of Paleolimnology* 56: 173–187).

This study is based on the new multi-disciplinary archive from the Sarno floodplain near the ancient city of Pompeii (Campania, Italy). A set of sediment cores were recovered in 2017 close to the *Terme del Sarno*, one of the main thermal baths at the southern edge of the settlement. This research project, led by the University of Padova in collaboration with Soprintendenza speciale per Pompei, focuses on the geoarchaeological investigation of the settlement evolution and the palaeoenvironmental reconstruction of the Sarno river plain (Furlan et al. submitted, *Journal of Cultural Heritage*). In particular, we present the ongoing results of palynological analyses from sediment levels dated from the Late Bronze/Early Iron Age to the AD 79 eruption of Somma-Vesuvius.

The palaeoenvironmental record is characterised by a succession of organic layers which formed the fluvial deposits of the Sarno river adjacent to the past coastline. The river environment was bordered by the Somma-Vesuvius slopes on the north, the Pompeii volcanic terrace on the east, the coastal dunes on the west and finally the river basin on the south (Vogel, Märker 2010, *Geomorphology* 115: 67-77). The preserved pollen grains refer to a vegetational landscape whose drivers of change through times were the human activities. The wet environment is evidenced by the presence of riparian trees (alder, ash) and aquatic plants that accompany deciduous and evergreen trees such as oaks, hazel and maple. An intensification of arboriculture and agriculture, in parallel with increasing use of fire, is recorded with the Roman urban growth in the last centuries BC. Such a process appears to have caused a consistent deforestation of the surrounding region, with a landscape characterized by fruit trees (walnut, hazel, olive) and herbs such as cereals, legumes and possibly vegetables from the spinach, cabbage and lettuce families. Caution is necessary in interpreting the presence of the latter because many wild and ruderal plants belong to the above-mentioned families. In any case the high number of herbs (among which also ribwort plantain and nettles) confirms strong human activities.

P-1268

## A big gap between flora and insufficiently described pollen in China: new worry about old issue on Quaternary pollen identification

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### Abstract

In the past several decades, some pollen atlases of living plants have been published as important references for Quaternary pollen analysis in China. According to newly updated online flora of China ([www.foc.org](http://www.foc.org)), there are 29,246 species of seed plants from 3,144 genera and 271 families in China. So far, the numbers of described pollen published are only 2,155 species, covering 1340 genera and 192 families (Fig. 1A). Apparently, there's a big gap between such a rich flora and poorly documented or described pollen and spores in available publications up to date, particularly in the case of seed plants from subtropical and tropical areas in China. An example of one important family in north hemisphere Fagaceae shows that some genera, like *Quercus* subgenus *Cyclobalanopsis* and *Lithocarpus*, need more pollen morphological investigations (Fig. 1B).

An old issue on Quaternary pollen identification based on such insufficiently described pollen flora from living plants in China has long been a worry (Fig. 1A). Nevertheless it's too hard to describe pollen morphology for all the species of living plants, moreover, considering some families or genera without diversity in pollen morphology, such as Poaceae, Amaranthaceae, Cyperaceae, ideal pollen atlas at least covering all genera is applicably useful for Quaternary pollen identification, especially for those genera with low diversity of pollen morphology. However, in the case of those genera with high diversity of pollen morphology (e.g., *Euphorbia*, *Polygonum*), it's necessary to describe at least all pollen types within the same genus, therefore, to update pollen atlas either in printed books or online searchable pollen morphological database, is an urgent task in China, so much work should be done before reasonable and helpful pollen atlas are to be updated.

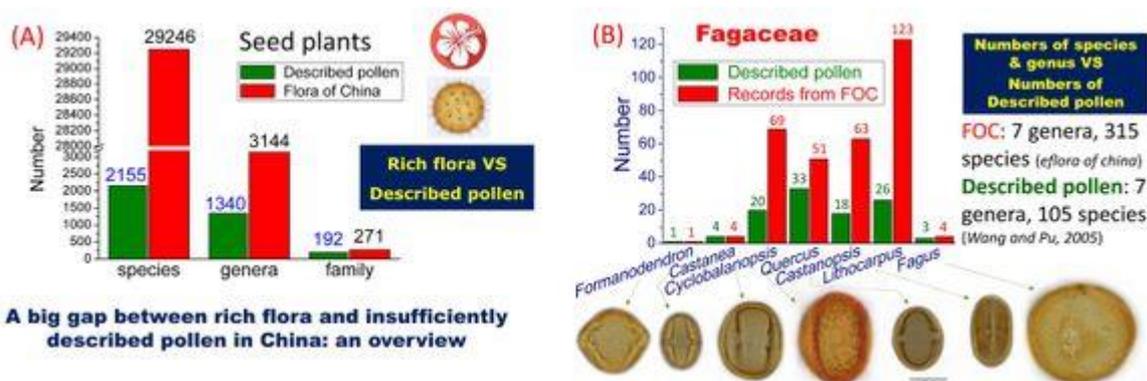


Fig. 1. A showing a big gap between numbers of living seed plants in China and insufficiently described pollen in species, genus and family levels; B showing an example of Fagaceae: numbers of species and genus VS numbers of described pollen, as well as 7 key pollen types in genus level below the diagram.

Notes: Number of seed plants in family, genus and species levels are based on Zhang and Gilbert MG (2015, Comparison of classifications of vascular plants of China. *Taxon*, 64, 17–26) and online FOC ([www.foc.org](http://www.foc.org)); Numbers of pollen in family, genus and species levels are mainly based on Pollen atlas of China plants (Wang et al., 1995),



Tropical and Subtropical pollen of China (1985), and Pollen morphology of Fagaceae and its biogeography (Wang and Pu, 2004).

P-1269

## Using Environmental Archaeological Data from Wetland Sites: From Resource Reconstruction to Nutritional Archaeology

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### Abstract

As pointed out many years ago by Margaret Davies palaeoecologists are very good at creating large quantities of data but this data is generally under-utilised. Environmental archaeologists and specialists are highly proficient at producing long lists of taxa from excavations, particularly wetland sites where preservation conditions are particularly favourable. This data is then used, generally selectively, in the site narrative(s) and particularly in the case of fauna to provide a picture of the major components of human diet. This generally leaves the vast majority of the data languishing in the Report Appendices and unused, at least in the short term. The rise of environmental databases, from pollen to fish, has partly ameliorated this situation but is still limited by the approaches taken to analyse this data beyond diachronic mapping. This paper presents a conceptual methodology for using this data by coupling faunal and floral lists with nutrient databases with the aim of investigating the nutritional space associated with the archaeological sites. There are many problems with this approach (e.g. taphonomic, a uniformitarian assumptions etc.) but it can provide a heuristic methodology which seeks to examine the reality of our dietary and life-way reconstructions. The example used here is Jomon sites in Japan, a period which is particularly well suited due to the large number of wetland archaeological excavations over the last 20 years around the coasts which have recovered remarkably well preserved remains of fish, animals and plants. These remains have been used to create a nutritional landscape within which these peoples, lived and which produced the famous 'affluent hunter-gatherer' (Jomon) society. The data can also be used to look at food culture over the long-term which is of contemporary interest as one of the overall effects of this dietary and cultural history is that Japanese society has traditionally had one of the globally highest life expectancies as well as a distinctive food-culture.

**P-1270**

## **Archival data mining activities in northwestern Canada: serendipitous science and its use in advancing understanding of Quaternary environments**

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### **Abstract**

Many examples of known and likely yet to be discovered archival datasets held by industry, governments, and regulatory bodies contain invaluable treasure troves (sometimes quagmires) of observational and instrumental data. Recognizing and identifying the potential of these (particularly those collected for unrelated/unintended purposes) is often a first step to constructing databases that enable significant and at times serendipitous advances in understanding diverse aspects of Quaternary environments. This study provides examples of three such projects and discusses their application and issues surrounding data formats, accessibility, interoperability, and uptake by researchers and the public. Momentum created by these kinds of database projects manifests in establishing formal arrangements for future data collection, standardization, and digital integration.

The first dataset discussed is seismic shothole drillers' logs which were dismissed by industry as "junk data" and only fleetingly used by Mackay and Rampton in the early 1970s to investigate buried ice in Tuktoyaktuk Peninsula, Canada, and by the Geological Survey of Canada in 1974-1975 as an aid to hurried surficial geology mapping along a proposed 1400 km pipeline corridor. These logs of shallow (avg. 18.6 m deep) lithostratigraphy were collected by industry as a means of simply understanding what the seismic charge was seated in (pertaining to implications for potential static interferences). Originally discovered by the author as a forgotten archive of 76 000 4"x6" paper file cards with hand-written and typed logs, these led to a 4 year industry-wide archival recovery project, that manifested as the single largest source (n=360,000 records) of baseline, near-surface geoscience information across 0.5 million km<sup>2</sup> of northwestern Canada. Interpolative databases, and derivative GIS products and models led to more than 12 thematic geoscience reconstructions ranging from geohazard identification, granular aggregate resources, and regional till facies, to offshore marine bottom-fast and winter lake ice thickness and extents, to baselines for assessing vegetative recolonization and habitat alteration.

The second dataset relates to grab samples collected during drilling of seismic shotholes that were then used to provide lithogeochemical information. Approximately 9000 basal and intermediary sediment/bedrock samples were collected over a 4 year period of intense seismic exploration activity through the western Canadian arctic mainland and island archipelago. These samples permitted preliminary lithological, sedimentological, paleontological, and geochemical assessments to be made across a vast, often unexplored area, greatly expanding the understanding and mapping of regional geology.

The final dataset relates to diamond drill hole and petroleum well logs reported in exploration company assessment reports filed with government regulators in Canada's Northwest Territories. These provide unique records of drift and bedrock thicknesses, and are being used to construct drift isopach maps and model till and other glacial deposit facies as an aid to regional mineral exploration activities.

**P-1271**

## **The advantages and limitations of old data and collections on the study of a new interglacial**

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### **Abstract**

Advances in the Quaternary sciences have had a major impact on the way archaeologists view the hominin occupation of Britain. While modern work is being undertaken, much of Britain's Palaeolithic record was recovered by antiquarians and amateur collectors before the invention of modern techniques. Data from these sites is compiled in the works of Roe (1968) and The English Rivers Project, valuable resources that are often used by Palaeolithic specialists. These have formed the foundations of current work on MIS 9. This work has highlighted the advantages and disadvantages of these large datasets as well as the old collections themselves. It is important to understand the limitations of past data and the need for some re-evaluation due to advances in methodology and in our understanding of Quaternary chronology. Sites previously obscured by a shorter chronology can now be assigned to previously unrecognised interglacials and provide insights not possible from previous work. Re-examination of assemblages from sites and find-spots dated to this period is giving MIS 9 a character of its own, as well as making contributions to the understanding of broader Palaeolithic patterns.

Roe's handaxe groups have recently been re-interpreted as being temporally significant, and the re-use of pre-existing collections is proving vital to fitting MIS 9 into the sequence. The re-evaluation of material referred to as Proto-Levallois/Simple prepared cores/tortoise cores offers the opportunity to examine the changes between the Lower and Middle Palaeolithic and the relationship between Levallois and other types of knapping.

Roe, D. 1968. *A gazetteer of British Lower and Middle Palaeolithic sites*. London, CBA research report 8.

**P-1272**

## **The vegetation history of Greater London**

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### **Abstract**

Over the course of at least the last 50 years, pollen analysis has been carried out on a vast number of sites across Greater London as a consequence of both research and developer-funded investigations. The investigation of each individual site has led to a reconstruction of various time periods since the beginning of the Holocene (~11,700 years ago). In short, Greater London contains a greater density and distribution of Holocene pollen records, than possibly any other major global city in the world. Over the summer of 2018, relevant palynological, stratigraphic and chronological data was systematically extracted and collated from a significant proportion of these palaeoenvironmental records, held at the University of Reading.

The taxonomy of the pollen data was harmonised across all sites, and new age-depth models constructed for all sequences. The majority of sequences included fewer than four radiocarbon dates, and thus linear or smoothing splines models were used to assign a calibrated age to individual samples. Counts were aggregated into continuous 250-year long time bins to facilitate correlation in both space and time. This resulted in count data for 112 taxa in 488 individual binned samples from 59 dated sequences. This is believed to be the densest concentration of pollen count data compiled to date. The majority of samples lie between 7000 - 2000 cal BP, detailing the period of time from the Mesolithic to the late Iron Age and the transition to settled agriculture across Greater London. Initial results show that the most significant transformation of vegetation took place between 3750 - 3250 cal BP, during the early to middle Bronze Age in this region, marked by a dramatic increase in taxa indicative of open ground conditions. This is broadly synchronous with the development of field systems, established from the archaeological record from the wider region. Mapping of key synanthropic taxa is beginning to reveal spatial patterning of land exploitation.

The future aims are: (1) to expand the Greater London database with palaeoenvironmental data from other sources and researchers, (2) use the dataset to explore the extent to which changing environmental conditions (such as topography, tidal influence, cultural activity) resulted in patterning of dryland and wetland taxa across Greater London.

P-1273

## What happened across Northern Eurasia at deglaciation? Finding records from Siberia and the Russian Far East.

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<sup>2</sup>Geography, Politics and Sociology, Newcastle University, Newcastle, United Kingdom. <sup>3</sup>School of Geography and Environmental Science, University of Southampton, Southampton, United Kingdom. <sup>4</sup>North-East Interdisciplinary Scientific Research Institute N.A. Shilo, Magadan, Russian Federation. <sup>5</sup>Quaternary Research Center, University of Washington, Seattle, USA. <sup>6</sup>Newcastle University, Newcastle, United Kingdom. <sup>7</sup>Department of Geography, University of Oregon, Eugene, USA

### Abstract

Siberia and the Russian Far East (SRFE) together comprise a large land area that is considered highly susceptible to current global warming in terms of vegetation and biogeochemical responses. Understanding past responses to other instances of rapid warming, such as the transition from the Younger-Dryas (GS1) stadial to the Holocene, can help identify spatial and temporal patterns in ecosystem responses across this key region. Past changes have probably been manifested unevenly in space and time, given the huge geographic coverage, but this remains uncertain as there are few currently available records for regional reconstructions. This partly reflects the fact that SRFE has few science centres and there are major logistic constraints on field studies; but also the historically parallel development of Soviet and western science and, currently, language barriers and physical isolation mean that much Russian work does not reach the international community.

This year, a new group (DIMA) was formed to cooperate on studying past environmental change in SRFE. We set ourselves several tasks, one of which is data rescue and collation, with a first aim of examining evidence for the Younger Dryas oscillation across the region. Climatology argues for a varied response related to latitude, longitude and ocean proximity, and we will use transient palaeoclimate simulations to develop a working climatological framework. We are reviewing not only internationally published records but also national and institutional publications to assess the quality of information across the region. The main challenges are adequate dating and adequate sample resolution. The poster presents patterns of change developed to date and examines their fit to the palaeoclimatic framework.

\* So far, scientists from 12 institutions across SRFE plus scientists from the UK form the DIMA group (Developing Innovative Multiproxy Approaches-for SFRE). The group is funded by several sources and welcomes new group members who are working in the region or who have an interest in working there. More details at <https://research.ncl.ac.uk/dima/> and <https://www.arctic.ac.uk/blog/>

P-1274

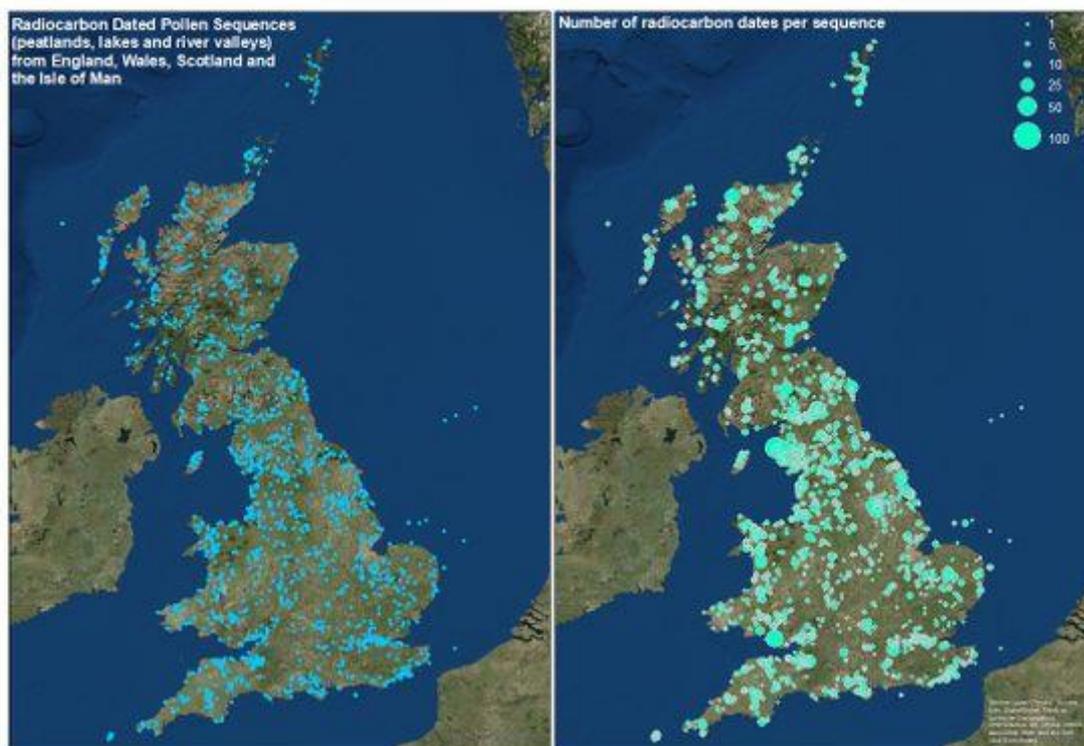
## The British Pollen Database (BPOL) - a metadata repository to enhance regional modelling of vegetation composition and data sourcing

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### Abstract

Pollen analysis provides a powerful and extensively utilised tool for understanding past vegetation composition, climate and human activity. This is due to pollen being preserved in a wide range of sedimentary environments and pollen being derived from, and therefore providing a record of, vegetation beyond the sampling location. Large datasets can now be compiled for identifying and exploring the complexities of pollen data temporally and spatially, facilitated by databases such as Neotoma. However such schemes are dependent upon voluntary contribution and may therefore only provide a snapshot of the total body of work undertaken within a given region. In order to bridge the gap between data freely available and potential datasets languishing with researchers, metadata repositories provide an important resource. The British Pollen Database (BPOL) has been developed to capture information on dated pollen sequences from sediment basins within England, Wales, Scotland and the Isle of Man, complimenting the metadata repository for pollen studies in Ireland (IPOL; <http://ipol.ie/index.html>). The database currently contains over 2600 dated sites dated up to 40ka, with full details of chronological data including over 9500 radiocarbon dates. This shows that <6% of dated British pollen sequences are currently available through the European Pollen Database



(EPD).

To illustrate the use of BPOL, the timing of the arrival and expansion of *Fagus sylvatica* (Beech) in lowland Britain is reanalysed utilising 1200 sites, supplemented with archaeological charcoal data. These combined datasets conclusively demonstrate that Beech was present in the British Isles from at least 6ka, compatible with



palaeoclimatic model predictions but significantly earlier than models based upon pollen data held within the EPD. This finding highlights the need for greater access to raw data and the requirement to carefully consider biases inherent in the available data such as specific geologies, site types and spatial distribution.

**P-1275**

## **From our correspondent in Wales: forty years of palynology recorded in the letters of Harold Augustus Hyde**

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<sup>2</sup>Department of Geography and Environment, University of Aberdeen, Aberdeen, United Kingdom

### **Abstract**

H.A. Hyde was Keeper of Botany at the National Museum of Wales from 1922 until 1962. His life was shaped by his fascination for palynology and his research was published in more than 100 scientific papers. Hyde corresponded with many leading palynologists throughout his long career and archived copies of his correspondence survive in the National Museum Wales. These first-hand accounts indicate major influences on Hyde and hint at turning points in his life.

Throughout the early twentieth-century palynology was evolving as a discipline and the letters provide a record of the early decades in this process. Thus, letters to L.J.D. Richardson and P. Sears show how Hyde and D.A. Williams came to coin the term 'palynology' in 1944. In 1952 the subject of staining was clearly controversial and K. Fægri confided to Hyde that 'The Berne meeting went very well. I cannot boast that I have converted the heathens yet, but I have a feeling that the old deities have lost their grip on the congregation. It was decided that the method (i.e. staining) should have a fair trial'; while J. Iversen wrote later that year 'there can be no doubt that all details of structure in fresh pollen will be much easier to study when the grains have been stained'.

More personal letters reveal something of the contrasting personalities and complex relationships of celebrated palynologists. The candid letters of Faegri provide fascinating details of meetings where leading figures such as G. Erdtman, Iversen and H. Godwin were vying to influence the direction of the discipline.

The privations and practical problems associated with World War II and its aftermath are illustrated. In 1954, when Godwin writes to enquire about a bog site at Craig-y-Cilau, Hyde explains that he has long been deterred from putting a borer into the bog following reports that the bog had been 'peppered all over with hand grenades.'

Over his 40 year career, Hyde exchanged over 200 letters with his long-term friend Sir Harry Godwin. Their letters reveal their shared enthusiasm for palynology and professional achievements and disappointments. For example, in May 1948 Godwin wrote to Hyde 'You have my sympathy in the matter of the directorship, especially so since an exactly similar experience has just been my own in respect of the Cambridge Chair.' In April 1960 Hyde writes 'my heartiest congratulations and sincere good wishes on your election to the Chair of Botany'.

Such examples demonstrate the research potential of archive collections. Their ability to reveal opinions, attitudes and motivations are especially informative when tracing discipline development and the sociology of science.

P-1276

## Radiocarbon dating method – 70 years in service of the Quaternary sciences

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### Abstract

The first half of the 20<sup>th</sup> century witnessed dramatic development of nuclear techniques. The discovery of <sup>14</sup>C was a consequence of this and the development following the early work on radioactivity and radioactive isotopes. The history of radiocarbon dating method and its application in Quaternary sciences is a fascinating story 'written' by numerous researchers during the last 70 years. In 1949 Willard Libby and his students published the first radiocarbon ages (curve of known) (Arnold and Libby 1949). Following this development, the first radiocarbon laboratories were created to establish chronologies of natural records and archives. The urge for obtaining absolute time mobilized geologists and their physicist colleagues to establish counting labs that would allow dating peat sections, mammoth bones and similar. In the USA the first labs: USGS Reston, Lamont, Chicago, Pennsylvania, and Arizona. News of the new method quickly reached Europe and the first laboratories were established in Cambridge (UK), Trondheim (Norway), Groningen (Netherlands), Uppsala (Sweden), Bern (Switzerland) and Gdansk (Poland) and others. A lab in New Zealand was also established about the same time. Despite the fact that grams of carbon were needed for a reasonable counting statistics (10 g in the first publication Arnold and Libby 1949) a number of radiocarbon dated samples grew rapidly and chronologies of important geological sites were created. By the end of the first decade lists of radiocarbon ages produced by 13 laboratories was published in the first issue of Radiocarbon Journal v. 1(1) (1959). In the decades that followed radiocarbon dating method was and is constantly developed and improved to become a modern and sophisticated tool that can be applied to the material as young as present day and as old as 50 ka. We will present an overview of this development and talk about the pioneers of the method.

Arnold JR, and Libby WF. 1949. Age Determinations by Radiocarbon Content - Checks with Samples of Known Age. *Science* 110: 678-680

P-1277

## Paleoenvironmental reconstruction of southwestern Mongolia during MIS 3: new evidence from lake sediment record

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### Abstract

The mechanisms that lead to the appearance of the Initial and Early Upper Paleolithic (IUP-EUP) are of major importance in order to evaluate models of emergence/dispersal of Anatomically Modern Humans (*Homo sapiens*) in Eurasia. An aim of the present study is to understand detailed paleoenvironmental changes in Mongolia, situated at key crossroads for human migration between central, eastern, and northern Asia. Available archaeological evidences have suggested the emergence of IUP at around ca. 45-40 ka (e.g., Zwyns *et al.*, 2014; Rybin *et al.*, 2016; Izuho *et al.*, 2018). However, yet the paleoenvironmental changes of this period in Mongolia is largely unclear, preventing us to understand whether the possible environmental and landscape changes were significant as a major driving force for modern human's lifeway.

In this paper, we present new record of paleoenvironmental changes in southwestern Mongolia during MIS 3. In January 2017, we took two parallel cores (OROG01, 24 m; OROG02, 21 m) from Orog Lake, a shallow saline lake located in northwestern margin of Gobi Desert. The high-resolution major and minor element composition changes were obtained using  $\mu$ XRF core scanner (Cox, Itrax) at Center for Advanced Marine Core Research, Kochi University. Based on the preliminary results of OSL and <sup>14</sup>C age dating, basal age of sediment core OROG01 yielded ca. 38 ± 4 ka, nearly accordant with the basal age of ~45 ka reported in the previous study (Yu *et al.*, 2019). On the basis of our high-resolution elemental composition data, in conjunction with previous sedimentological and palynological data (Yu *et al.*, 2019), the paleoenvironments of southwestern Mongolia were more humid with higher lake levels during MIS 3 than Holocene. Our results also suggest periodic and higher amplitude paleoenvironmental changes in this region, which likely correspond to Dansgaard-Oeschger events. This new record would allow us to discuss potential relationship between paleoenvironmental changes and ecosystem changes in Mongolia during the IUP-EUP.

### References

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Rybin, E. P., *et al.* (2016). Geochemical imprints of coupled paleoenvironmental and provenance change in the lacustrine sequence of Orog Nuur, Gobi Desert of Mongolia. *Quaternary International*, 425, 69-87.

Yu, K., *et al.* (2019). Late Quaternary environments in the Gobi Desert of Mongolia: Vegetation, hydrological, and palaeoclimate evolution. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 514, 77-91.



Zwyns, N., *et al.* (2014). The open-air site of Tolbor 16 (Northern Mongolia): Preliminary results and perspectives. *Quaternary International*, 347, 53-65.

**P-1278**

## **The specific technique of core platform preparation in the Initial Upper Palaeolithic assemblages of Kara-Bomian cultural tradition (Altai Mountains)**

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### **Abstract**

In this paper, we presented the results of a study of the main techniques of core platform preparation that are common in the Initial Upper Palaeolithic assemblages of Kara-Bomian cultural tradition. Kara-Bomian is the most ancient Upper Paleolithic tradition in the Altai region. The stone assemblages of this tradition have a similar set of cultural attributes, including specific technologies for producing elongated blades, the production of Upper Palaeolithic types of tools and personal ornaments, as well as evidence of the ochre use. The age of the Kara-Bomian IUP tradition complexes is in the chronological range of 47,000–37,000 cal yrs BP.

At present, questions about techniques of core platform preparation within the framework of the Kara-Bomian large blade production technology have been studied relatively poorly. Reliable evidence of the existence of a single set of these techniques in the complexes of this cultural tradition was absent. As part of our study, we studied the collections of core and blades from archaeological sites Kara-Bom (excavation area 4, 1992–1993, cultural horizon UP2), Ust-Karakol-1 (excavation area 1, 1986, habitation level 5.4–5.5) and Kara-Tenesh (lithological layer 3).

The traceological analysis and the study of cores and blades platform morphologies have shown that the technology of large blade production included a combination of several methods of fracture zone preparation. The first technique is represented by the reduction of the platform edge with a direct strike from the stone hammer or smoothing with unspecialized stone tools. The second method involves retouching of the platform edge transverse to the flaking surface, removing the overhang – reverse reduction. The third method of fracture zone preparation is very specific for the Initial Upper Paleolithic of Southern Siberia and Central Asia – the pecking. This technique suggested a point impact by a stone tool for crushing and removing small particles of stone raw material. The relatively even and rough surface created with these techniques provided better grip of the hard hammer stone with the core platform at the moment of impact, which was important for obtaining extremely long and wide blades. Careful preparation of the fracture zone significantly increased the degree of fracture control, allowed to standardize the process of production large blades and reduce the percentage of artisan errors.

The combination of pecking with the other methods of core platform preparation was noted in the context of the blade reduction of the Initial Upper Paleolithic assemblages of the of Southern Siberia and Central Asia. On the territory of the Altai Mountains, this specific technological method is reliably recorded in the context of the earliest archaeological complexes, mainly belonging to the Kara-Bomian cultural tradition.

We are grateful to the RFBR (grant 18-39-00167 and 18-39-20003) for supporting our research.

**P-1279**

## **Kula Unesco Global Geopark: a valuable resource of data for river-valley and landscape evolution**

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### **Abstract**

Kula Geopark. Located on the northern shoulder of the Alesehir graben in the Aegean Region of Turkey, is a tectonocally and volcanically region in which the most recent eruptions of basaltic lava, associated with volcanic cone formation, was in the latest Pleistocene and Holocene. Much older volcanism within the same volcanic province is also in evidence, with some of the older lavas capping mesa-style hills, such that they have preserved underlying poorly consolidated sediments that would otherwise have been lost to erosion. Beneath these hill-capping lava, above Neogene sediments representing endoreheic basin-fill, are early sediments of the River Gediz system, forming narrowly separated terraces (separation by a few metres) thought to have formed in response to the ~40 krs obliquity-driven climate cycles of the Early PLeistocene. The rarity of terrace preservation from this early part of the Quaternary makes this a very valuable aspect of the geopark, all thanks to the unique sitiation in which the unconsolidated fluvatile sediments have been protected by the resistant lavas. There is also evidence of periodic damming of the river system by lava eruptions, bringing about lacustrine phases that can be recognized from lake sediments and deltas that were built into the former lakes. The poster will concentrate on the evidence from the geopark for progressive deepening of the gediz valley, following 'inversion' of the Neogene endoreheic basin system.

**P-1280**

## **Conserving our Quaternary geoheritage in the 21st century: the role of geoscientists and scientific associations in Britain**

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### **Abstract**

Conservation of our Quaternary geoheritage is vital for both science and society. Scientists need access to well-managed sites for fieldwork (both for research and educating students), whilst society relies on information from Quaternary geoscience to understand how our Earth system works and changes over time. In Great Britain, there is considerable demand for land, housing and infrastructure development, mineral extraction and the provision of high-quality greenspace, all of which have the potential to enhance, threaten, destroy or prevent access to Quaternary sites. Furthermore, attempts to constrain or 'manage' geomorphological processes such as coastal and fluvial erosion can also impact Quaternary sites. Given these threats and potential opportunities to enhance sites in terms of access, study and interpretation, effective and evidence-based Quaternary geoconservation is needed now more than ever.

In Great Britain, nationally and internationally important Quaternary geoheritage is protected through legislation, with the delivery of conservation facilitated by Quaternary experts in government conservation agencies in England, Scotland and Wales. Locally important sites can also be identified and notified to local planning authorities whereby they are taken into account when planning decisions are made. However, ensuring that this protection delivers effective conservation on the ground relies on strong partnerships between conservation practitioners, Quaternary scientists and scientific associations. Quaternary and geological associations and individual Quaternary scientists have made a valuable contribution to successful conservation since the first geoconservation legislation was enacted in 1949.

Here we review the vital contributions that Quaternary geoscientists and scientific associations have made to national and local site selection and audits, the safeguarding of individual sites during development planning, and to the conservation and management of Quaternary sites. We discuss the wider role that scientific associations have had in Quaternary geoconservation, for example in engaging with government consultations, responding to local campaigns, providing evidence when sites undergo legal scrutiny and giving expert feedback to consultations on site management. Future opportunities for supporting conservation of our Quaternary geoheritage, including raising awareness of conservation approaches and principles, encouraging scientific involvement in conservation, providing funding for conservation and outreach, and enabling the sharing of evidence and best practice are also reviewed. Finally, the lessons learned from activities to date are explored and aspirations for the development of Quaternary conservation geoscience in future are set out.

**P-1281**

## **Recognising geodiversity and encouraging geoconservation – some lessons from Callander, Loch Lomond and the Trossachs National Park, Scotland.**

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### **Abstract**

Scotland for its size, has an internationally recognised geodiverse landscape. With a geological history of over 3 billion years, geological resources have contributed to the economic wealth of a nation and this geoheritage has also formed the basis for scientific thinking across natural history with Hutton, Lyell and Darwin all inspired by Scottish landscapes.

The importance of this geodiversity has been recognised in the formation of UNESCO Geoparks (North West Highlands Geopark and Shetland Geopark) and National Parks (Loch Lomond and the Trossachs National Park and Cairngorms National Park). Scotland's Geodiversity Charter (Scottish Geodiversity Forum, 2017) was first launched in 2012, coordinated by a group including non-governmental agencies (Scottish Geodiversity Forum, GeoConservation UK) and governmental bodies (Scottish Natural Heritage, British Geological Survey). The Charter encourages the promotion and management of Scotland's geodiversity and provides a framework for stakeholders and agencies to engage in sustainable geoconservation. The document has been kept live with regular updates and case studies and is now supported by 88 signatories, including national organisations, local authorities, community groups and businesses.

Here we present some of the barriers and challenges around the implementation of the Geodiversity Charter with a review of geoconservation issues around the town of Callander, a southern gateway to Loch Lomond and the Trossachs National Park. It has been a tourist destination since Victorian times but within the scientific community is known for its exceptional set of glacial geomorphological features including moraines, eskers, kame terraces and drumlins. These features face pressures, either from sand and gravel extraction or housing development. Over decades, important features have gradually been lost, often without adequate recording. The area presents an important case study about how the academic and geoconservation community can engage with the planning process, and the challenges of communicating with planning authorities and local communities. We consider what official designation of sites means for conservation and what a wider more holistic approach (for example green spaces, biodiversity, education) may bring to more effective local designation status.

The case study highlights that there is a real desire to protect sites that the scientific community view as valuable to science, but that challenges exist to balance demands on these sites. The Geodiversity Charter offers a framework that stakeholders can use to recognise the value of such features and work towards sustainable management and education. Case studies such as Callander provide lessons and solutions to overcome the challenges that arise and highlight the need for the participation of both national and local groups.

Scottish Geodiversity Forum (2017). Scotland's Geodiversity Charter 2018–2023. Edinburgh: Scottish Geodiversity Forum.

P-1282

## Wansunt Pit SSSI: the importance of Visual Management Plans in Quaternary geoconservation in England

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### Abstract

Wansunt Pit Site of Special Scientific Interest (SSSI) (unit 1, Geological Conservation Review (GCR) number 846; TQ 515738) is a 1.44ha former gravel pit situated on the border of Greater London and Kent, UK. Notified for its Quaternary of the Thames features, the site provides exposures of Dartford Heath Gravel, overlain by the Wansunt Loam silt deposits for which Acheulian hand axes have been recovered. Historically, the site was better known for its much-debated stratigraphic relationships: whether the Dartford Heath Gravel was stratigraphically equivalent to the nearby Swanscombe sequence, and whether or not they related to the Boyn Hill Terrace. Now largely resolved, the importance of Wansunt Pit now lies with the in-situ Palaeolithic artefacts found within the Wansunt Loam, representing hominin occupation of the site and larger-scale connectivity to hominin activity at Swanscombe.

However, bridging the gap between scientific significance and public awareness (including that of the owners, occupiers and land managers) is key when considering how protected geological sites should be conserved and managed. At Wansunt Pit, a lack of contextualisation and understanding of its geoheritage correlated with overgrowth of vegetation, combined with a lack of communication of geoconservation strategies, meant that condition of the notified geological features, and hence the SSSI as a whole, had become unfavourable. Using Wansunt Pit as a case study, a partnership approach involving land managers, academics and geoconservation specialists was therefore implemented with the aim of returning the site to favourable condition using the creation of a Visual Management Plan (VMP) as a communication and collaborative tool. The VMP is a powerful way of imparting geoheritage information; fostering greater understanding of why conservation is needed, as well as illustrating geoconservation targets that are mutually agreed and achievable.

The Wansunt Pit VMP integrated text, maps and annotated photos in order to i). resolve previous issues with location of exposure localities and ii). pinpoint sections requiring management and iii). explain the importance of the geological and archaeological features. Two key areas were the focus of vegetation clearance: section 6 for the Wansunt Loam, plus a new section identified for the Dartford Heath Gravel, hereby named section 9. Agreed vegetation clearance and cutting techniques for both sections were illustrated in the VMP, along with the rationale for geoconservation. The VMP was well received by the SSSI land managers and the geoconservation work illustrated in the VMP is being planned. The Wansunt Pit VMP demonstrates the efficacy of visual plans for communicating and agreeing the geoconservation requirements of often complex geological SSSIs. As a collaborative effort, VMPs also have great potential for the sharing geoheritage knowledge, geoconservation techniques and best practice guidance, which is integral to transforming scientific discovery in to public knowledge.

**P-1283**

## **Capturing advances in Quaternary Science for geoconservation in the UK – an evolving approach spanning 70 years.**

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### **Abstract**

In the UK the conservation of Quaternary deposits, landforms and landsystems is founded on the assessment and safeguard of key protected areas principally for their scientific values. The evaluation of site networks for Quaternary deposits and landforms (including glacial, fluvial, coastal, mass movement, karst and cave features) has evolved since the late 1940s in parallel with scientific advances, culminating in the Geological Conservation Review (GCR) site assessments undertaken between 1977 and the early 1990s. Significant scientific progress over the last 25 years has arisen, for example, from re-investigation of existing sites and discoveries of new sites, developments in geochronology and the formulation and application of new concepts and models. Both the GCR site lists and the supporting site documentation now require updating in the light of this progress. While updating the GCR is a valid and worthy approach, it binds conservation to a snap shot approach with the need for repeated scientific review. The inherited approaches from 1977 have some limitations, yet developments in science as well as wider geoconservation globally show other opportunities. Today there is greater emphasis on the wider, non-scientific values of geoconservation including, for example, on ecosystem services, links with biodiversity and cultural heritage, geotourism and the benefits for human health and wellbeing through improved understanding of dynamic landscapes, climate change and natural hazards. Involvement of wider public support beyond the geoscience community and fostering better integration of geoheritage within the developing nature conservation agenda, including protected area planning and management, natural capital and connecting people and nature will help protect our Quaternary geoconservation heritage.

P-1284

## Palaeocological approaches to urban conservation: A case study of Sydney, Australia's water reserves

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### Abstract

Sites are often prioritised for conservation based on the premise that they represent remnants of bygone landscapes of natural and/or cultural significance. These approaches are, however, often constructed in the absence of any long-term socio-ecological data, making it challenging to draw parallels between the site being conserved, and the past landscape that it ostensibly mirrors. The marrying of palaeoecological and historical data can provide a wealth of information pertaining to the evolving natural and cultural values assigned to protected areas. This is an invaluable resource for reconstructing past physical environments, linking these changes to evolving social attitudes through time, and using these data to improve conservation management via redefining policy directions, constructing restoration objectives, or targeting new sites for protection.

The Lachlan Nature and the Botany Water Reserves are located within an urbanised zone of southern Sydney, Australia, and are managed as the last remnants of once-extensive swamplands that formed the basis of the city's water supply from 1827 to 1896 C.E. This research presents results of a married palaeoecological and historical reconstruction of these sites, to 1) assess the validity of the contemporary conservation goals applied to the sites; and 2) develop a spatio-temporal framework for future management of the Reserves. This includes assessment of the socio-ecological values that are actually reflected within the protected sites, and investigation of alternative sites that perhaps better mirror the 19<sup>th</sup> century swamplands.

Our results challenge core assumptions underlying the contemporary management approach applied to these sites, emphasising the key role that long-term socio-environmental perspectives can play in developing pragmatic conservation policy. We argue that a multidisciplinary historical and palaeoecological approach can provide an invaluable resource for evidence-based management of protected sites, and encourage a broader uptake within conservation practice.

P-1285

## Quaternary palaeoecology and the historic environment: challenges and potentials

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### Abstract

The potential contribution of the study of Quaternary palaeoenvironmental deposits to our understanding of the historic environment and archaeology, is considerable; from reconstructing past (changes in) climate and environment in order to understand landscapes previously inhabited, to identifying resources that were available and exploited – providing evidence of past cultures and societies.

Such palaeoecological and archaeological evidence is best preserved in waterlogged deposits, in terrestrial and coastal areas, and can be considered at both a landscape scale (e.g. the Somerset Levels), and at an individual site or feature scale – whether these are naturally formed (e.g. kettle holes, intertidal peat exposures) or constructed by people (e.g. ponds, moats). Work by Historic England aims to highlight the palaeoenvironmental and archaeological potential of such deposits more widely; for example, the report outlining the importance of small wetlands (Farrell and Hazell, 2016) and the on-going '*Exceptional waterlogged heritage*' project (see Heathcote and Campbell, 2013). In addition, Historic England's (2018) guidance outlines best practice if/when considering clearance of water features within historic environment settings – principles which can also be applied to a range of wet or waterlogged deposits preserved within other feature types, natural or human-made.

Yet often, when site works are undertaken – be it for development, or to achieve historic environment and/or nature conservation objectives (e.g. 'restoration' or habitat creation purposes) – the heritage value of these deposits is not considered adequately, and therefore their research potential is rarely fully realised. Possible reasons for this will be explored, starting with the difficulty in affording some of these sites statutory protection within current historic environment designations; perceptions of archaeological science within archaeology more widely, in particular why environmental archaeology is often overlooked or discounted within the discipline; and difficulties in establishing the significance and value to these deposits, especially where the remains are at depth, out of sight and (until discovered) hypothetical. Deposit modelling can provide early warning of organic deposits, but if they are not clearly linked to cultural remains, justification for detailed attention within an archaeological project, especially if development-led, is difficult. Given the lack of specific historic environment designations, protection can default to natural environment designations, which, understandably, have their own drivers and priorities; closer collaboration between agencies could help align methods and approaches.

This paper will outline, from a historic environment perspective, the heritage importance of the remains preserved within waterlogged deposits, whilst using case studies to explore commonalities with other disciplines. By promoting Historic England's activities and interest in this collectively-recognised resource, it is hoped that the identification of complementary interests (e.g. via natural capital concepts) will help strengthen the understanding, value and subsequent protection of these Quaternary deposits to the benefit of current and future generations.

P-1287

## Palaeolithic archaeological potential of Pleistocene deposits in England: a geological mapping approach

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### Abstract

Both Article 5 of the *European Convention on the Protection of the Archaeological Heritage* (Council of Europe 1992) and associated national legislation/guidance [*National Planning Policy Framework* in England (Department for Communities and Local Government 2018)] requires that the potential impact on archaeological heritage must be considered when planners assess development plans. Archaeologists working for planning authorities and in the commercial Cultural Resource Management sector are familiar with the archaeology of and methods for investigating later prehistoric and historic period remains in turn meaning that robust approaches are in place for detecting and investigating Holocene archaeological sites. However, the Palaeolithic is another matter and these same archaeologists are much less confident in assessing where such sites are likely to occur and thereafter determining their importance. The *Palaeolithic archaeological potential of Pleistocene deposits in England: a geological mapping approach* project is a Historic England-funded initiative that will enhance resources available to English planning authorities in their consideration of the Palaeolithic. The Project takes the following as its source material: 1/50,000 British Geological Survey superficial geology maps; relevant national archaeological inventories, i.e. the Southern Rivers Palaeolithic Project, English Rivers Palaeolithic Survey, the Gazetteer of Upper Palaeolithic sites in England and Wales and National Record of the Historic Environment (NRHE); as well as the archive resulting from Aggregates Levy Sustainability Fund-sponsored Palaeolithic research and the published record. Archaeological (e.g. type and quantity of finds) and geological data (e.g. age, mode of formation, diagenesis) are cross-referenced to derive an index of Palaeolithic archaeological potential. The product will be an England-wide online GIS tool for curators comprising Pleistocene superficial geology polygons with appended Palaeolithic archaeological potentials and made freely/easily available to planning authorities via the British Geological Survey's LandFit portal. This poster presents results from the Project's first study area, namely the South-east of England, which show that areas of high Palaeolithic archaeological potential are associated with some river terraces and raised beaches, while areas of low potential coincide with higher river terraces and 'head'.

Council of Europe (1992) *European Convention on the Protection of the Archaeological Heritage* (Revised). <https://rm.coe.int/168007bd25>. (Accessed 8 January 2019).

Department of Communities and Local Government (2018) *National Planning Policy Framework*. <https://www.gov.uk/government/publications/national-planning-policy-framework--2> (Accessed 8 January 2019).

**P-1288**

**Studying Quaternary sedimentation, palaeontological occurrences and their site conservation through remote sensing and field observations in central Narmada basin, India.**

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**Abstract**

Since the 19<sup>th</sup> century, the Narmada River is well known for discovery of abundant vertebrate fossil localities, wide range of archaeological assemblages and first hominid fossil site in India near Hathnora. The fossil and archaeological remains occur in several sedimentary contexts: boulder conglomerate, sandy-pebbly gravel, cemented sandy gravel, and cross-bedded sand in the later Middle to Late Pleistocene deposits. Preliminary field investigations in the Central Narmada basin mark the presence of 26 individual localities within a stretch of 70 km<sup>2</sup> of the Narmada in Narsinghpur District. Paleontological analysis revealed that a variety of animals adapted to sub-humid climate of both aquatic and terrestrial landscapes thrived in this area during Pleistocene period. Various taphonomic processes in this region are responsible for the preservation and destruction of the fossil record in the different geological formations, soil type, climatic conditions, rich calcium carbonate presence, encrustation and patination.

It is interesting to note that most of the fossil localities are found at elevation range of 310-350 meter above mean sea level. During field surveys the fossil rich localities were found restricted within the river terraces, wide floodplains, river gravel bed and major occurrences were observed near the confluence of major and minor stream channels along Narmada River for example Devakachar and Umariya, Barmaan are high potential fossil locality for more than 100 years.

Most of the fossil occurs along with Middle Palaeolithic assemblages or in spatial proximity. The landscape all over the Narmada Basin was inhabited by prehistoric populations and a variety of fauna as evidenced the ample lithic and fossil assemblages across the region. There is a definitive pattern of occurrences of the Quaternary vertebrate fossils and archeological assemblages in the landscape which require detailed investigations and mapping to understand the spatial distribution pattern and nature of associated sedimentary environment.

In addition, this uniquely fossil-rich area requires proper protection and long-term preservation as it is heavily impacted by modern anthropogenic factors such as agriculture, sand mining and other activities.

P-1289

## Wistman's Wood: A tale of conservation value and forest dynamics

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### Abstract

High conservation value has often been associated with the idea of long forest continuity in western European *Quercus* and *Fagus woodlands*, however this has rarely been tested (Bradshaw *et al.* 2015). The antiquity of bryophyte-rich woodlands in western United Kingdom has been discussed by a number of members of the palaeoecological community including Birks (1993), who presented evidence relating current plant community development as a result of late Holocene human activities. Small forest hollow pollen and charcoal analysis of Wistman's Wood, Cornwall, U.K., is used to demonstrate that the modern vegetation community within this ancient woodland, has in fact been influenced by recent human disturbances. Previous to human disturbance, the woodland had a rich tree flora until the eleventh century when it then experienced heavy grazing and browsing until the late nineteenth century, when *Quercus* woodland developed with its associated high conservation value. The diverse histories of western European woodlands is common and current conservation values being placed on the result of both natural and anthropogenic processes.

P-1290

## **Cross-over between heritage- and geo-conservation of the Lower and Middle Palaeolithic: Middle Pleistocene fluvial sites in the south of Britain.**

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### **Abstract**

For archaeological heritage representing the earliest human presence in Britain, there has always been an absence of recognisable structures of the sort required for designation of heritage sites (such as scheduled ancient monuments). Given that there is an overlap with Earth-science interests, this shortcoming has been overcome by the designation of numerous important Lower Palaeolithic localities as geological sites of special scientific interest (SSSIs) and, in one case, a national nature reserve (NNR). The last mentioned is the celebrated Swanscombe locality (north Kent), where the discovery of numerous artefacts with at least three separate industries in superposition is perhaps surpassed in importance by the well-known hominin skull fossil. This 'jewel in the crown' is supported by a large group of SSSIs covering all parts of the Lower and Middle Pleistocene with a concentration of such sites in the Lower and Middle Thames. Issues arise, however, when geological sites lack scientific importance other than sediments which contain rich archaeological material, as the brief of the government agency responsible for Earth-science conservation (Natural England) does not include archaeology. Nonetheless a case can be made for rich artefact assemblages to be considered as trace fossils, and as such to be an integral part of geological science, sometimes of value for the relative dating of sedimentary sequences. This poster will explore case-study examples from ongoing research by the authors.

**P-1401**

## **Drivers of extreme glaciation events: A transient coupled climate – ice sheet modeling case study**

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<sup>4</sup>Earth and Environmental Systems Institute, Pennsylvania State University, Pennsylvania, USA

### **Abstract**

In our study, we present new model simulations with a recently developed three-dimensional coupled climate – ice-sheet model (LOVECLIM – Penn State University ice-sheet model) covering the period from 240 thousand years ago (ka) to 170ka (Marine Isotope Stage, MIS 7 to MIS 6). A series of initial sensitivity experiments reveals the presence of multiple climate – ice-sheet equilibria and run-away effects. To overcome unrealistic ice-sheet growth, we adjust several global parameters (such as climate sensitivity etc.) and enhance the basal sliding coefficient over Hudson bay; which suggest the importance of regional scale adjustments in simulating global responses to orbital variations. More realistic simulations also show the emergence of millennial scale variability. We further test the hypothesis that millennial-scale dynamics play a pivotal role in ice-sheet growth/decay on orbital timescales. Additionally, the effect of inherent instabilities in large ice sheets for rapid deglaciation are explored.

**P-1402**

## **Climatic effect of Antarctic meltwater overwhelmed by concurrent northern hemispheric melt**

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### **Abstract**

Records indicate that 14,500 years ago, sea level rose by 12–22 m in under 340 years. However, the source of the sea level rise remains contentious, partly due to the competing climatic impact of different hemispheric contributions. Antarctic meltwater could indirectly strengthen the Atlantic Meridional Overturning Circulation (AMOC), causing northern warming, whereas Northern Hemisphere ice sheet meltwater has the opposite effect. This story has recently become more intriguing, due to increasing evidence for sea level contributions from both hemispheres. Using a coupled climate model with freshwater forcing, we demonstrate that the climatic influence of southern-sourced meltwater is overridden by northern sources even when the Antarctic flux is double the North American contribution. This is because the Southern Ocean is quickly resalinated by Antarctic Circumpolar water. These results imply that the pattern of surface climate changes caused by ice sheet melting cannot be used to fingerprint the hemispheric source of the meltwater.

P-1403

## Marine ice sheet instability and ice shelf buttressing of the Minch Ice Stream, northwest Scotland

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### Abstract

Uncertainties in future sea level projections are dominated by our limited understanding of the dynamical processes that control instabilities of marine ice sheets. The last deglaciation of the British–Irish Ice Sheet offers a valuable example to examine these processes. The Minch Ice Stream, which drained a large proportion of ice from the northwest sector of the British–Irish Ice Sheet during the last deglaciation, is constrained with abundant empirical data which can be used to inform, validate, and analyse numerical ice sheet simulations. We use BISICLES, a higher-order ice sheet model, to examine the dynamical processes that controlled the retreat of the Minch Ice Stream. We perform simplified experiments of the retreat of this ice stream under an idealised climate forcing to isolate the effect of marine ice sheet processes, simulating retreat from the continental shelf under constant “warm” surface mass balance and sub-ice-shelf melt (figure 1). The model simulates a slowdown of retreat as the ice stream becomes laterally confined at the mouth of the Minch strait between mainland Scotland and the Isle of Lewis, resulting in a marine setting similar to many large tidewater glaciers in Greenland and Antarctica. At this stage of the simulation, the presence of an ice shelf becomes a more important control on grounded ice volume, providing buttressing to upstream ice. Subsequently, the presence of a reverse slope inside the Minch strait produces an acceleration in retreat, leading to a “collapsed” state, even when the climate returns to the initial “cold” conditions. Our simulations demonstrate the importance of the marine ice sheet instability and ice shelf buttressing during the deglaciation of parts of the British–Irish Ice Sheet. We conclude that geological data could be applied to further constrain these processes in ice sheet models used for projecting the future of contemporary ice sheets.

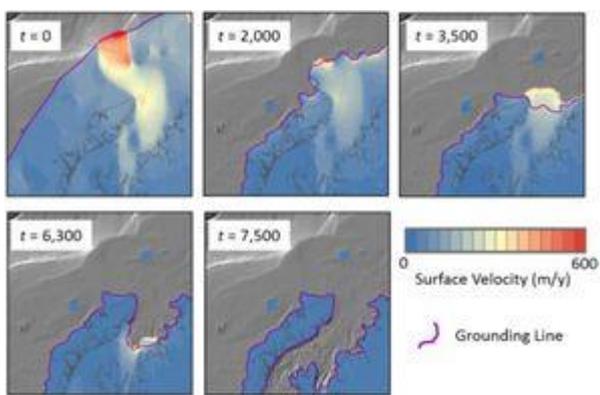


Figure 1: Simulated retreat of the Minch Ice Stream from the continental shelf edge through an idealised climate forcing.

P-1404

## Glacial-interglacial contourite dynamics on the Irish margin over the last 340,000 years: insights from IODP Site U1318, Northeast Atlantic

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### Abstract

IODP (Integrated Ocean Drilling Program) Expedition 307 cored an 95m thick sediment drift at Site U1318B, on the eastern fringe of the Porcupine Seabight (northeast Atlantic). Detailed sedimentological and microfossil analyses reveals a ~340,000 year record of Irish ice sheet advance and retreat and the resultant changes in contourite deposition. A basal late Miocene carbonate unit is overlain unconformably by a series of sediment drift deposits with alternation between active interglacial bottom-currents and lower energy glacial conditions near the ice sheet margin. New foraminiferal assemblage and oxygen isotope data suggest that this region experienced mixed polar water conditions (with abundant *Neogloboquadrina pachyderma* sinistral) for most of the last 400,000 years with occasional periods of subarctic conditions and inflows of warmer Mediterranean Outflow Water (*Globorotalia inflata*, *Neogloboquadrina incompta* and other warmer water species). The region was north of the polar front during Marine Isotope Stages 8, 6 and possible during MIS 4. IRD detritus (250mm) are most common when the region lay south of the polar front. Mean sortable silt data suggest generally high current velocities during warmer phases with the lowest current velocities when the region was north of the polar front.

P-1405

## Persistent overturning of the upper Atlantic as a driver for abrupt climate change

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### Abstract

The relationship between the glacial Atlantic Meridional Overturning Circulation (AMOC) and the millennial-scale climate variability is still debated. Here, we overturn the common deep-centric perception of AMOC reconstruction by reporting changes in near-bottom flow speeds and water-mass chemistry from six French Atlantic margin sites (~1,000 to 2,450 m water depth). Grain-size proxies together with C/O and Nd isotopes reveal an intense glacial eastern boundary current (GEBC) in the North Atlantic ~50,000-20,000 years ago, interpreted as a southward shift of the North Atlantic Current system, *i.e.* the upper limb of AMOC, relative to present. GEBC variability suggests that a weaker/stronger thermohaline overturn corresponds to respective Dansgaard Oeschger cooling/warming. Our data also point to an intra-stadial / interstadial AMOC variability concomitant with far-field atmospheric changes but, more importantly, we note the persistence of a relatively vigorous upper limb of AMOC throughout the last glacial. The persistent poleward export of oceanic heat to the Northeast Atlantic impacted the surrounding ice-sheets, inevitably causing climate instabilities. Based on the above, we propose a conceptual model to explain the origin of climate changes in the glacial North Atlantic. In particular, we argue that the stadial and interstadial periods of Bond cycles are sequentially linked and, further, that Heinrich Stadials are events that break the inherent tendency of both the Bond and ~100 ka glacial cycles to drive Earth's climate towards colder and colder conditions. That is, Heinrich Stadials both prevent boundless climate cooling and are able to tilt Earth's climate from the glacial to interglacial state.

**P-1406**

## **Drivers of change in the position of the Atlantic ITCZ**

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### **Abstract**

Precipitation reconstructions from the low-latitude Atlantic indicate meridional shifts in the annual mean position of the Intertropical Convergence Zone (ITCZ). It is well-known that these shifts connect with large-scale patterns of climate change, including changes in continental ice sheets, ice-berg melting in the North Atlantic and changes in the strength of the Atlantic meridional overturning circulation. In general Atlantic ITCZ dynamics have shown high sensitivity to extra-tropical temperature changes in both the Northern and Southern Hemisphere. However, the complexity of reconstructed past precipitation changes doesn't allow us to disentangle cause and effect, or the effectiveness of different mechanisms driving ITCZ shifts. What role do (local) low-latitude insolation changes play in driving Atlantic ITCZ shifts? Are they driven by temperature change in the North Atlantic, changes in the Atlantic meridional overturning circulation, Southern Ocean temperatures? Perhaps Atlantic ITCZ shifts are a response to greenhouse-gas changes or the size of the continental ice sheets and could there be a role for changes in the amount of Agulhas leakage?

We combine new and existing results from various global climate models to describe the response of the Atlantic ITCZ to forcings such as orbitally-driven changes in insolation, freshwater input to the North Atlantic and the Southern Ocean, changes in greenhouse-gas levels, changes in continental ice sheets and test the potential impact of changes in the strength of Agulhas leakage. We discuss low-latitude Atlantic precipitation characteristics that are robust among models, uncertainties and implications for the interpretation of paleoclimate time-series.

P-1407

## The late Quaternary NW Pacific: regional ice-rafted debris sources and distribution, and fluctuations in regional climate and oceanography

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### Abstract

The NW Pacific contains a largely unexplored late Quaternary iceberg-rafted-debris (IRD) record, but what data that exists points to multiple periods of enhanced iceberg flux from the NE Russian coast and indicates periods of significant change to the terrestrial ice masses of the Kamchatka-Koryak region (St. John and Krissek, 1999; Bigg, 2008; Barr and Clark, 2009). At times, in some places, the IRD concentrations are comparable in magnitude to the much more detailed records of North Atlantic Heinrich Events, however there is little evidence of temporal synchronicity of enhanced iceberg flux between the North Atlantic and the NW Pacific. Additionally, there is little understanding of the localised sources of icebergs in the NW Pacific due to lack of both terrestrial and marine core data.

Through IRD counts in two key NW Pacific cores (ODP 1207A on the Shatsky Rise: 37.79°N, 162.75°E; and DSDP 580 east of the Kurile Islands: 41.37°N, 153.58°E) in addition to previously published records, we address these uncertainties and find that the regional late Quaternary IRD signal does not indeed have a regionwide expression, and instead varies on a sub-regional-scale with no clear synchronicity in IRD peaks between cores. This suggests the existence of more iceberg sources than previously suspected, and a heightened possibility of a significant iceberg source on the Sea of Okhotsk coast.

The IRD record at ODP 1207A is particularly significant because IRD was not previously thought to be present as far south as 37°N in the NW Pacific. The core's age model, comprised of radiocarbon dates, benthic foraminiferal  $\delta^{18}\text{O}$ , tephrChronology and foraminiferal assemblages, place the periods of enhanced IRD flux in mid-late MIS 3. The planktic foraminiferal assemblages suggest, however, that the subarctic front of the NW Pacific moved southward of ODP 1207A more decisively during the penultimate glacial period (MIS 6), but this oceanographic shift was not accompanied by enhanced IRD. This implies that the southward extent of IRD is not governed by the position of the subarctic front but by changes to ice cover in NE Asia between glacial periods.

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**P-1408**

## **Seasonal discrepancies of the ‘Atlantic-Pacific thermal seesaw’ during Heinrich Stadial 1**

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### **Abstract**

Paleoceanographic evidences have characterized the North Pacific sea surface temperatures (SSTs) by anti-phase changes against the North Atlantic during millennial-scale abrupt climate changes, thus constituting an ‘Atlantic-Pacific thermal seesaw’. During HS-1, a North Atlantic cold interval of the last deglaciation, the North Pacific upper ocean has been suggested for warmer or warming conditions by marine proxies. In contrast, some other paleoceanographic evidences have characterized the high-latitude North Pacific by insignificant change or even lower SSTs during HS-1, indicating an in-phase rather than seesaw change with the cooling over the northern North Atlantic. By decoding the complexity of the North Pacific climate change in HS-1, our modelling work in this study aim to further develop the understanding about the climatic linkage between the North Pacific and North Atlantic and thus the physics of ‘Atlantic-Pacific thermal seesaw’.

We utilized a complex Earth System Model, Max-Planck-Institute Earth System Model (MPI-ESM) and simulate the Last Glacial Maximum and HS-1 climates by applying the freshwater perturbation over the North Atlantic Ice rafted debris Belt. Our results characterized the North Pacific SST anomalies of HS-1 to LGM by a seasonal discrepancy of a summer cooling and winter warming compared to the LGM conditions, controlled by two processes of ‘ocean warming potentials’ and ‘atmospheric cooling effect’. Moreover, these seasonal behaviours resulted in inconsistent temperature change along with the depths in the North Pacific Ocean from the LGM to HS-1. According to our results, the existing heterogeneities of ‘Atlantic-Pacific thermal seesaw’ indicated by marine proxies correlate to their distinct depth and seasonal preferences among various marine proxies.

P-1409

## Records of Dansgaard-Oeschger millennial oscillations during the last two climate cycle

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### Abstract

Investigating key European records of the last climate cycle, we have demonstrated a strong correlation between millennial variations of loess accumulation rates in Europe, and the North Atlantic climate oscillations known as Dansgaard-Oeschger (DO) interstadial–stadial cycles that punctuated the last climate cycle. Stadials are cold and dusty glacial conditions; they are even colder when associated with the huge iceberg discharges from the Northern Hemisphere ice sheets known as Heinrich events. DO interstadials are warm phases, with reduced dust concentration in the atmosphere, following abrupt temperature increases in the North Atlantic (by more than 10°C in Greenland in less than 100 years). These interstadials correspond to paleosols found in European loess series, whose type depends on the interstadial duration. Longer interstadials correspond to more mature paleosols. New investigations of European loess records from MIS 6 reveal the occurrence of alternating loess intervals and paleosols, similar to those from the last climatic cycle. The paleosols are correlated with interstadials described in various Northern Hemisphere records. Therefore, referring to the warm events described in the record of the last climate cycle in European loess sequences, the MIS 6 interstadials can confidently be interpreted as DO-like events of the penultimate climate cycle. If this interpretation is correct, DO events and DO cycles are not restricted to the last climate cycle.

In parallel of our field work, our recently published model has shown to replicate the observed characteristics in  $\delta^{18}\text{O}$  variations, such as the sawtooth shape of the DO cycles, with abrupt warming and slower cooling to glacial conditions, as well as the time intervals between successive DO events over the past 130,000 years, and also the opposite phasing of the observed climate signal in the Greenland ice cores and in Antarctica: when Greenland warmed, Antarctica cooled and conversely. This model has provided, moreover, a unified framework to explain the major characteristics of millennial climate variability, including both DO cycles and Heinrich events during the glacial intervals of the last climatic cycle.

Our results herein clearly indicate that these millennial oscillations appear to be solely due to mechanisms intrinsic to the climate system, and imply that their understanding requires further investigations that need to encompass at least the last two climate cycle.

**P-1410**

## **First direct dates for northwest Laurentide ice-sheet deglaciation during the Younger Dryas from cosmogenic surface exposure ages of glacial erratics**

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### **Abstract**

The timing of northwest Laurentide ice-sheet deglaciation is important for understanding how ice-sheet retreat, and associated meltwater discharge, may have been involved in abrupt climate change and rapid sea-level rise at the end of the last glaciation. However, the deglacial chronology across the western Canadian Shield is poorly understood, with only a handful of minimum-limiting <sup>14</sup>C dates constraining the timing and pattern of northwest Laurentide ice-sheet retreat across >1000 km of ice-sheet retreat to the marine limit west of Hudson Bay. We use cosmogenic <sup>10</sup>Be surface exposure dating of glacial erratics at two sites, within a ~160,000 km<sup>2</sup> region with no reliable temporal constraints on ice-margin retreat, to directly date the timing of northwest Laurentide ice-sheet deglaciation. Five erratics sampled near the Acasta Gneiss "Discovery Site" have exposure ages between 12.8±0.6 and 12.2±0.6 thousand years ago (ka; ±1sigma), with an inverse weighted mean of 12.4±0.6 ka (including production rate uncertainty). Five erratics were also sampled 115 km to the east at Point Lake; four exposure ages are currently in-process, but one erratic from this site yielded an exposure age of 11.6±0.5 ka. When corrected for decreased atmospheric depth due to isostatic uplift since deglaciation, the data indicate that the Laurentide ice sheet retreated through this part of the western Canadian Shield ~13.3-12.1 ka, or >1 kyr earlier than inferred from the canonical compilation of minimum-limiting <sup>14</sup>C dates for deglaciation and paleo-glaciological models. We tentatively infer preliminary ice-margin retreat rates of ~0.1 m kyr<sup>-1</sup> over this interval spanning much of the Younger Dryas which, compared to earlier estimates, implies a substantially lower volume of meltwater flux from the retreating northwest Laurentide ice sheet at this time. Additional exposure ages on glacial erratics across this data-poor region are needed for validation of existing deglacial ice-sheet models, which can in turn contribute to comprehensive testing of hypotheses related to northwest Laurentide ice-sheet retreat rate, abrupt deglacial sea-level rise, and potential forcing of associated climate change events.

**P-1411**

## **Key roles of sea ice–surface wind feedback in maintaining contrasting modes of glacial Atlantic meridional overturning circulation and climate**

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### **Abstract**

During the glacial periods, the climate and the Atlantic meridional overturning circulation (AMOC) varied between two contrasting modes. Previous studies focused on the role of sea ice in maintaining contrasting modes of the AMOC through its insulating effect of the oceanic heat flux and the buoyancy flux; however, the effect of feedback from the atmosphere remained unclear. Here, by conducting partially coupled experiments with a comprehensive atmosphere–ocean coupled general circulation model, we show that sea ice–surface wind interactions over the North Atlantic play a key role in maintaining the AMOC. Experiments show that sea ice reduces surface winds through suppressing oceanic heat flux, and the wind anomaly drastically reduces the AMOC through weakening the wind-driven ocean salt transport. Together with the sea ice–buoyancy flux and sea ice–surface wind feedback, changes in sea ice and oceanic heat flux maintain the contrasting modes of AMOC.

**P-1412**

## **The Last Deglaciation Meltwater Paradox**

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### **Abstract**

In recent years, the ability of computer models to perform fully transient simulations of the Last Deglaciation (21 – 9 ka BP) has advanced greatly and is now the focus of a PMIP4 working group. Several modelling groups have run, or in the process of running, such simulations. The first GCM based simulation of this period was the TRACE 21k simulation (Liu et al., 2009) which has been hugely successful. The model was able to successfully reproduce some of the major climate change events during this period, particularly the Bolling-Allerod rapid warming event. The mechanism for this warming was the recovery (and overshoot) of the Atlantic meridional overturning circulation (AMOC) due to a sudden termination of freshwater discharge to the North Atlantic. However, the melt water discharge scenario was not based on glaciological reconstructions of the ice sheets and was at the upper end of sea level reconstructions. The PMIP4 deglaciation protocol recommends an alternative meltwater discharge scenario which is consistent with the glaciological reconstructions and is markedly different to TRACE21k.

We will show results contrasting the climate response to these two different meltwater discharge scenarios, using the HadCM3 climate model. The PMIP4 meltwater discharge produces a small weakening of the AMOC after Heinrich 1 and a large weakening at meltwater pulse 1A. This results in a climate response over Greenland which is inconsistent with the ice core record. However, if we use the TRACE21k meltwater scenario, then we successfully simulate the Bolling-Allerod warming, confirming the original result of Liu et al (2009) but using a different climate model.

This leads to the paradox. If we use the large meltwater forcing of TRACE21k (which is not consistent with glaciological reconstructions), then we successfully simulate the climate change over Greenland during the Deglaciation. However, if we use a more glaciologically realistic meltwater history, then the climate response does not accord with the data. Ideas to resolve this paradox will be discussed.

Liu, Z. et al. (2009) Science, 325, p310-214. [10.1126/science.1171041](https://doi.org/10.1126/science.1171041)

P-1413

## Cryogenic structures and desiccation cracks in the southwest of the West Siberian lowland

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### Abstract

The wide spread of vein structures in the Siberian Pleistocene geological sections (not only in the northern parts of the region) was already known in the first half of XX century. Two alternative opinions regarding their origin were formed in the middle of XX. According to the first suggestion (Fedorovich, 1962) all these structures, up to 38° N in China, are ice veins pseudomorphs. According to second one – they are (at least, in Irtysh-Ishim interfluves) related exclusively to the desiccation fissures (Volkov et al., 1969). In particular, disseminated single (rarely - coupled) pseudomorphs on ice and/or ice-ground veins of Sartan Cryochron are presently proven to be widespread in southwest of the Western Siberia, to the South of 57°N, as well as in the Northern Kazakhstan (Aubekero, 1992; Larin et al., 2016). In recent years we have made an attempt to distinguish wedge structures of cryogenic and “arid” origins for certain geological sections in the southwest of the Western Siberia with a help of determination of the cryogenic contrast coefficient (CCC) suggested in (Konishev & Rogov, 1994). So it has been found out that the 11a vein near Uporovo settlement has CCC=1.03-1.99 at its basement, i.e. this vein was originally developed as cryogenic one. Meanwhile it evolved in its middle part without cogenesis (CCC=0.75-0.14) and only in its upper segment CCC increases up to 1.35, that is probably caused by the seasonal permafrost influence. Near Kamenka settlement CCC of the vein filling is decreased from the bottom to the top from 1.58 to 0.57 etc. The study of the surface morphology of quartz grains from sediments of ground vein near Uporovo with scanning electron microscope (with the increase from 300-400 to 1500-2000 times) shows the predominance of particles aeolian sedimentation environment (up to 92%) with cryogenic textures (up to 60-84%). The proportion of alluvial grains (up to 12-16%) and particles with traces of water transfer on average does not exceed 4-8%, sometimes - 20%. Low values of the Chemical Index of Alteration (CIA= 51-60) (H.W. Nesbitt, G.M. Young, 1982), Chemical Index of Weathering (CIW = 55-66) (Fedo et al., 1995), elevated values (greater than 1) the Index of Compositional Variation (ICV = 1.09-1.36) (Cox et al., 1995), a sign of weak change sediments groundwater lived in cold arid climate. Relative Sr/Ba = 0.23-0.47 (Retallac, 2001, 2003) also reconstructed cold but relatively humid landscape and climatic conditions. The values of the coefficients TiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> and Zr/TiO<sub>2</sub> (Bettina Schilman et al., 2001) show a fairly homogeneous substrate formed one maternal breed without the addition of any foreign material. This base of the data indicates that relict thread structures in under cover sediments were formed in a changing periglacial conditions.

**P-1414**

## **About of reflection of the stages of Sartan Glaciation in sections of West Siberian Plain**

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### **Abstract**

N.V.Kind (1974) has found in the Yenisei lower reaches the moraines of all four stages of Sartan glaciation. Then the authors of (Astakhov et al., 2016) have shown, that all the moraines, which were earlier attributed as Sartan glaciations structures, are pre-Sartan ones; with Sartan moraines being found to lie at the Kara sea bottom. In the light of these data, the assignment of the marks of eight glaciation stages in the Aksor Lake area (Zykyn et al., 2003) may seem to be strange. Actually, the Aksor Lake is located already in the mountains, between offsets of the Ulbin and Kalbin ranges, and the geological section studied in (Zykyn et al., 2003) reflects the eight stages of the latest mountain glaciation of the Altay-Sayan mountain area. Meanwhile, marks of the land ice-sheet glaciation ought to be expected in the central parts of the plain. However, no marks of the stages of this glaciation have been found in Sartan time layers in Ob river areas of Surgut region (Arkhipov et al., 1980; Laukhin et al., 2006 et al.). So, heavy loams, unlaminated and marked by palynological spectra of hygrophilous tundra vegetation (in the bottom of the sequence) but laminated and marked by the spectra of "arid" tundra plants, overlay paleosoils dated by ~27 Ka in the section of Kirias (Laukhin et al., 2006). Only southerly, in the lower reaches of Irtysh river between Semeika and Gornaya Subbota settlements, the author of (Arkhipov et al., 1980) has suggested the existence of Vertikoss Interstadial (~15 Ka.) marks. While the marks of Sartan Cryochron can be observed in the Kotachygy section, between Ishim and Irtysh rivers (Sychevskaya et al., 2015). In this section the paleosoil aged ~25 Ka is intensively crumpled by solifluction - the 1<sup>st</sup>, maximal, glaciation stage deposits - and overlaid by coastal lake sands inreached by abundant Malacofauna, which is characteristic for a climate similar to modern one. Sands are overlaid by loams with the texture transient from coarse-schliere type to the lattice one – it is the 2<sup>nd</sup> glaciation stage. All the sand-loam sequence is intruded by single epigenetic pseudomorphs along the ice-soil veins of 1.5-1.8m vertical scale – it is the 3<sup>rd</sup> stage of the glaciation. Intercalated 3.5m thick sequence of Holocene (?) loams lies above.

**P-1415**

## **Role of ice sheet dynamics in the collapse of the early-Holocene Laurentide Ice Sheet**

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### **Abstract**

The last stage of the deglaciation of the Laurentide Ice Sheet (LIS) (~9000 to 7000 years ago) provides an analogy and insight to the possible responses of contemporary ice sheets in a warming climate. What makes LIS particularly interesting is that meltwater from the collapse of an ice saddle over Hudson Bay was recently shown to be the most likely driver of the 8.2 ka event, an abrupt northern hemisphere cooling of several degrees. The evolution of the LIS during this period was likely influenced by its interaction with marginal lakes and the ocean, and its major ice stream, which exported ice towards Hudson Strait. Accurately simulating the early Holocene LIS evolution thus requires a latest generation ice sheet model such as BISICLES, which is capable of accurately and efficiently resolving ice stream dynamics and marine margin retreat (so-called grounding line migration) thanks to the combined use of higher order physics and adaptive refinement of the resolution.

We drive the BISICLES model using a positive degree day mass balance scheme with monthly precipitation and temperature from the HadCM3 climate model under climatic conditions from 10,000 to 8,000 years ago. We evaluate plausible rates of ice sheet retreat and associated sea level rise caused by the Hudson saddle collapse and the sensitivity of this to uncertain initial conditions, and model parameters. We find that dynamical processes are important for accurately simulating the pattern of ice retreat. Rates of meltwater discharge during the Hudson saddle collapse depend on basal sliding and surface mass balance parameters.

**P-1416**

## **Time and impact of NE Pacific Late Pleistocene ice sheet related floods**

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### **Abstract**

Extreme freshwater inputs, such as megafloods, are known to have caused ocean circulation impacts. These floods normally are triggered by a collapse of glacial lakes due to warming (glacial/deglacial change). Such impacts, like the ones caused by floods originated from Lake Agassiz are related to climate changes as they affected the North Atlantic circulation. The timing and impact of such changes in the North Atlantic have been fairly studied. Similar floods happened in the North America and entered the North Pacific. However, even though these are less known, the impact of such amounts of freshwater into the Pacific must have caused regional effects in the NE Pacific environment. The first results from two cores off North California margin (600 km south of the Columbia River) show that during these floods, not only the salinity could have been decreased by as much as four salinity units, but also the known coastal upwelling system was suppressed as a consequence.

Here we present a reassessment of the magnitude and timing of North Pacific megafloods during the past 30,000 cal yr B. P., particularly after the Last Glacial Maximum. We studied the presence (relative percentage and assemblages) of freshwater diatoms in four cores located off Oregon and California. The source of these floods has been related to Glacial Lake Missoula (19,000 -17,000 cal yr B. P.). However, some of the freshwater diatom's peaks predate the existence of glacial Lake Missoula, implying some possible contribution from subglacial freshwater sources located in British Columbia.

Finally, we will present a comparison of the timing and magnitude between the floods known to affect the North Atlantic with the ones we identified in the North Pacific.

**P-1417**

## **A tephra-based synchronization of a marine and ice core palaeo record spanning 32 – 40 ka b2k**

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### **Abstract**

Understanding the dynamics behind past abrupt climate changes, such as Dansgaard-Oeschger (DO) events, and thereby, more generally the mechanisms of the climate system, increasingly depends on the combination of disparate climate archives. However, comparing palaeo records requires compatible age models, which is often hampered due to the environmental-specific uncertainties (e.g. marine reservoir ages, etc.). Hence, an independent method to synchronize these records is needed to identify the leads and lags within the climate system.

Cryptotephrochronology offers such a key correlation, synchronization and dating tool as instantaneously deposited and geochemically unique tephra horizons can act as isochrons linking marine and ice core records (Davies, 2015).

Here, we investigate the potential existence of marine cryptotephra horizons common to those previously identified in the Greenland ice cores which specifically constrain rapid climate events (Bourne et al., 2015) aiming to synchronize a marine and ice core palaeo record. In particular, marine sediment core MD99-2284 from the southern Norwegian Sea has been explored for cryptotephra layers between ca. 32 – 40 ka b2k. Cryptotephra concentrations were counted using light microscopy and distinctly separate volcanic horizons were analysed using electron-probe microanalysis for determination of major element concentrations. Subsequently, the geochemical composition of each volcanic horizon was compared to that of the Greenland ice core horizons in order to establish tie-points that can link the different climate archives.

Our results argue for the existence of six horizons spanning a time interval of four DO events (DO 5-8). Five marine tephra horizons geochemically correspond, both graphically and statistically, to the previously observed tephra horizons within the NGRIP and NEEM ice cores. These findings allow for a refined age model elucidating the sequence of events. In particular, our results provide independent tephra-based evidence of a synchronous oceanic and atmospheric temperature rise during the stadial-interstadial transitions characterizing the last glacial period.

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**P-1418**

## **Variability of Asian summer monsoon during the MIS 7-9 inferred from a high-resolution speleothem $\delta^{18}\text{O}$ record**

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### **Abstract**

The variability of Asian summer monsoon has been characterized by various geological archives, especially, the well-dated speleothem  $\delta^{18}\text{O}$  records have unveiled the orbital to millennial scales Asian summer monsoon variations over the past 640,000 years. However, there is only one stalagmite from Sanbao cave with much lower resolution has been reported during the MIS 7-9, i.e. 190-337ka BP, hindering the in-depth study of Asian summer monsoon and the related mechanisms. Here, we present a high-resolution (average 77 years) speleothem  $\delta^{18}\text{O}$  record from Didonghe Cave, Shaanxi Province, China, spanning the period from 190 to 337 ka BP. This record was based on two stalagmites DDH-B6 and DDH-B9 which were collected from a deep chamber inside the cave. The values of speleothem calcite  $\delta^{18}\text{O}$  range from -12‰ to -3‰, slightly larger than that of the  $\delta^{18}\text{O}$  record from Sanbao Cave. The replication of  $\delta^{18}\text{O}$  profiles of these two stalagmites during the overlapped time period from 284-298ka indicates that the speleothem calcite was formed under the isotope equilibrium condition. We then interpret the calcite  $\delta^{18}\text{O}$  as indicating the isotope composition of the drip water, i.e., the amount-weighted precipitation  $\delta^{18}\text{O}$ , considering the large changes of 9‰ in calcite  $\delta^{18}\text{O}$  values.

On orbital scale, the precession period is prominent in both Didonghe and Sanbao records, and their general trends are consistent with the northern hemisphere summer insolation, further supporting the hypothesis that the Asian summer monsoons is driven by changes in Northern Hemisphere summer insolation. In addition to the general similarity aforementioned, our high-resolution record similarity aforementioned, our high-resolution record also discloses more characteristics than those observed in the  $\delta^{18}\text{O}$  record from Sanbao Cave. For example, around the time period from 215-230ka, the peak summer insolation in the northern hemisphere during the past 600,000 years, a prominent weak monsoon event occurred, likely corresponded to a forceful ice-raft event in the north Atlantic. Also, the Termination IIIa exhibits a two-stage decreasing structure in our Didonghe  $\delta^{18}\text{O}$  record, a pattern different from that shown in the speleothem  $\delta^{18}\text{O}$  record from Sanbao, but similar to the changes in atmosphere methane recorded in Antarctic ice. We then discuss the potential factors and processes contributing to these dissimilarities in detail.

**P-1419**

## **Insights into the Last Deglaciation using a Coupled Climate/Ice Sheet Model: the LGM, Bølling-Allerød, and Younger Dryas**

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### **Abstract**

Climate changes accompanying ice age deglaciations represent the largest temperature and sea level changes seen during the last 800,000 years. These deglacial periods represent excellent test cases for models, which can then be used to attain a solid grasp on the mechanisms of cryosphere/climate interactions that may occur in the future. In the current study, we examine several key periods during the last deglaciation — the Last Glacial Maximum, the Bølling-Allerød, and the Younger Dryas — using a fully coupled, high resolution atmosphere/ocean/ice-sheet/ice-shelf model. We explore the phase space and test the sensitivity of the system with respect to key ice sheet parameters controlling the subglacial boundary conditions and ice-shelf/ocean interactions, as well as the classic orbital and greenhouse gas parameters influencing incoming solar radiation. For the first time in such a coupled framework, we are able to demonstrate the influence of ice sheet melting events on the climate system without the need for idealized freshwater perturbation experiments and disentangle cause/effect relationships between Laurentide ice sheet mass loss and Atlantic Meridional Overturning.

**P-1420**

## **Sensitivity analysis of modelled Antarctic ice sheet dynamics during MIS 11 climate warming**

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### **Abstract**

Marine Isotope Stage 11 (MIS 11; ~424-374 ka) is a long interglacial period that serves as a potential analogue to investigate the current interglacial, including projected variations in climate conditions. Although CO<sub>2</sub> levels and insolation were comparable to pre-industrial values, current estimates indicate that global mean temperatures might have been ~1 K warmer and sea level 6-13 m higher than today. Such sea level rise would require significant contributions from the Greenland and Antarctic ice sheets. While the evolution of the former during the MIS 11 has been relatively well documented, the history of the latter and its contribution to sea level remain highly unconstrained.

Using a version of the 3D thermomechanical Antarctic ice sheet-ice shelf model SICOPOLIS optimised for paleo-simulations and driven by MIS 11 atmospheric and oceanic conditions from the Community Climate System Model version 3, we perform an extensive sensitivity analysis of the dynamics of the Antarctic ice sheet during this super interglacial. Our analysis explores the complex interactions between uncertainties in the configuration of the ice sheet, external forcing, and other boundary conditions. Our simulations assess the individual impacts of a wide range of initial conditions and unconstrained processes, such as the choices of initial size-, coverage-, and internal thermal memory of the ice sheet, the interaction between the ice shelves and a warming ocean, perturbations to the climate forcing, the influence of post-glacial rebound, and uncertainties in the geothermal heat flux, bedrock topography, and basal friction. Based on this ensemble of simulations, we will provide a range for the potential Antarctic sea level contribution towards and at the peak of the MIS 11, while investigating the dynamics of the ice sheet under possible analogue conditions to those projected for the future.

P-1421

## An astronomical mechanism for rapid climate change: a lunar role

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### Abstract

The lack of a known mechanism and a poor understanding of abrupt climate change in the 1-3 ky range has triggered debates over potential causes. Various explanations have been offered to explain this quasi-periodicity, including changes in the thermohaline current, millennial-scale ENSO variability and intensity, lunar forcing, a combination of unknown factors with solar forcing, and stochastic processes internal to Earth's climate system. Dansgaard-Oeschger variations in atmospheric temperature were found in the oxygen-isotope record of Greenland ice-cores and occur at times of rapid warming between stadial and interstadial. Bond ice-rafted debris events occur in the North Atlantic and accompany Dansgaard-Oeschger events during the glacial, continuing into the Holocene. Both cycles are influential in the 1-3-ky range. The thermohaline current and ENSO were both criticised as candidates for this role. The deep-water formation/thermohaline scenario was seen as lacking a mechanism for rapid dispersal over the planet as the oceanic circulation system is sluggish. The tropical scenario was seen as lacking a locking mechanism and the ability for it to be locked in the first place. However, the global nature of the signal suggests external forcing.

Here I present statistically-significant results between independent total solar irradiance (TSI) reconstructions based on Antarctic <sup>10</sup>Be data during the late Holocene and the modelled superposition the ~209-yr Suess de Vries cycle, a 133-yr cycle found in 5.5 ky of astronomical data during the Holocene, and extremes of sunspot maxima and minima. This 133-yr cycle is found in Earth-Sun and Earth-Moon distances and solar declination, based on the 19-yr cyclical interaction of the New Moon with perihelion, the closest point in Earth's orbit to the Sun. The Suess de Vries cycle is present throughout the extent of the <sup>14</sup>C record and is an inferred solar cycle, even though the longest known solar cycle is the ~11-yr cycle of variability in solar luminosity. The ~209-yr periodicity is also found in lunar declination data. This cyclical interaction between these two factors results in a ~1470-yr cycle, which can be seen as a high-frequency expression of the Milankovitch precessional cycle. The ~21±2 ky Milankovitch precessional cycle is produced by the forward movement of the perihelion (apsidal precession) and the retrograde movement of the spring equinox through the tropical year (equinoctial precession). Equinoctial precession is produced by solar and lunar gravitational forces acting on the Earth's tidal bulge. From these results, it can be inferred that lunar gravitation modulates the cosmogenic nuclide in addition to the influence of solar variability and solar wind on cosmic rays. Together, the Sun and Moon, shape Earth's climatic record through tidally-forced climate signals of Earth's ocean and atmosphere.

P-1422

## Long-term east-west asymmetry in the influence of monsoon moisture over the Himalayas inferred from earlywood and latewood $\delta^{18}\text{O}$ records

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### Abstract

In present study, we examined the relationships between earlywood and latewood  $\delta^{18}\text{O}$  chronologies from two sites located in the east (YD) and west (JL) of Mt. Qomolangma (Everest) along the Himalaya. Climate response analysis reveals that earlywood and latewood  $\delta^{18}\text{O}$  from both sites are influenced by precipitation in the early and late season of India summer monsoon (ISM), respectively. Generally, correlations between latewood  $\delta^{18}\text{O}$  series remained positive and significant, however, remarkable discrepancy in earlywood  $\delta^{18}\text{O}$  variations is detected in most of the investigation period. Combined with moisture transport models and published tree ring  $\delta^{18}\text{O}$  series along the Himalayas, we found the east part of Himalaya is specifically influenced by ISM precipitation in May to October, while the influence of ISM on west part of Himalaya is from June to September. During the early season of ISM, the high ridges of Mt. Everest blocks most of the moisture from Bay of Bengal which results in the difference of earlywood  $\delta^{18}\text{O}$  series. Furthermore, the running correlation analyses suggest that the influence of El Niño-Southern Oscillation (ENSO) on earlywood  $\delta^{18}\text{O}$  is weak and not consistent. However, the response of latewood  $\delta^{18}\text{O}$  to ENSO is relatively stable and significant over the time. This distinct response of Himalaya earlywood and latewood  $\delta^{18}\text{O}$  to ENSO is consistent with the hypothesis that local Hadley cell circulation has affected the precipitation during the early season of ISM, and thus the earlywood  $\delta^{18}\text{O}$ ; but the larger-scale ENSO, such as eastward or westward shifts in the Walker circulation, could be more responsible for teleconnections observed during the late season of ISM, and thus the latewood  $\delta^{18}\text{O}$ . Our finding suggests that the separation of earlywood and latewood may be important for the isotopic dendroclimatology study in this region.

P-1423

## Is Serbian loess represents a history of Košava wind?

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### Abstract

Loess covers huge parts of the continents, especially in the middle latitudes of the Northern Hemisphere. However, except in the case of the Chinese Loess Plateau, which is linked with the East Asian Monsoon, we do not know the potential relationship between loess formation and responsible air circulation type(s) in any other region. Current analyses of recent meteorological data, morphology of aeolian landforms and explicit numerical simulations that modelled prevailing winds from the second quadrant during the Last Glacial Maximum indicate the predomination of air circulation associated with the so-called Košava wind. Košava is a strong wind that blows from the southeast quadrant over Serbia, Bulgaria and Romania. The Siberian high and West-Mediterranean cyclones, together with the orography of the eastern Balkans, are the main drivers of the Košava wind. Generally, Košava blows during the whole year in several periods of a few days. In winter, this wind can cause temperatures to drop to even around  $-30^{\circ}$ , however in the summer dry and dusty.

In this study, we present long-term variations of U-ratio, which represents proxy of wind strength and potential illustration of changes in domination of Košava wind during the last million years in the region. Surprisingly, we discovered that loess-paleosol sequences in Northern Serbia preserved unique information about the dynamics of several thousands and hundreds kilometers distant North European and Alpine glaciers, respectively. An increase in Northern European Ice volume influences significant migration on permanence of the Polar Front to the south. Higher contribution of coarse grains, the thinness of loess layers, sedimentation rates and increase of U-ratio is observed in Serbian loess-paleosol sequences associated with more pronounced decrease of Sea surface temperatures in the Western than in Eastern Mediterranean. These differences in the sea surface temperatures in the Western and Eastern Mediterranean illustrate more polar front fluctuations over the Alps and more frequent cyclone genesis in Genova gulf, which in association with anticyclones over the Russian plain initiates an increase in the Košava wind activity.

P-1424

## Magnetic signatures of natural and anthropogenic sources of urban dust aerosol

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### Abstract

The characteristics of urban dust aerosols and the contributions of their natural and anthropogenic sources are of scientific interest as well as being of substantial sociopolitical and economic concern. Here we present a comprehensive study of dust flux, magnetic parameters, and magnetic particulates' morphology and elemental composition of atmospheric dustfall originating from natural dust sources in East Asia and local anthropogenic sources in Xi'an, China. The results reveal a significant inverse relationship between seasonal variations of dust flux and magnetic susceptibility ( $\chi$ ).

By comparing dust flux and  $\chi$  records, the relative contributions of dust from local anthropogenic sources are estimated. The results show that local anthropogenic contribution decreases in spring and increases in other seasons. Local anthropogenic contribution variation exhibits a similar seasonal pattern to  $\chi_{if}$ , but opposite trend to that of dust flux with the maximum in spring. This means that a great amount of distant natural dust input with less magnetic content makes a great contribution to atmospheric dustfall in spring, which results minimum  $\chi_{if}$  and anthropogenic contributions during this period. Hence, the local contribution is reduced as a result of increasing natural dust flux.

Analyses using Scanning Electron Microscopy (SEM) combined with Energy Dispersive Spectroscopy (EDS) indicate that magnetic particulates from different sources have distinct morphological and elemental characteristics. Detrital magnetic particles originating from natural sources are characterized by relatively smooth surfaces with Fe and O as the major elements and a minor contribution from Ti. The anthropogenic particles have angular, spherical, aggregate, and porous shapes with distinctive contributions from marker elements, including S, Cr, Cu, Zn, Ni, Mn and Ca. Our results demonstrate that this multidisciplinary approach is effective in distinguishing dust derived from distant natural sources and local anthropogenic sources, and for quantitative assessment of contributions from the two end-members.

P-1425

## Using zircon U-Pb ages to assess the provenance of high-resolution $^{14}\text{C}$ dated loess deposits in Hungary

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### Abstract

Loess deposits serve as informative archives of past atmospheric dust dynamics. Despite its fundamental role in the climate system, our understanding of dust-climate interaction is limited by uncertainties over the source as well as transport pathways of the material. In order to decipher the source information of loess deposits, the use of single grain techniques with a focus on detrital zircon U-Pb dating has increased in the recent years. Through the application of this method, striking advances have been achieved in the understanding of the Chinese loess provenance. However, comparably few single grain provenance studies have attempted to unravel the specific dust sources of the Eastern European loess belt. The origin of the loess deposits in the Carpathian Basin has been subject of debate in numerous studies. Competing scenarios of dust transport have been presented evaluating the contribution of local sources, mountainous sources and long-range transported material under the varying atmospheric conditions of glacial and interglacials. Nevertheless, none of the proposed hypotheses regarding the dust source and the question of temporal source variability on Quaternary timescales has been demonstrated using single grain provenance techniques. The most precise age model for European dust deposits, based on 125 accelerator mass spectrometry  $^{14}\text{C}$  ages from Dunaszekcső, Hungary revealed glacial dust deposition variability on centennial-millennial timescale that corresponds to fluctuations of the Greenland dust record. This high-resolution  $^{14}\text{C}$  chronology from the Carpathian Basin allows us to investigate if observed changes in the dust deposition rate are associated with changes in dust source during the time slice of 36 to 24 ka b2k. Detrital zircon U-Pb age spectra of 13 samples selected according to the abrupt changes in the mass accumulation rate are used in combination with bulk geochemical data to detect variability in the material's provenance through time. Identifying the dust sources and transport pathways during the last glacial dust deposition variability may help to understand the atmospheric mechanisms underlying the North Atlantic climate fluctuations. Preliminary work and previous studies highlight the challenges of the applied method to unequivocally identify the provenance since potential source regions show overlapping zircon U-Pb ages.

**P-1426**

## **The loess deposits in Northeast China and the late Pleistocene monsoon evolution**

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### **Abstract**

Chinese loess deposits are extensively distributed in northern China, which are recognized, combined with polar ice and deep-sea sediments, as the three most important records for Quaternary paleoenvironmental studies. However, most studies of the Chinese loess have focused on the loess-paleosol sequences in the Chinese Loess Plateau. Loess deposits from other regions of China have long been less well investigated, and therefore the basic issue of loess deposits in other regions of China, especially in Northeast China, is not well known. In this study, we investigated the origin of the loess sequences in Songliao Basin, Northeast China, and the late Pleistocene evolution of monsoonal climate, through field observations and sedimentological, geochemical as well as fossil molluscan studies based on 27 sections. Our results show that loess deposits are extensively distributed over the Songliao Plain, without constraining by geomorphology. They are mainly composed of silts and major and minor elements that are similar to the loess sequences in the Chinese Loess Plateau. The fossil snails are all terrestrial, without freshwater and amphibian species. The dominant species are those from genera *Vallonia* and *Cathaica*. All these characteristics are similar to those from loess deposits in the Chinese Loess Plateau, indicating that loess in Northeast China is a wind-blown deposit and thus is a new record of monsoon evolution in the Pleistocene. Using ratios of major/minor elements ( $\text{SiO}_2/\text{Al}_2\text{O}_3$ , Rb/Sr) as summer monsoon index, the paleoclimate during the late Pleistocene shows a gradual cooling trend, which may be caused by weakness of the East Asian summer monsoon.

P-1427

## Erosional transition of shoreline blocks by lichen colonization in Cantabria associated to the end of the LIA

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### Abstract

Lichen colonization of surface rocks depends strongly of the environmental conditions and nutritional disposal, mainly nitrogen and carbon dioxide. The presence of lichens could accelerate the surface erosion by chemical weathering, although they could prevent mechanical erosion as well. Lichen covering prevent for this erosion except in the case of strong eolian weathering, where multiple impacts of grain-sized particles avoid the lichen growth. The presence of carbonate megablocks along the shoreline between Santander and Bilbao (Cantabria domains, north of Spain) exhibit different overlapping of erosional processes. These blocks show ventifacts (groove marks) along the external surface related to strong winds hitting with airborne quartz grains, and which size ranging between 0.1-0.3 mm. The present wind-blow trending in the coastal range is W-NW, which is coincident with the ventifacts arrangement and orientation. Overlapping to the ventifacts, we can observe a chemical weathering of the aeolian-polished sides of the blocks, and in different patches with centimetric extension and depth. We can observe that the wind-struck boulder-side has been colonized by calcicolous lichen specie, *Verrucaria maura* (tar lichen). This lichen is sea-spray resistant and its annual growth rate has been calibrated from cemeteries close to the shoreline, having similar environmental conditions that in the coast (precipitation and temperature). The lichen colonization of these beach boulders indicates a period of weak aeolian abrasion and prevalent chemical weathering. We assume that this fluctuating erosional process is directly related to a change in the climatic conditions during the LIA ending times affecting rainfall, humidity and therefore wind entrainment of sand grains affecting the shoreline. The oldest lichen measured in these blocks suggests that the end of the LIA could be in the year  $1855 \pm 6$  yr. NAO variations and the annual precipitation curve in the area during the last 300 yr. support this data.

P-1428

## Distribution of branched glycerol dialkyl glycerol tetraethers (brGDGTs) in soils from Central Asia

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### Abstract

Loess-paleosol sequences are excellent recorders of terrestrial climate change over Quaternary timescales. Substantial deposits blanket the piedmonts of Central Asia, where the convergence of major continental climate subsystems (the westerlies, polar front and monsoon) makes it an ideal location to investigate causal relationships between dust dynamics and climate change. Past temperature changes are a key component for understanding climate dynamics in this region, yet terrestrial paleotemperatures have yet to be adequately explored with quantitative climate proxies.

New quantitative paleotemperature proxy information can now be obtained based on the distribution of glycerol dialkyl glycerol tetraether (GDGT) membrane lipids. Although the focus of this technique so far has been on marine and lacustrine environments, there exists strong potential to extend this approach to terrestrial sediments. In fact, several studies have quantified annual mean air temperatures (MAT) and soil pH for loess-paleosol sequences using the Methylation of Branched Tetraether (MBT) and the Cyclisation of Branched Tetraether (CBT) indices.

However, this approach lacks not only adequate regional calibration, but also systematic application to long loess-paleosol sequences in the Central Asian piedmonts. Reliable application of brGDGT climate proxies requires precise calibrations to temperatures using modern soil samples from the region of interest, for which climate parameters are known. No such calibration exists for Central Asia, either as a separate region or as included in existing global calibrations. Previous work also indicates that available brGDGT calibrations are uncertain in some arid environments, running the risk of air temperature overestimation. A reliable calibration dataset is therefore a critical first step for reliable climate reconstruction in the region.

Here we will present the first temperature calibration for brGDGTs from Central Asia, based on modern soil samples from mountain piedmonts in semi-arid Tajikistan and Kazakhstan. We discuss our results in relation to differences in elevation, vegetation cover and other potential influencing factors. We also provide the first paleotemperature framework for two late Quaternary loess profiles in Tajikistan (Karamaidan) and Kazakhstan (Remizovka).

**P-1429**

## **The role of dust in glacial cycles dynamics**

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### **Abstract**

Mineral dust aerosols affect global climate through its impact on Earth's radiative balance, clouds and biogeochemistry. Here we use the CLIMBER family of intermediate complexity Earth system models (the well established CLIMBER-2 and the newly developed CLIMBER-X) to assess the importance of dust for glacial cycles dynamics. More specifically, using transient and time-slice model simulations we explore the importance of the lowering of snow albedo by mineral dust deposition on ice sheet growth and melt and the effect of iron fertilization on ocean primary production and consequently on atmospheric CO<sub>2</sub> concentration during glacial times.

We show that the evolution of the Northern Hemisphere ice sheets over the last glacial cycle is very sensitive to the representation of the dust darkening effect on snow albedo in the model. Ignoring the effect of dust on snow albedo leads to an excessive ice build-up during glacial times and consequently to a failure in simulating deglaciation. We also show that assuming slightly different optical properties of dust leads to very different ice sheet and climate evolutions in the model.

The increased rate of dust deposition over the ocean during glacial times compared to present day acts as a fertilizer for primary production in iron limited regions like the tropical East Pacific and the Southern Ocean, strengthening the biological pump and leading to an atmospheric CO<sub>2</sub> decrease of ~10-30 ppm in the models. The actual decrease in CO<sub>2</sub> strongly depends on the assumed change in the magnitude of dust deposition between glacial and interglacial times, which is very uncertain.

**P-1430**

## **LGM experiments using MIROC Earth System Models: some preliminary analyses on dust aerosol**

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### **Abstract**

The deposition flux of mineral dust aerosol has synchronously changed with temperature reconstruction through glacial-interglacial cycles (Winckler et al. 2008). However, it has been difficult to obtain enough dust flux at glacial time by models (Takemura et al. 2009, Hopcroft et al. 2015). Therefore, in modelling studies, realization of dust amount in glacial era is one of key issues to understand the mechanism of interaction of dust and climate (Mahowald et al. 2006). We discuss how to realize dust distribution at the Last Glacial Maximum (LGM) in two versions of MIROC earth system models and discuss how the dust interact LGM climate.

We performed LGM experiments using MIROC-ESM (Watanabe et al. 2011). One experiment had done with the standard Paleoclimate Modelling Intercomparison Project phase 3 (PMIP3) type setting (Sueyoshi et al. 2013). In other experiment, glaciogenic dust flux estimated by Mahowald et al. (2006) is constantly imposed (Ohgaito et al. 2018) on the standard PMIP3 LGM experiment. Ohgaito et al. (2018) concluded that the appropriate amount of dust flux over the Southern Ocean affects surface temperature surrounding of the Antarctica through aerosol-cloud interaction. We are now testing a LGM experiment with erodibility map proposed by Albani et al. (2016) which is recommended by Paleoclimate Modelling Intercomparison Project phase 4 (PMIP4) protocol instead of glaciogenic dust, as an advanced method to emit higher dust flux at LGM.

On the other hand, in order to contribute PMIP4, we are now conducting a LGM experiment using a newly developed model MIROC-ES2L. In the procedure of setting up the experiment, we adopted the erodibility map. The effect of the erodibility map resulted about doubling of dust deposition in global average compared to another LGM experiment without the erodibility map.

In the presentation, we will discuss the robustness and model dependence of the effect of dust on the LGM climate using the above listed LGM experiments.

**P-1431**

## **A Holocene geochemical peat record for paleo-dust tracing in NE China**

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### **Abstract**

Atmospheric mineral dust-climate interactions and their underlying factors can be studied through geological archives. Although the deserts of East Asia are one of the main sources of atmospheric mineral dust [1], there is still a lack of terrestrial records in the region. The potential of peatlands as climate and geochemical archives (dust deposition and source tracing) is now well established [2, 3, 4]. Rare earth elements (REE) are recognized as valuable dust provenance tracers [3, 4].

Here we present a Holocene geochemical dust record from the Hani peatland, northeastern China. Elemental (lithogenic and rare earth elements (REE)) and isotopic (Nd and Sr) geochemistry was combined with grain-size analyses to help in the reconstruction of past climatic events and the identification of dust sources as part of an ongoing study on the influence of the East Asian Monsoon on the dust cycle in NE China.

The REE patterns,  $\epsilon\text{Nd}$  (-7.8 to -9.2),  $^{87}\text{Sr}/^{86}\text{Sr}$  (0.71017-0.71599) and grain size suggest that, for most of the Holocene, the source of the dust deposited on Hani peatland was relatively constant and represented a mixture of particles originating from desert dust (Gobi, Taklamakan). A number of episodes display distinct Eu anomalies ( $\text{Eu}/\text{Eu}^* > 1.2$ ) when compared to the rest of the record ( $\text{Eu}/\text{Eu}^* : 0.98-1.05$ ) especially around 11ka and 1.8ka BP. Particles deposited during these events also display distinct  $\epsilon\text{Nd}$  (-2.4) and  $^{87}\text{Sr}/^{86}\text{Sr}$  (0.70513) signatures as well as greater grain-size which could be pointing to a more local source. This is further confirmed by the REE patterns which are similar to local soils and volcanic rocks in the region. We postulate that these events are linked to a strengthening of the East Asian Summer Monsoon resulting in increased rainfall facilitating the supply of locally derived mineral particles.

[1] Biscaye (1997) JGR: Ocean 102; [2] de Jong et al. (2010) Climate and Peatlands in Changing Climates, Earth Systems and Society, Springer, p. 85-121; [3] Kylander et al. (2007) GCA 71, 942-960; [4] Ferrat et al. (2012) GCA 91, 7-31

P-1432

## The role of Saharan dust in modulating monsoon response in MPI-ESM mid-Holocene simulations

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### Abstract

In mid-Holocene (ca. 6,000 years ago) different orbital conditions caused more summer insolation in the Northern Hemisphere than at present-day. This had led to a dramatic increase in the vegetation cover in North Africa and a strengthening of the West African Monsoon (WAM). Since the Sahara was mainly covered by grassland and savanna, the atmospheric burden of Saharan dust was substantially lower than today. It is typically difficult to fully reproduce the WAM behaviours in mid-Holocene from proxy reconstructions with climate models, if they do not account for accurate changes in vegetation and dust aerosol. While many models have implemented interactive vegetation in Earth System Models, dust aerosol is often prescribed with a climatology and not interactively calculated in paleo-simulations, e.g., due to the computationally expensive aerosol schemes. Here, we present results from mid-Holocene simulations performed with the Max Planck Institute Earth System Model (MPI-ESM). The prescribed distribution of dust aerosol and its optical properties are derived from an aerosol-climate simulation with ECHAM6-HAM (Egerer et al., 2016), that has the same atmospheric model as MPI-ESM. Our results show that accounting for Saharan dust reduction substantially warms mid-Holocene summers both locally in the Sahara and even globally, with a global mean warming of about +1.2 K relative to the control simulation, based on pre-industrial dust. The regional hydrological cycle changes substantially. Evaporation increases in the region between 10°N - 20°N of the ascending branch of the Hadley circulation, leading to a dramatic change in the P-E balance there. The net effect of this response is an about 14% weaker and narrower WAM compared to the simulation with the pre-industrial dust aerosol. These changes are an improvement of the model performance in comparison to the proxy reconstructions in deep tropics (5°N - 10°N) and in the Sahel region (15°N - 20°N). Our results point to the importance of desert-dust aerosol for simulating global and regional climates.

**P-1433**

## **Elemental analysis and reconstruction of late Holocene aeolian dust fluxes from the Rio Rubens peat bog in Patagonia**

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### **Abstract**

The mechanism, timing and dynamic of paleoclimatic changes in southern Patagonia in the Holocene, still remain unclear. The main climatic driver in the study zone are the Southern Westerlies Winds (SWW), whose changes have the potential to modify dust emissions in southern South America. During the Holocene in Patagonia, the SWW in environmental paleorecords have shown changes in position and strength. In order to understand paleoclimate dynamics in southern Patagonia and correlations between dust deposition and SWW, we sampled an ombrotrophic peat bog in the locality of Rio Rubens, close to the present-day SWW core maximum position, on the east flank of the Andes Mountains. Elemental analyses from ombrotrophic peat bogs have allowed successful reconstruction of past atmospheric dust changes, providing new data for interpreting and determining variations in the atmospheric circulation through the Holocene.

Previous palynological studies carried out in this bog indicate a basal age of 13 ka, with a purely ombrotrophic section of 5 ka. In order to determine the dust fluxes, a 1,5 m long core was recovered and subsequently subsampled each 1 cm, for elemental inorganic geochemistry (major and rare earth elements) as well as for radiocarbon and Pb210 dating. Preliminary results show an increase in the magnitude of dust flux interpreted as a southward shift in the SWW position, bringing the core of the SWW closer to the Rio Rubens peat bog through the late Holocene.

**P-1434**

## **Aeolian relationships across the Al-Azraq Basin, Jordan and Quaternary implications for regional dust fluxes using grain size, geochemistry, and IRSL**

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### **Abstract**

second largest draining the east side of the Rift Valley highlands and southern Syria. The very near surface sediment of the Al-Azraq Qa are early Holocene in age demonstrated by previous research, covered by thin layer of modern alluvial and aeolian surface sediments. Within the basin are three distinctly different deflated and eroded older aeolian deposits. On the western margin of the basin, flanking the Al-Azraq Oasis, are low, grey vegetation-anchored nabkahs. A nabkah (NK1) is composed of 80 percent aeolian silt-sized sediment of dominated by quartz and feldspar mixed with evaporite minerals of calcite and organic inputs from the oasis. Along the northeast margin of the qa is a linear stretch of white carbonate-cemented dunes composed of euhedral quartz, feldspar, calcite, gypsum, and clay minerals, possibly chlorite. The linear dunes are in close proximity to spring deposits and are dominated by calcite. Forming the eastern margin is a large red massive dune field sampled to 4.5 meters below the dune surface. Analyses reveal a wider range of minerals including subhedral quartz, feldspar, mica, heavy minerals, and green clays. Secondary gypsum indicates longer sedimentary history with episodes of evaporation. This research examines sedimentary and temporal relationships between these distinct aeolian deposits within the Al-Azraq basin and compares them to regional dust flux records.

P-1435

## Isotopic evidence (Sr, Nd and Pb) of South Africa as a dust precursor for atmospheric depositions in Antarctica

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### Abstract

Dust recovered from Antarctic ice cores represents a valuable archive of the atmospheric paleo-circulations in the Southern Hemisphere (SH) during glacial and interglacial periods. Dust preserves the chemical and isotopic composition of the region where it was deflated and on the basis of different geochemical tools, many studies have shown compelling evidence that South America seems to be the major dust source for Antarctica. However, there is no consensus on the relative contribution of potential secondary sources like Australia, New Zealand, South Africa and Antarctica itself. In particular, South Africa has recently called the attention of researchers due to its growing potential to enhance the airborne particle production and thus, plays an important role in the global radiative balance, hydrological cycles and climate system. In southern South Africa, Namibia is considered as a small, but persistent dust source but its relevance and extent to Antarctica are still not well constrained. Most of the studies to exclude South Africa as a dust supplier to East Antarctica are based on global meteorological and climatic models and a lack of systematic and detailed studies based on the specific potential source areas it became apparent. Keeping that in mind, we carried out a comprehensive and comparative geochemical characterization of several potential dust source regions in southern South Africa, followed by simulated experiments to reproduce the dust genesis from the sediment precursor. In Namibia, sediments from large dry river beds (Omaruru and Huab rivers) were collected and then, aerosols were generated into an atmospheric simulation chamber (CESAM) to mechanically reproduce the saltation and sandblasting processes responsible for the release of mineral dust in natural conditions. The initial bulk sediments, together with the obtained mineral dusts collected on Teflon filters were digested and analyzed for their trace element abundances (HR-ICP-MS) and Sr, Nd and Pb isotopic compositions (Nu Plasma MC-ICP-MS). The obtained results were compared with data recovered on atmospheric particles, filtered from subsurface snow samples from East Antarctica (Dronning Maud Land). In general, this study will fill the important gap concerning the identification of secondary dust sources in the SH and the wind circulation and the contribution of South Africa as a potential dust supplier for the East Antarctica.

**P-1436**

**Characterization of Aeolian Source Material from the Al-Jafr Basin, Jordan Using Grain Size, X-Ray Diffraction, Geochemical Analysis and SEM. (Poster)**

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**Abstract**

This research project characterizes the texture, morphology, composition, mineralogy and geochemical of dune sediments from the Al-Jafr Basin, Jordan. Using various analytical methods reveal the paleoenvironmental processes dominating landscape formation at this location. Microscope examination revealed the presence of vegetation and fossils. Grain size results throughout the sand dune samples identified the sediment as predominately silt size particles, predominately fine silt. This indicates moderate and steady wind energy to transport these particles.

The Al-Jafr dune samples are rich in numerous organic materials, along with evidence of fossil brachiopod and ostracod remains. The brachiopods maybe secondarily deposited, form older eroded landscapes. The ostracods potentially indicate past aquatic conditions.

P-1437

## Geochemical characteristics of Holocene aeolian deposits and their paleoclimatic implications: a case study in East of Qinghai Lake, China

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### Abstract

**Abstract:** The paleoclimate evolution in the northeast of Qinghai-Tibet Plateau (QTP) has always been concerned by scholars, due to the particularity of geographical location, especially the Qinghai Lake Basin (QLB). However, because of the ambiguity of proxies and the lack of enough precise chronological data, the evolution of paleoclimate since Holocene in this region has been controversial. Hudong Dunefield is located in the east of Qinghai Lake, which is the largest sand accumulation area in QLB. Aeolian sand-paleosol sequences of Hudong Dunefield are precious terrestrial archives that contain information on paleoclimate change and aeolian activity. In this study, deposits of the Holocene aeolian sand-paleosol sequences CGE and QHH in Hudong Dunefield are systematically analyzed to determine their elemental geochemical characteristics and paleoclimatic implications. Combination with the grain size, total organic carbon (TOC) and redness, emphasis is placed on the paleoclimate change since Holocene in this region and its response to the East Asian Summer Monsoon (EASM). The relatively consistent immobile elements content and ratio indicated that the aeolian sediments have similar sources during the Holocene, which mainly from the insitu weathering products of the rocks. The higher  $\text{Na}_2\text{O}/\text{Al}_2\text{O}_3$  and lower chemical index of alteration (CIA) showed most of them in the stage from unweathered to weakly weathered degree, except some samples reach the moderate weathered during mid-Holocene, implying that several transition from warm-wet to relatively cold-dry during the Holocene epoch in the QLB. The multi-proxy indicated that the regional climate was broadly coincident with the northeast of QTP and most regions of northern China, implying that the paleoclimate of QLB was closely correlated with the evolution of EASM during the Holocene. Additionally, after the 9.2 ka BP cold event, the chemical weathering increased gradually; in 8.7-4.0 ka BP, the higher CIA and TOC, lower redness and mean grain size are possibly associated with the mid-Holocene climate optimum period, indicated an intensified chemical weathering, denser vegetation cover and weakened aeolian activity in QLB in response to warmer and more humid climate. After 4.0 ka BP, the obviously weakened chemical weathering indicates that the study area is dominated by a relatively cold and dry climate, and there have been several alternating warm-wet and cold-dry intervals in 3.2-0.6 ka BP. Collectively, our new multi-proxy data add supporting evidence for the mid-Holocene climate optimum period, in addition, we also conclusion that the EASM dominated the chemical weathering in the HSL region

**P-1438**

## **Holocene dune activity – implications for multidecadal drought in the Colorado Plateau, USA**

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### **Abstract**

The Colorado Plateau and the Colorado River headwaters, a critical water supply for the southwestern United States, are linked through similar regional climate factors, especially for drought. Recent multi-annual drought has stressed this region, already limited in water resources. Longer term decadal to centennial droughts are recorded in tree-ring records and have been implicated in the past abandonment of pre-historic communities. The potential for multi-decadal drought driven by climate change is a serious concern in this region. Dune activity records here contribute to our understanding of natural climate variability, aiding in development of adaptive strategies for predicted climate change characterized by higher temperatures and decreased precipitation.

Sand dunes are complex geomorphic landforms responsive to threshold climate conditions of aridity, wind power, vegetative cover and sediment supply. Using optically stimulated luminescence (OSL) dating and radiocarbon (<sup>14</sup>C) ages from charcoal we investigate eolian activity in two dune fields in southern Utah. Geomorphic maps were constructed for each dune field based on vegetation density and dune morphology. The stratigraphy, geomorphology, sedimentology (grain-size), and age control obtained from OSL and <sup>14</sup>C dating are used to differentiate sediment packages and develop a chronostratigraphic record of dune activity. We interpret coeval dune activity in these dune fields as representing persistent ( $\geq$  decadal scale) regional droughts leading to changes in threshold conditions for dune mobility. In addition to the record of past dune mobility we present analyses of modern wind regimes from climate stations across the region, reflective of late Holocene conditions. We present geochemical and grain size analyses to determine the sediment source for two dune fields and discuss geomorphic processes contributing to dune field development.

P-1439

## Holocene variability in sea ice, primary productivity and terrigenous input in the northeastern Baffin Bay and its paleoclimatic significance

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### Abstract

Arctic sea ice is a critical component of the climate system, changing and affecting the gas exchange, salinity, heat and moisture between ocean and the atmosphere. Current developments in the use of IP<sub>25</sub> (Ice proxy with 25 carbon atoms only synthesized by Arctic sea ice diatoms) have proven it to be a suitable proxy for palaeo-sea ice reconstructions over shorter to longer timescales. For the NE-Baffin Bay, a climate-sensitive region characterized by strong seasonal sea ice variability and strong melt-water discharge from the Greenland ice Sheet, however, such proxy records are not available so far. In order to fill this gap, we have investigated several sediment cores along the north-south transect that provide high-resolution Holocene sea-ice records. IP<sub>25</sub>, open-water phytoplankton biomarker and PIP<sub>25</sub>-based sea ice reconstructions carried out at Core GeoB19927-3, the northernmost site of our transect (Melville Bugt, 73°35.26' N, 58°05.66' W; water depth: 932 m; recovery: 1147 cm), indicate seasonal to ice-edge conditions during most of the Holocene period. Between 11.1 to 10 cal ka BP, our proxies display very low biological growth near the core site characterized by extensive sea ice cover and enhanced terrigenous debris deposition points to the ablation of ice sheets and a cooling event, followed by a period of a persistent, albeit strongly variable, appearance of the West Greenland Current (WGC) between 10.0 and 8.6 cal ka BP. This early-Holocene warming can be characterized by reduced sea ice cover as a result of enhanced deglacial melting induced by high insolation coupled with enhanced WGC penetration up to the northern Baffin Bay. From about 8.6 to 7.8 cal ka BP, we notice elevated values of IP<sub>25</sub> signaling towards enhanced seasonal sea ice cover, and opening of Nares Strait led to the increased influx of Polar Water into Baffin Bay and consequently a cooling event. Between 7.8 and 3.8 cal ka, most likely, a relatively warm and strong WGC was continuously present as reflected by gradual decrease in sea ice diatoms. This indication of a mid-Holocene warming trend is widely reported in studies from East/West Greenland, Canadian Arctic islands and Baffin Bay areas. From about 3.8 cal ka BP, our combined proxies suggest, a long-term Late-Holocene ("Neoglacial") cooling, interrupted by short warming events (RWP - Roman Warm Period, MCA - Medieval Climate Anomaly). The variable advance and/or retreat in sea ice cover is supported by records from Disko Bay and North Atlantic marine as well as terrestrial records. The observed change in sea ice seems to be connected to regional and global changes in oceanic circulation in the North Atlantic driven by solar forcing.

P-1440

## An annual cycle of diatom succession in two contrasting Greenlandic fjords recorded by sediment traps

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### Abstract

The rapid loss in the extent and thickness of Arctic sea-ice cover is one of the most significant signs of Arctic climate warming. Sea-ice decline affects e.g. global carbon balance, marine and terrestrial ecosystem dynamics and global climatic and oceanic/atmospheric circulation. To fully predict the consequences of future sea-ice decline, there is a need to understand past natural sea-ice variability beyond the satellite observation era.

Marine protists such as diatoms have a rich and abundant (sub)fossil record, and surface sediment calibration sets based on species assemblage compositions are often used to infer past sea ice conditions. In order to reliably use these calibration sets, and interpret reconstruction results, understanding the living environment and ecology of the taxa is essential. However, the biology and ecology of the key species used in diatom reconstructions is not well known, and the role of some sea-ice associated species as ice indicators appears complicated. Therefore, more knowledge of the annual sea ice dynamics and diatom species succession are needed.

As the sedimentary record represents essentially an integration in time and space, an important aspect is to refine the complex environmental triggers that structure community composition over seasonal cycles. To address this issue, we analysed diatom fluxes from two differing Greenland fjord systems: Young Sound, a high-Arctic fjord in NE Greenland and Godthåbsfjord, a sub-Arctic fjord in SW Greenland. These two fjords have distinct oceanographic settings and ice regimes. Young Sound is covered by sea ice for nine to ten months each year, whereas Godthåbsfjorden experiences inter-annually varying extent of sea ice only in the innermost parts of the fjord for less than six months per year. We will present results of seasonal diatom succession based on sediment trap analyses from both fjords. Sediment samples were collected over a year at 1 week to 1 month intervals and are investigated to determine seasonal time windows for diatom production in the water column and ice, with special focus on sea-ice associated species. The diatom assemblages from both fjords are compared to assess the presence of ice-associated species in comparison to the sea-ice conditions. This will provide important information for evaluating the potential and limitations of diatom-based sea-ice reconstructions.

P-1441

## Can ancient sedimentary DNA of marine diatoms serve as a new proxy for sea ice reconstructions?

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### Abstract

Past climate oscillations have led to the presence or absence of sea ice in the North Pacific Ocean, which in turn has driven changes in community compositions. Marine diatoms (Bacillariophyceae) are unicellular, siliceous organisms that can respond sensitively to environmental change such as sea surface temperatures. Moreover, they are the dominant group of sympagic microalgae in the Arctic with a few species producing the sea ice proxy IP<sub>25</sub> – a highly branched isoprenoid with 25 carbon atoms. So far, marine diatom records have been mainly analysed by microscopic observations, while only a handful of studies attempted a paleogenetic diagnostic. Here, we present an 18,000 year record based on ancient sedimentary DNA metabarcoding of diatoms for the Northwest Pacific Ocean and tackle the question if this approach is suitable as a new proxy for sea ice reconstructions. Our study site is located near the coast of Kronotsky Peninsula (Kamchatka). We collected 54 marine sediment samples from the 9.05 m long core SO201-2-12KL, which was taken at 2173 m water depth (N 53.992660, E 162.375830) and covers the time period since the deglaciation after the Last Glacial Maximum. In this core IP<sub>25</sub> was previously detected in time slices representing Heinrich event 1 (15.1 ka BP) and Younger Dryas (12.2 ka BP). Since chloroplast DNA is present in several copy numbers in diatoms the probability of its long-term preservation in marine sediments is very likely. Therefore, we applied a short metabarcode of the chloroplast *rbcl* gene (76 bp), which was amplified for each sample three times independently. Subsequent PCR products were prepared for high-throughput sequencing. In a pre-study with a subset of only 12 sediment core samples all four classes of diatoms were detected, expectably centric diatom genera like *Porosira*, *Chaetoceros* and *Thalassiosira* dominated the dataset. Genera containing ice-associated diatoms, such as *Melosira*, *Rhizosolenia*, *Navicula* or *Haslea* were recovered, but sparsely. Based on our preliminary results, we await high quality data for the larger data set. By now, our study demonstrated that DNA metabarcoding of marine diatoms has the potential to support and complement the analysis of long-term developments of community composition and diversity changes, e.g. in areas of low diatom preservation due to silica dissolution.

**P-1442**

## **Can sedimentary ancient DNA (*sed*aDNA) be used for sea ice reconstructions?**

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### **Abstract**

Records beyond observational time scales are essential for documenting and understanding the natural variations in Arctic sea ice extent. However, the tools to document the evolution of sea ice conditions on historical to geological time scales are few and have limitations. It makes that sea ice, although a crucial component of the Arctic and global climate system, remains incompletely understood. Using *sed*aDNA in paleoceanographic and paleoclimatic studies is still in its infancy. Here, we have explored using sedimentary ancient DNA, or *sed*aDNA, as a novel tool for past sea ice reconstructions. We used metabarcoding and single-species quantitative DNA detection methods to document the sea ice conditions in a Greenland Sea marine sediment core. Metabarcoding has allowed identifying biodiversity changes back to ~100,000 years ago that we relate to changing sea ice conditions. Detailed bioinformatics further revealed several sea-ice-associated taxa, of which several were previously unknown from the “traditional” (micro)fossil record. The results from our genetic approaches corroborate sea ice reconstructions by traditional tools (dinoflagellate cyst assemblages and sea ice biomarker IP<sub>25</sub>). In summary, we show that *sed*aDNA has great potential for documenting past sea ice conditions beyond instrumental time scales and provides a new tool to better understand past sea ice evolution.

**P-1443**

## **Environmental sensitivity of diatom biomarker lipids linked to phytoplankton blooms dynamics in high latitude settings.**

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### **Abstract**

The different ecological habitats of various classes, genera or species of microorganisms in polar marine settings offers the potential to identify unique or source-specific lipids that may serve as suitable biomarker proxies for discrete oceanographic settings.

Highly branched isoprenoid (HBI) alkenes represent one such a class of lipids. These structurally unusual secondary metabolites are biosynthesised by a relatively small number of diatom genera, but are, nonetheless, common constituents of global marine environment. And while their cellular roles remain unknown, the source-specific nature of HBIs makes them potentially useful biomarkers for paleo environmental studies.

Over the past decade, the source or environmental specificity of certain  $C_{25}$  HBIs has seen their application as organic geochemical proxies for seasonal sea ice reconstructions, particularly in the Arctic. Thus, while sedimentary analysis of a mono-unsaturated  $C_{25}$  HBI, termed  $IP_{25}$ , has been shown to provide a direct proxy measure of the past occurrence of seasonal Arctic sea ice, more detailed descriptions of sea ice conditions have been obtained by combining  $IP_{25}$  data with those of other HBIs, particularly those derived from open-water marine phytoplankton.

In the current study, we continue to build on the previous HBI work in the Arctic and explore the potential of two closely related tri-unsaturated HBIs, biosynthesised by pelagic phytoplankton community, to provide further refinement to HBI based sea ice reconstructions in the Arctic. The sedimentary data, mapping occurrence and distribution of two isomers were obtained through analysis of ca 200 surface sediments from the European Arctic and sub-Arctic regions, specifically in the Barents Sea and the neighbouring Norwegian Seas. Outcomes of sedimentary data were compared with overlaying oceanographic settings extracted from regional satellite records. Both biomarkers were readily detectable across study region, with distribution between the two isomer clearly varying between the different regions of the study area.

Early findings indicate, that within the study region at least, the distributions of two tri-unsaturated HBIs, may potentially provide otherwise unavailable proxy-based measurement of temporal shifts in phytoplankton blooms dynamics in high latitude settings. Such an insights could also be invaluable in the further contextualisation of e.g. sea surface temperature (SST) proxies, for which seasonality data are generally absent or assumed.

To provide further context to the sedimentary findings, we also conducted temporal investigation into the occurrence and distribution of the two isomers from temperate location, and compare findings with known environmental variables including those associated with productivity indicators.

**P-1444**

## **Out-of-Phase relationship between the East Asia summer and winter monsoon variations during the early Holocene**

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### **Abstract**

Great differences were observed in previous studies of the relationship between the East Asia summer monsoon (EASM) and winter monsoon (EAWM) due to the scarcity of winter monsoon geological archives. Here we present high-resolution elemental results together with twelve <sup>14</sup>C dates of a 13.5-m terrace sediment on the western Chinese Loess Plateau to infer the monsoon variability since the last deglaciation. Our results indicate that the ratios of Rb/Sr and Zr/Rb are sensitive indicators of chemical weathering and winter wind intensity, respectively, exhibiting significant fluctuations since the last 16 kyr BP. During the last deglaciation, two cold intervals of the Heinrich event 1 and Younger Dryas were characterized by intensified winter monsoon and weakened weathering intensity. In the early Holocene, weakening of the winter monsoon was gradually weakened around 10.7 kyr BP, leading to the abrupt increasing of the chemical weathering around 9.7 kyr BP. The winter monsoon intensity was relatively strong during the early Holocene and decreased gradually afterwards, whereas the summer monsoon intensity reached a maximum during 8-4.5 kyr BP. Such a discrepancy is likely attributable to different impacts of solar insolation and the remnant Laurentide Ice Sheet on the wind and moisture changes.

**P-1445**

## **Provenances and Paleoclimatic Response of Holocene Sediments in the Inner Shelf of the East China Sea**

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### **Abstract**

Holocene sediments from the inner shelf of the East China Sea (ECS), with its high deposition and continuously sedimentary record which is sensitive to environmental change, is an important recorder of regional responses to global paleoclimatic and paleoenvironmental changes. Based on the precise AMS<sup>14</sup>C dating data, We analyze grain size, clay minerals and trace elements of S05-3 sediment cores, investigating the sediment provenances of the southern inner shelf of ECS, deducing the evolution of East Asia Monsoon in the past 4.7ka. Comparing the clay minerals in the southern inner shelf of ECS with one from different potential source areas, the results indicate that sediments in the study area came from the Yangtze River, the Yellow River and rivers from Taiwan, while every potential source area making contribution in the different periods. In the period of 4.7-4.2ka, sediments from the Yangtze River and Taiwan's river is the main source of sediments. From 4.2ka to 3.2ka, sediments of study area mainly consist of the sediments of the Yangtze River and the Yellow River. Since 3.2ka, sediments from all of potential source areas had some response on the study area.

The evolution of East Asia Monsoon in the past 4.7ka can be deduced based on the grain size sensitive components, the ration of Rb/Sr and montmorillonite/kaolinite. Referring to the  $\delta^{18}\text{O}$  of GSP2 and stalagmite of Dongge Cave and the evidence of cooling of different materials in other regions, 9 high values could be recognized corresponding to the cooling events caused by the East Asia Monsoon. The core S05-3 records 4 strengthen periods of the East Asia Monsoon: weak and stable during 4.7-4.2ka BP; increased and began to fluctuate during 4.2-3.2ka; a little weak with highly fluctuation during 3.2-2.0ka BP; the East Asia Monsoon increased slightly with fluctuations weakened.

P-1446

## History of Lake Ulaan in southern Mongolia since 16 ka: the ostracod, gastropod and charophyte record

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### Abstract

Lake Ulaan was a terminal lake in the Gobi Desert until the 1990s when the lake desiccated. The Ongin River is the main tributary of the modern playa originating in the southeastern Khangai Mountains ca. 250 km to the northwest. A sediment core of 5.88 m length was obtained and the chronology of the sediments established using OSL and radiocarbon dating.

Calcareous and other fossils from the sediment core were studied to reveal the lake history since the late glacial and in the Holocene. Most abundant microfossils in the sediments are valves of ostracods (micro-crustaceans). The ostracod assemblage is dominated by *Limnocythere inopinata* in the late glacial and early-mid Holocene section of the core. Valves of *Ilyocypris cf. gibba* and gyrogonites and oospores of charophytes occur almost exclusively in the postglacial section. Gastropod shells of *Gyraulus* and *Radix* were mostly recorded in the early Holocene sediments of Lake Ulaan.

Sediments are almost devoid of fossils during the periods from ca. 15-12.5 and 6-3 ka, likely indicating least favorable conditions in the lake environment. In contrast, the highest concentrations of fossils and the highest diversity between ca. 11-8.5 ka probably result from wettest conditions in the catchment of Lake Ulaan. The presence of valves of *Cypridopsis vidua*, *Heterocypris salina*, *Sarscypridopsis aculeata* and *Pseudocandona* sp. in addition to those of *L. inopinata* and *I. cf. gibba* indicate that Lake Ulaan was a shallow lake with fresh to slightly brackish waters during the most stable, favorable period in the early Holocene.

**P-1447**

## **Spatial contrasts of Holocene climate evolution across East Asia**

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### **Abstract**

The East Asian climate, with its monsoon system, is a very dynamic component of the global climate system. To extend our understandings on climate evolution and its spatial patterns, we investigated the spatial patterns of this East Asian climate during the Holocene by analysing the results of multiple palaeoclimate models (with full-climate forcing).

Our analysis on these simulations suggests that the Holocene climate patterns and trends are not the same everywhere in East Asia. The most distinct feature is the contrast in the Holocene wetness evolution between the northern and southern East Asia. The wetness in northern East Asia increased during the Holocene with a drier early Holocene, while the Holocene wetness had a decreasing trend in the southern East Asia (with a boundary of  $\sim 40^{\circ}\text{N}$ ). This N-S contrast in wetness trends is supported by proxy data, including quantitative precipitations records and composite moisture reconstructions. This N-S contrast in Holocene climate/wetness changes can be attributed to different mechanisms. Reduced early Holocene wetness and related increasing Holocene trend of wetness over the northern East Asia is associated with the strength of the westerly airflow. By contrast, in southern East Asia enhanced wetness at 11.5 ka and the decreasing Holocene wetness trend is caused by the monsoon circulation.

What is new in this present study is that we diagnosed a spatial contrast in the Holocene wetness evolution over East Asia in multi-model simulations performed with full-climate-forcings. We also explored the potential drivers behind the detected latitudinal wetness contrast. Additionally, enhanced wetness during the early Holocene in the southern East Asian domain is similar as the predicted high rainfall for the future. Thus, the early Holocene can be an analogue to the future climate over the Asian domain.

**P-1449**

## **Climate variability in the northern Arabian Sea during the Holocene**

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### **Abstract**

The Arabian Sea is affected by an extremely dynamical climate system characterized by a pronounced seasonal monsoonal atmospheric circulation associated to changes in ocean circulation. Seasonal reversals and intensity changes of wind systems drive the development/suppression of strong coastal upwellings. High surface productivity, linked to upwelling reinforcement, together with supply of oxygen-poor intermediate waters result in establishment of an intense oxygen minimum zone in the water column and sediments. The seasonal reversal in wind direction is also associated with variable moisture sources. Currently, there are limited studies from the northern Arabian Sea that reconstruct high resolution hydroclimatic and terrestrial environmental changes during the Holocene and their potential link with marine conditions.

In this study we use a multi-proxy approach (from marine and terrestrial indicators) of a partially laminated marine sediment core (MD04-2875C; recovered during CHAMAK campaign, 2004) in the upper part of the Makran accretionary prism (northern Arabian Sea) to investigate the climatic variability and its local manifestation on the marine and terrestrial environmental system during the Holocene.

Based on combined hydrogen and carbon isotopic composition of leaf wax n-alkanes ( $\delta D$  and  $\delta^{13}C$ ), we identify three time periods (0.5-4.5 kyr BP, 4.5-9 kyr BP, 9-12 kyr BP) with distinctive  $\delta D$  signatures exhibiting successively depleted values towards the end of the Holocene.  $\delta^{13}C$  values, which can be seen as an indicator for a vegetation composition change between C3 and C4 plants, show only marginal changes between 4.5-12 kyr BP and remain constant thereafter. Based on this we propose changes in local precipitation and moisture sources as the principal drivers of  $\delta D$  signature. Since the start of sediment lamination coincides with the observed  $\delta D$  shift around 4.5 kyr BP, we propose that a major atmospheric reorganization is synchronous to the creation of an oxygen minimum zone. In this context, we also discuss possible implications of climate variability on the development of regional human societies.

P-1450

## Plant Diversity and Climate during the Quaternary: palynological evidences of species extinction and migration from India

Anjum Farooqui

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### Abstract

A substantial palaeoclimate data exhibiting vegetation succession during the Quaternary period in varied biogeography such as Trans Himalayan, Himalayan, Desert, Semiarid, Western ghat, Deccan plateau, Gangetic plain, North east and the Coastal zone is available from the vast territory of India. Spanning a time period of about 2.6 million years ago of the Earth's history, the palynological records in sedimentary archives have revealed the responses of vegetation to the climatic spasms during the period. Palynological records from India show that the cyclic episodes of interglacial and glacial periods have impacted upon vegetation which has led to endemism, local extinction, migration and introduction of new plant species. For this, multiple sedimentary archives have been investigated for identifying the diversity and evolution of vegetation through time. Most of the endemic flora which is found nowhere in the World is present in the Western ghats of India and is one of the hotspots of biodiversity. The relicts of the oldest vegetation in the Indian-subcontinent is now present only in the south-western ghats. The palynological records reveal that the monsoonal pattern in this region has remained similar since the Miocene time period and therefore, the endemic biodiversity is recorded till date in this part of India. However, the extinction of many species cannot be ruled out as is evidenced in palynological records of the past in the region. A continuous record of pollen-based vegetation from this region is available since ~140 ka to present. Similar rainforest palynological records are available ~ 1.95Ma from the Karewa Basin, Kashmir, in the north. It is concluded that although the vegetation in most part of the Indian-subcontinent remained in equilibrium with the fluctuations in Quaternary climate, the landscape/geomorphological evolution in varied biogeographic zones have left impact on vegetation particularly in the Himalayas and the coastal zone. Overall palynological results reveal that the rainforest vegetation although rejuvenated during Middle Holocene warm period in most part of the Indian-subcontinent but during Late Holocene it has squeezed into pockets in the south-western ghats, coastal areas and north-eastern region of India. The two plant species, *Ongoekia gore* and *Basella keralensis* recorded in sedimentary archives deposited before 74Ka (YTT event- Volcanic eruption in Sumatra) are now not present in the Indian sub-continent. While the former has migrated to more moister south-east Asia, the latter became extinct from the globe. Thus, *B. keralensis* can be used as palyno-marker of pre YTT time period until its palaeorecord is further available from any part of the world.

**P-1451**

## **Indian summer monsoon variability of the last 2000 years documented from lake pollen records, Yunnan Plateau, Southwestern China**

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### **Abstract**

A high-resolution pollen-based precipitation reconstruction from a sediment core from Xingyun Lake, central Yunnan Plateau, southwest China, reveals the Indian summer monsoon (ISM) evolution over the last 2000 years. Pollen assemblages document four stages of regional vegetation history: (i) During 350 BC-700 AD, the Xingyun Lake catchment was covered by mixed forest of pine and oaks, with a variety of ferns and herbs in the understory. (ii) From 700 to 1400 AD, broadleaved forest dominated by evergreen oaks expanded to the maximum and the pine forest areas shrunk. (iii) From 1400-1900 AD, *Abies* and *Picea* forest occurred on the surrounding high mountains, and at the same time, the regional vegetation became more open, with pine forest increased but broadleaved forest declined. (iv) Since 1900 AD, the regional vegetation was dominated by a secondary forest of *Pinus* and *Alnus*. The vegetation history of Xingyun Lake indicate a drying climate and a gradually strengthened human activity during the last 2000 years. Despite the intensifying human influences, the Xingyun Lake records still reflect a general pattern of the climate change. The variations of the pollen-based quantitative precipitation suggest that the ISM weakened gradually during the last two millennia, with the strong ISM influence occurring during the Medieval Warm Period (MWP) with a weak ISM during the Little Ice Age (LIA). Besides, several important climatic periods were also captured, such as the weak monsoon period in 1000-1100 AD during the MWP and the strong monsoon period in 1600-1800 AD during the LIA, as well as the most remarkable dry period of the recent 200 years. Our reconstruction of the ISM is compatible with the records both from Yunnan Plateau and the ISM domain. In addition, our record bears significant solar activity cycles, suggesting that the solar forcing may affect the variability of the ISM and likely the ENSO as well.

P-1452

## Environmental conditions framing the evidence of the first *Homo sapiens* in Indochina (Tam Pà Ling cave, NE Laos)

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### Abstract

Tam Pà Ling cave (northeast Laos) holds evidence of the first arrival of *Homo sapiens* in Indochina. Recently, several modern human remains have been excavated and dated about  $70 \pm 8$  kya. These findings support the hypothesis of migrations across Southeast Asia during MIS 4 and they represent an important record to understand the colonization of this area of the world by our species. Generally, environmental conditions are important factors framing human movements. However, the limited information available for this region challenges the interpretation of Tam Pà Ling archaeological findings. This study uses the stable isotope composition of biocarbonates to investigate the environmental conditions prevailing from MIS 4 to MIS 1 in northeast Laos. The analyses are conducted on terrestrial gastropod shells excavated throughout the sequence. Shell carbon stable isotope composition ( $\delta^{13}\text{C}$ ) is used to infer the proportion of  $\text{C}_3$  (arboreal vegetation) and  $\text{C}_4$  (grasses and shrubs) plants. The availability of these specific vegetation types relates to the occurrence of open vs closed habitats. Furthermore, shell oxygen stable isotope composition ( $\delta^{18}\text{O}$ ) is adopted as precipitation proxy. The results indicate that during MIS 4 and MIS 3 (from  $70 \pm 8$  to  $34 \pm 2$  kya) the landscape was mainly dominated by arboreal vegetation, as it is in modern times. These forested environments were sustained by enhanced precipitation derived by intense summer monsoons. However, during MIS 2, the shell stable isotopes record a significant environmental change with the disappearance of closed forests in favor of more open habitats and the tendency toward drier conditions, potentially related to the weakening of the monsoon system. Ultimately, during Holocene, the area returned to be characterized by wet and forested conditions. These results provide insights into the type of environment encountered by the first *H. sapiens* populations in Indochina and how it changed through time.

P-1453

## Holocene Geomorphology And Evolution of the Lower Palar River Basin, Tamil Nadu

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### Abstract

The Palar River is an eastward flowing river in Southern Peninsular India and receives dominantly the NE monsoonal rains. Neotectonic activity, that occurred owing to the prolonged stress along the Mulki Pulikat Axis (MPA), during the Quaternary times, uplifted the western side of the Palar River, which resulted in rejuvenating the preexisting faults and lineaments in the upper and middle reaches of the Palar River. The Palar River migrated ~25km south. The present day Palar River and its paleochannels located in the southern peninsular India were investigated with a multidisciplinary approach. The main aim of the study was to reconstruct the palaeoenvironment history of the Palar River basin and to delineate the role of Holocene fluctuations that played a major role in the geomorphological evolution of the region since the Holocene period. The results obtained based on sedimentary facies analysis supported by elemental concentrations and optically stimulated luminescence (OSL) dates, reveal distinct seven climatic phases since the last ~10 ka. Phase 1 signifies a very high precipitation as supported by the low CWI with high Rb/Sr ratio. Subsequent to Phase 1, a decreasing trend in the Northeast monsoon rainfall (NEMR) is observed (phase 2). Phase 3 (~4.83 ka - 3.59 ka) reflects a decrease in NEMR further supported by low Mn/Al, Mg/Al and CIA values. Phase 4 (~ 3.59 ka) is marked by high sand flux, K/Al, Ti/Al, Rb/Sr and Ba/Sr coupled with lower values of CaO/MgO, Mn/Al, Fe/Al indicate wetter conditions in the catchment area resulting in the intense weathering of the bedrocks caused owing to the increase in NEMR precipitation. Phase 5 (3.26 ka- 2.42 ka) reveals a decline in NEMR precipitation coupled with rapid upstream avulsion due to neotectonic activity that occurred in an intense dry phase. Phase 6 (~1.88 ka - 1.44 ka) is marked an augment NEMR causing high K/Al, Mg/Al, Ti/Al ratios, CIA and CWI values. Finally, phase 7 (~1.44 ka to present) is marked by lowered elemental solubility and mobility reflecting short periods of weaker or deteriorated NEMR. The documented record of Palar River and paleochannels suggest Holocene NEMR variability in the study region and is synchronous with the various proxy records of NEMR dominated regions however revealing an inverse coupling with SWMR during the Holocene period.

**P-1454**

## **Late Pleistocene Monsoon History of the lower Bengal Fan (IODP Expedition 354)**

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### **Abstract**

IODP Expedition 354 drilled seven sites along an east west oriented core transect of 320 km length at 8°N in the lower Bengal Fan (France-Lanord et al., 2016). The sites were recovered to reconstruct the Himalayan uplift, the monsoonal development, and the turbiditic depositional mechanisms. We studied the Pleistocene sections of these sites using physical, optical, geochemical, stable isotopic, and grain-size properties, to establish the chronology and provide constraints on the depositional history of the last 1.25 Ma in relation to monsoon, climate, and sea-level development. Low-resolution bio-, magneto- and tephrostratigraphy were used as ground-truth chronological control to identify five sedimentary units that mostly changed synchronously across the fan: two regionally extensive hemipelagic Units (2 and 5) as well as three intercalated turbiditic Units (1, 3 and 5).

The top hemipelagic Unit 5 was studied in detail at Site U1452C (Weber et al., 2018, Global and Planetary Change). This ~5 m thick sequence shows dominantly precession cycle forcing of wet-bulk density as well as color reflectance  $b^*$  and  $L^*$ . Using these fluctuations, we are able to provide an insolation-tuned chronology for the last 200 ka (MIS1–7). This chronology agrees well with an independent age model derived from relative paleointensity and shows that moisture-driven monsoonal changes happened synchronously to  $\delta^{18}\text{O}$  changes reported for Chinese cave records. Accordingly, grain-sizes were coarser and marine productivity was higher during insolation minima, indicative for an enhanced NE monsoon during glacials and stadials. Our proxies indicate teleconnections to both high northern and high southern latitudes.

Using orbital cyclicity detected in sediment physical properties of all seven sites, we also tuned high-resolution color reflectance data ( $L^*$ ) to the LR04 benthic isotope stack to obtain new constraints on the timing of depositional changes since the Middle Pleistocene (Weber and Reilly, 2018, Quaternary Science Reviews). Accordingly, above turbiditic Unit 1, the lower hemipelagic Unit 2 commenced around 1.25 Ma, and terminated around 0.68 Ma - the start and end of the Middle Pleistocene Transition (MPT), respectively. The dominantly turbiditic Unit 3 ends around the time of the Mid-Brunhes Transition (~MIS 12). The following turbiditic Unit 4 likely changed asynchronously across the eastern fan during MIS 8-7, where it transitions into the topmost hemipelagic Unit 5. All in all, we find evidence that deposition across the lower Bengal Fan changed with the evolution of Pleistocene monsoon, climate, and sea level and hence responded to external controls on sediment accumulation and fan architecture rather than to fan-internal, autocyclic mechanisms alone.

P-1455

## Plant Diversity and Climate during the Quaternary: palynological evidences of species extinction and migration from India

Anjum Farooqui

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### Abstract

A substantial palaeoclimate data exhibiting vegetation succession during the Quaternary period in varied biogeography such as Trans Himalayan, Himalayan, Desert, Semiarid, Western ghat, Deccan plateau, Gangetic plain, North east and the Coastal zone is available from the vast territory of India. Spanning a time period of about 2.6 million years ago of the Earth's history, the palynological records in sedimentary archives have revealed the responses of vegetation to the climatic spasms during the period. Palynological records from India show that the cyclic episodes of interglacial and glacial periods have impacted upon vegetation which has led to endemism, local extinction, migration and introduction of new plant species. For this, multiple sedimentary archives have been investigated for identifying the diversity and evolution of vegetation through time. Most of the endemic flora which is found nowhere in the World is present in the Western ghats of India and is one of the hotspots of biodiversity. The relicts of the oldest vegetation in the Indian-subcontinent is now present only in the south-western ghats. The palynological records reveal that the monsoonal pattern in this region has remained similar since the Miocene time period and therefore, the endemic biodiversity is recorded till date in this part of India. However, the extinction of many species cannot be ruled out as is evidenced in palynological records of the past in the region. A continuous record of pollen-based vegetation from this region is available since ~140 ka to present. Similar rainforest palynological records are available ~ 1.95Ma from the Karewa Basin, Kashmir, in the north. It is concluded that although the vegetation in most part of the Indian-subcontinent remained in equilibrium with the fluctuations in Quaternary climate, the landscape/geomorphological evolution in varied biogeographic zones have left impact on vegetation particularly in the Himalayas and the coastal zone. Overall palynological results reveal that the rainforest vegetation although rejuvenated during Middle Holocene warm period in most part of the Indian-subcontinent but during Late Holocene it has squeezed into pockets in the south-western ghats, coastal areas and north-eastern region of India. The two plant species, *Ongoekia gore* and *Basella keralensis* recorded in sedimentary archives deposited before 74Ka (YTT event- Volacanic eruption in Sumatra) are now not present in the Indian sub-continent. While the former has migrated to more moister south-east Asia, the latter became extinct from the globe. Thus, *B. keralensis* can be used as palyno-marker of pre YTT time period until its palaeorecord is further available from any part of the world.

**P-1456**

## **Palynological evidences of major climatic events of the past two millennia from Southeast coast of India**

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### **Abstract**

A high-resolution palynological reconstruction of vegetation succession in two sedimentary profiles from the Godavari delta, India was analysed to decode the events of extreme climatic variability during the last 2 millennium. These historical records of natural climate variability are crucial in quantifying the future climate change with enhanced anthropogenic inputs. Climatic periods inferred from the pollen record include (1) a basal warm/humid period (BC 250–AD 450) with dominance of mangroves and tropical moist deciduous taxa, (2) a gradual weakening of monsoon leading to arid conditions with a decline in true mangroves and arboreal taxa comparable to Dark Ages Cold Period (AD 450-910), (3) a Medieval Warm Period (AD 910–1385) with a strengthened summer monsoon as evidenced by rejuvenation of true mangroves and tree taxa, (4) a relatively cool and dry condition with abundance of dry deciduous and non-arboreal taxa possibly corresponding to Little Ice Age (AD 1385–1850) with a weakened monsoon, and finally (5) the current warm period, since AD 1850. A semiquantitative aridity index based on variations in humidity has also been used to detect for the first time in India the millennial-scale climatic cyclicality in the pollen record. The Little Ice Age is recorded with high aridity values between AD 1385 and 1850, with a peak at AD 1700 (Maunder Minimum) whereas the Roman and Medieval Warm Periods are noticed through low aridity values at BC 250-AD 450 and AD 910-1385, respectively.

P-1457

## Response of the Indian vegetation and monsoon rainfall to the current and last interglacial warmings in the Mahanadi river region

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### Abstract

A number of records provides evidence of Asian monsoon variability over the last 125,000 years. However, the regional response of the tropical hydroclimate to increasing greenhouse gas concentrations and global temperatures and the controlling factors modulating this response remain among the most challenging questions. This study focuses on the dynamics of the Indian Summer Monsoon (ISM) subsystem, which brings most of the annual rainfall in areas such as Central India, in the so-called Core Monsoon Zone (CMZ) where the ISM has its most representative expression.

This work seeks to characterize changes in vegetation and monsoon rainfall in Northeast India, within the CMZ, in response to the large global climate changes that operated during the last and penultimate deglaciations and during the current and last interglacial periods. We will present results derived from pollen analysis of marine sediments from the IODP site U1446. This site, which covers the last 1.4 Myr, was collected during the IODP expedition 353 "Indian Monsoon Rainfall" on the eastern Indian margin off the Mahanadi river exit, recruiting pollen from the vegetation of this river basin. Pollen data will be compared to sea surface temperatures derived from alkenones analysed in the same sample set than pollen. We will also present results on MIS 11c (~400 kyr ago), one of the best orbital analogues of the current interglacial, to examine further the ISM response during periods of weak insolation forcing (MIS 1 and 11c), contrasting with the strong insolation forcing of last interglacial period (MIS 5e).

Our preliminary results show that during glacial-interglacial transitions the Mahanadi landscape dramatically changed from a grassland and marshland dominated vegetation with very sparse trees to a temperate moist deciduous forest inland with a well-developed mangrove in coastal areas, showing the strengthening of the monsoon rainfall. Over the course of the interglacial periods, mangrove strongly reduced and grassland expanded as boreal summer insolation decreased.

**P-1458**

## **Indian vegetation and monsoon response to millennial and orbital climate variability during the last glacial period**

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### **Abstract**

The Indian Summer Monsoon (ISM) bringing up to 80-90% of the annual rainfall in areas such as Central India, in the so-called Core Monsoon Zone (CMZ), is highly variable and sensitive to global climate change. Its impact affects the daily lives of billions of people (IPCC 2014) and has had large devastating impacts on populations and economies in the past. However, predictability of the ISM variability by numerical simulations are still uncertain, especially because processes underlying the natural variations of the ISM at the different timescales remain unclear and are still debated.

With the aim to better constrain the ISM variability in response to abrupt climate changes or changing boundary conditions, such as CO<sub>2</sub> increase, ice sheet melting and insolation change, we investigated samples from the IODP Site U1446 collected during the Expedition 353 "Indian Monsoon Rainfall".

Our study is based on an original approach that consists of pollen analysis of marine sediments. Pollen assemblages at IODP Site U1446 represent an integrated image of the regional vegetation, and therefore climate, in the Mahanadi hydrological basin, which is ideally located in the eastern part of the CMZ. This approach enables a direct comparison of terrestrial and marine tracers without chronological ambiguities.

We present herein the preliminary results of our palynological investigations. Pollen data is compared with others records from site U1446, such as SST estimates derived from alkenones. The outstanding nature of the record provides insight on the key mechanisms driving the ISM variability at orbital and millennial scales. More specifically, we document the ISM response to insolation changes in a glacial context (MIS 4 to MIS 2) and to the abrupt climate changes of the last glacial period. At centennial to millennial time scales, we attempt to discriminate the respective influence of the northern high latitude forcing, controlling the pace and magnitude of weak monsoon intervals, from the subtropical forcing, impacting Indian Ocean surface temperatures and, thus regional evaporation feeding summer rainfall in India.

**P-1459**

**A ~6000 year high resolution continuous paleoproductivity and paleoenvironmental record reconstructed from the paleolake sediments of Pinder valley, Garhwal Himalaya**

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<sup>1</sup>Wadia Institute of Himalayan Geology, Dehradun, India. <sup>2</sup>Kumaun University, Nainital, India

**Abstract**

The Holocene epoch which spans ~11,700 years before present is considered significant for understanding the natural variability of climate before the industrialization in the absence of anthropogenic activities. Indian Summer Monsoon (ISM) which is of great socio-economic importance to millions of people of Indian sub-continent has varied during the Holocene. Several short and long term weakening and strengthening phases of ISM have been recorded during this time interval which have been linked to the evolution and collapse of various civilizations. Thus, comprehensive study of spatio-temporal variability of ISM during Holocene will help in understanding the past climate events and their impact on human settlements. In this regard, total organic carbon (TOC), stable carbon isotopes ( $\delta^{13}\text{C}$ ), grain size, major and trace element concentrations were analyzed to reconstruct the paleoproductivity and paleoclimatic variability at centennial scale during the last ~6,000 cal yr BP from paleolake sediments of Bedni, Pinder valley, Garhwal Himalaya, India. In this study, evidences of several centennial scale cold-dry and warm-wet events were recorded that corresponded with global climatic events e.g., cold-dry periods between ~2830 and 2630 cal yr BP and ~500 and 320 cal years BP (AD ~1450 to 1630) correspond with the Bond event 2 and Little Ice Age respectively. The warm and wet periods between ~2630 and 1750 cal yr BP and ~1010 and 760 cal yr BP (AD ~940 to 1200) correspond to the Roman warm period and Medieval Warm Period respectively.

**P-1460**

## **Mid- to late Holocene changes in the Indian Summer Monsoon: a multi proxy record from Bhagirathi valley, Northwest Garhwal Himalaya**

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### **Abstract**

The agricultural based socio-economic development of over a billion people depends on the moisture availability from the Indian summer monsoon (ISM). To understand the future precipitation variability, an understanding on the past climate and its forcing mechanisms are essential. Significant spatial-temporal variability in precipitation at regional scale has been observed in the Himalayan basins. Several studies have demonstrated that Holocene climate in Himalayan regions is more complex and heterogeneous than other parts of the Northern hemisphere. Therefore, for precise and regional understanding of the Holocene climate history of Himalaya, high density as well as high resolution and multi-disciplinary palaeoclimate data are indispensable. A new multi proxy dataset (pollen, loss on ignition and magnetic susceptibility) constrained by AMS  $^{14}\text{C}$  radiocarbon dates from the peat deposit located at an alpine meadow of Dayara, Bhagirathi valley, Northwest Garhwal Himalaya is presented. The dataset provides a high resolution continuous palaeovegetation and palaeomonsoonal variability for the past  $\sim 6100$  cal yr BP. The peat accumulation in Dayara region has begun at  $\sim 6100$  cal yr BP, which is marked by the sharp lithologic contact with the underlying debris flow sequence and an abrupt decline in detrital influx. Between  $\sim 6100$  and 5930 cal yr BP, pollen assemblages were dominated by the diverse herbaceous and tree taxa. The tree taxa characterised by the coniferous and broad-leaved trees, indicates a mixed forest landscape in the region in the prevalence of reasonably warm and wet climate. The progressive decrease in percentages of evergreen tree pollen and LOI% from  $\sim 5930$  to 5320 cal yr BP indicates a relatively reduced ISM precipitation than the preceding pollen assemblage. From  $\sim 5320$  to 3690 cal yr BP and  $\sim 1860$  to 950 cal yr BP, percentages of evergreen broad-leaved tree pollen decreased, while coniferous tree pollen and magnetic susceptibility increased substantially, indicating a deterioration of summer monsoon in the Bhagirathi valley. An increase in broad-leaved, herbaceous taxa and fern over conifers, and decrease in magnetic susceptibility during  $\sim 3690$  to 1860 cal yr BP and  $\sim 950$  to 500 cal yr BP suggest warm and wet climatic conditions during these periods. The high resolution multi proxy palaeoclimate record from the ISM dominated Dayara peat profile, Bhagirathi valley reflects rapid response of ecosystem to even small scale changes in ISM precipitation. The large scale (millennial) palaeovegetation and palaeoclimatic changes reconstructed from Dayara peat profile are in accordance with the palaeoclimatic records of other ISM dominated regions, whereas small scale (decadal to centennial) palaeovegetation and palaeoclimatic variability is due to the variation in altitude, basin topography and distance from the sea.

**P-1461**

**Late Holocene hydroclimate changes in central Taiwan inferred from pollen and Itrax XRF elements records from an alpine pond**

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**Abstract**

We studied pollen, grain size, and the Itrax XRF element analysis from a lacustrine core, in central alpine Taiwan, Tunlumei Pond (TLM), to investigate vegetation dynamics and environmental changes during the past 2,400 cal yr BP. The trend in variation between percentages of temperate coniferous forest taxa and wetland taxa suggested that climate changed from cold/dry to warm/humid climate from 1,800 cal yr BP, reflecting the fluctuation of East Asian summer monsoon intensity. The rapid increase in mean grain size, and the ratios of Sr/Ti and Rb/Ti indicate a strong variation in local hydroclimatic condition at 1,510 cal yr BP and the Little Ice Age (LIA). The extremely precipitation may be caused by the intense paleo-typhoon activity, correlating to ENSO fluctuation, which increases strong or/and frequent typhoons passing through Taiwan and the southern China.

**P-1462**

## **Interpreting event layers in lacustrine records using XRF core scanning**

Ludvig Löwemark<sup>1</sup>, Tsai-Wen Lin<sup>1</sup>, Jyh-Jaan Steven Huang<sup>2</sup>, Alice Chien-Yi Liao<sup>1</sup>

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### **Abstract**

Lacustrine sedimentary records often contain discrete layers of distinctly different color and composition, compared to the general lithology. The origin of these layers are often the subject of animated discussions. Are they representing periods of distinct events or shifts in the climate system? Are they caused by stochastic variations in lake-internal processes? Or, are they caused by lake-external processes acting in the catchment?

Interpreting these layers often requires using a mosaic of different proxies to solve the puzzle, as single proxy records can give very misleading results. Here elemental ratios (or log ratios) obtained through XRF core scanning can provide a powerful tool to help disentangle the relative influence of the different processes. Based on examples from a number of lakes in Taiwan, it is demonstrated how activities and processes such as landslides, infrastructure construction, typhoon events, and lake level fluctuations can be distinguished from climatic trends and shifts.

An improved understanding of the different processes that are recorded in the sediment is particularly important when dealing with late Holocene material, because agriculture, forestry and other human activities may locally overshadow natural climate variability.

**P-1463**

## **Interpretation of XRF data from Tasmanian lake records**

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### **Abstract**

We present a review of the application of XRF data in Tasmania to date with details of a selection of sites spanning the west-east environmental gradient across Tasmania from a wetter, rainforest dominated west to a drier, sclerophyll dominated vegetation in the east. XRF data is interpreted in light of complementary pollen, charcoal and other sediment analyses and depositional settings.

**P-1464**

## **Evaluation of quality assurance and quality control (QA/QC) of XRF-core scanning data by a novel depth-dependent local similarity approach**

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### **Abstract**

XRF-core scanners allow fast, non-destructive, and ultra-high resolution analyses of relative element abundances directly on the sedimentary archives and therefore have revolutionized paleo-environmental research over the last decade. Since the XRF-core scanning (XRF-CS) data are originally outputted as elemental peak area (counts), a timely- and economically-efficient QA/QC evaluation is essential towards robust data processing and interpretations. To date, several approaches have been proposed to evaluate the repeatability and/or reproducibility of XRF-CS results. However, most of these methods focus on reporting the entire trends of replicate measurements in the original scanning resolutions, while elements are usually not evenly distributed along the scanning samples or show isolated perturbations at certain depths. Those QA/QC evaluations, therefore, may be over- or underestimated and thus led to misuse and misinterpretation of XRF-CS data, especially for the elements with either low concentration or low detectability. Here we propose a depth-dependent local similarity approach to evaluate the repeatability of XRF-CS data locally. By using this mathematical method, the correlation coefficients of replicate scanning measurements at a given scanning point can be calculated and visualized in order to appraise the performance of each individual element throughout the sample. Moreover, our method can also determine the optimal calculated resolution with reasonable correlation coefficient by changing the depth window. To verify our new method, we further used two alpine lacustrine XRF-CS datasets obtained from the Eastern Alps, including Lake Fischersee (high-organic vs. glacially detrital sediments) and Lake Millstättersee (laminated sediments comprising event deposits). Our method can therefore better address the long-standard challenges among the XRF-CS community, including which quantitative and/or relative-trend information of which elements within which core intervals at which scanning resolution can be reproduced, allowing reliable analyses and scientific interpretations of XRF-CS data.

**P-1465**

## **An application of ITRAX XRF scanning of lake and marsh sediment cores for palaeotempestology.**

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### **Abstract**

Hurricanes are one of the world's most destructive natural disasters and it is believed that these large scale events are increasing with global warming. As instrumental records only date back to the 1850's, it is essential to examine longer time periods to analyse the effects and aid future predictions. Palaeotempestology is the study of hurricane events during the Holocene by a multitude of geological proxies. This study uses a multi-proxy approach to analyse Holocene hurricane frequency and intensity and to assess environmental change as a result of these large scale events at Gulf Shores, Alabama, USA. It highlights the potential of ITRAX XRF core scanning as a tool for palaeotempestology.

In May 2018, two 6 m lake cores and one 3 m marsh core were extracted from Middle Lake and Little Lake Marsh, Alabama, USA. The cores were split open and inspected for visible sand layers. Identifying visible sand layers is the most commonly used method for initially identifying hurricanes. Sand layers represent hurricane presence as during a hurricane event, storm surges and strong winds transport sand and beach debris inland and deposit into lake and marsh environments.

Once visually inspected, the cores were then processed through an ITRAX scanner at the University of Manchester, U.K. The cores were scanned at 1 mm intervals, with a 30 s dwell time, using a Molybdenum x-ray tube. High-resolution photographic images and radiographic images were acquired at 200  $\mu\text{m}$  resolution throughout the cores.

Preliminary results of the XRF count data and the ratios; Si/Ti, K/Ti, Ca/Ti, Fe/Ca will be presented, highlighting the potential of ITRAX XRF core scanning as a tool for palaeotempestology.

**P-1466**

## **Improvement of the data shifting problem when interpreting XRF core scanner data from sedimentary cores**

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### **Abstract**

XRF core scanner has an important place in paleoenvironmental research to help reconstruct paleoclimatic records. It can efficiently provide nondestructive, continuous data for both lake and marine sedimentary cores, as well as for many other kinds of samples. In order to get a reliable downcore XRF data, consistent parameter settings should be used during scanning of different sections of the same core to minimize differences between sections and generate a continuous result. However, despite using identical settings, shifts between different sections are sometimes observed in the elemental data. Previous studies have demonstrated the influence of the water content during core scanning. However, a number of other factors may cause the shifting of data. For example, the data tuning process of the Q-spec software, or different oxidation level between different sections leading to migration of elements towards or away from the sample surface can both cause systematic shifts between core sections. Our aim is to use different methods to understand the underlying processes that are responsible for the observed discontinuities, and outline the most efficient ways to minimize the shifting in order to produce authentic and verifiable results when interpreting XRF core scanner data from sedimentary cores.

P-1467

## The interpretation of micro-XRF geochemical data from a tropical nearshore basin in Kingston Harbour, Jamaica

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### Abstract

Hunts Bay is a shallow, eutrophic embayment located in Kingston Harbour, the 7th largest natural harbour in the world. The bay is one of the most polluted in Jamaica and receives freshwater and sediment input from multiple sources including rivers, storm drains and gullies that traverse the city of Kingston and nearby alluvial plains. Environmental management efforts at Hunts Bay have been stymied by a paucity of knowledge about its natural pre-industrial state, as well as insufficient understanding of the key drivers of environmental change in these settings. To this end, we investigate both natural and anthropogenic drivers of environmental change in the Bay using ITRAX  $\mu$ -XRF geochemical data from sediment cores recovered from Hunts Bay. However, the interpretation of elemental data from marginal marine environments is challenging given that these systems are highly dynamic and respond rapidly to consistently changing coastal processes leading to significant signal variability over relatively short spatiotemporal scales.

Our data reveal that positive excursions in the molybdenum incoherent:coherent scattering (incoh/coh) ratio are consistently associated with organic-rich lithostratigraphic units and support the use of the incoh/coh ratio as a suitable proxy for organic matter. Similarly, the interpretation of the Ti and Fe signals are straightforward because these elements are strongly positively correlated across the basin and consistently reflect changes in both lithostratigraphic and radiographic profiles. Therefore, the signal variability of these elements is likely associated with changes in terrigenous material with a combined fluvial and aerial provenance. In contrast, the signals for Ca and Sr are more variable spatiotemporally because of the diverse sources of Ca and Sr (principally authigenic versus detrital) and this underlies one of the challenges of using these elements in the palaeoenvironmental reconstructions of tropical karstic settings. In Hunts Bay, the possible sources of Ca and Sr were differentiated based on the nature of their correlation with detrital elements (K, Ti and Fe). A negative correlation was interpreted as suggesting authigenic precipitation of calcium carbonate (or a marine source) while a positive correlation implied a detrital source. The interpretation of the Mn/Fe ratio is also less straightforward because the signal in some lithostratigraphic units might possibly reflect early and post-depositional diagenetic chemistry of Mn rather than a palaeoenvironmental signal. Additional multiproxy analyses (particle-size and palaeoecological analyses) of the sediment cores are ongoing in order to better constrain our interpretation of the geochemical data.

**P-1468**

## **μXRF analysis of Lateglacial Swedish clay varves**

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### **Abstract**

One of the most widely recognised varve chronologies is the Swedish Timescale (STS). It is based on cross-correlation of numerous clastic varve series and provides an annually resolved record of Fennoscandian Ice Sheet retreat. However, the total number of varves in the STS is contested and several researchers have identified that there are “missing varves”, in particular 700-900 years are missing during the Younger Dryas - Pre-Boreal period (12.9-11.35 ka BP). One explanation for missing varves is a lack of precision in macroscale varve counts which are the traditional means of developing site varve chronologies. This emphasises the need to analyse STS varve records at the microscale however, microscale sediment analyses have not been routinely applied to these varved sediments. Whilst thin section analysis is commonly applied to varve records to generate precise varve chronologies, production is extremely labour-intensive and costly. This project explores the potential application of the much cheaper and non-destructive μXRF analysis as a glaciolacustrine varve counting tool using sediments from the STS.

We present the results of μXRF analysis of clastic varves from three Lateglacial/early Holocene records in Östergötland, Sweden. Principal Component Analysis of normalised μXRF data was used to determine which element ratios demonstrated the greatest variation and therefore were useful in detecting grain size changes between the coarse-grained (summer) and fine-grained (winter) lamination within a single varve. Element ratios were site-specific, reflecting local sediment sources within the Baltic Ice Lake basin. When compared to particle size analysis, X-radiographs, core surface images and thin sections, changes in μXRF element ratios (at 200 μm resolution) appear to mirror grain size changes within a single varve. However, varves counted under thin section were not consistently identified by μXRF element ratios due to the presence of thin laminations (<1 mm). For greater than 1cm-scale varves, there are 2-3% fewer varves counted from μXRF analysis than from thin sections. However, for <1 mm scale varves, the difference between thin section and μXRF counts can be as high as 40%.

The results demonstrate that μXRF analysis is effective at identifying grain size changes within cm-scale varves. However, varve count data demonstrate that thin section analysis is the most effective method for varve identification and counting. If continuous thin section analysis is not feasible within the time and cost constraints of the researcher, μXRF analysis, in combination with X-radiographs and core images, can be used to produce a minimum varve count. If feasible, targeted thin sections across a range of varve thicknesses should be produced to estimate the associated varve count error if μXRF analysis is the primary varve count method.

**P-1469**

## **Using high-resolution geochemical data from XRF core scanning to interpret major climatic events at the Uddelermeer site (The Netherlands)**

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### **Abstract**

High-resolution X-ray fluorescence (XRF) scanning data is used as a palaeoclimate proxy on a long sediment record retrieved from Lake Uddelermeer. Lake Uddelermeer is the only lake in The Netherlands to contain a continuous record of environmental and climate change from the late Pleistocene to present. Due to its unique character, the lake has been studied by various research groups since the 1950s. Here we focus on a newly retrieved sediment core which has been radiocarbon dated and for which a variety of palaeoecological and palaeoclimatological data is available. We scanned the 15.6 m sediment sequence at 200  $\mu\text{m}$  interval and geochemical proxies were utilised to infer changes in the lake system during major climatic events, and compared our results to existing palaeoecological and palaeoclimatological data from the same sediment sequence. Commonly used proxies such as Si/Ti can imply changes in biogenic silica and Rb/Sr can suggest chemical weathering. These proxies were looked at in detail in conjunction with the dates to confirm the timing and impact of the following major events: the Bølling-Allerød, Younger Dryas, Pre-boreal oscillations, the 9.3 ka, 8.2 ka, 2.8 ka and the Little Ice Age.

Additionally, the use of high-resolution XRF scanning can be very useful for finding crypto tephra, and in this presentation, we will explore the potential occurrence of the Vedde Ash (Iceland) and the Laacher See Ash (Germany) in the sediment sequence, as well as other unidentified crypto tephra during the Last Glacial termination.

**P-1470**

## **$\mu$ -XRF-inferred evolution of the Orakei maar paleo-lake (Auckland, New Zealand)**

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### **Abstract**

Late Quaternary lake sediment cores are important archives of past environmental and climatic change. Maars, lakes formed in volcanic craters, are phenomenal depositional basins thanks to the small size of the catchment. Thus, sediment at the lake bottom can be understood as a direct record of processes in the atmosphere and water column. An important aspect of paleoclimate reconstructions are changes in the geochemical composition of the sediment deposited in the lake.

Non-destructive  $\mu$ -XRF core scanning is an increasingly common and powerful technique for the study of Quaternary sediment sequences. Changes in the elemental composition of the sediment allows interpretation of the depositional processes and origin of the sediment.

The Orakei maar in the Auckland Volcanic Field (AVF) presents an outstanding, long and high-resolution record from northern New Zealand. The Orakei sediment sequence is a crucial window into the climatic past of the SW Pacific. Down-core elemental variations recorded by the  $\mu$ -XRF Itrax core scanner allow the reconstruction of the maar's evolution from the crater-forming phreatomagmatic eruption to a rim-breaching sea-water incursion in the early Holocene:

The local basement Waitemata sandstone is overlain by unconsolidated basaltic ejecta derived from the Orakei eruption resulting in a crater soon after filled by a lake. A small interval indicating a shallow lake with oxic conditions is overlain by finely laminated sediment with anoxic bottom water followed by an episode of common mass movement deposits from the crater rim identified by the geochemical signature of the basaltic eruptive material from the rim. Further alternating episodes of deep lake sediment and fast deposition from the crater rim are overlain by a multitude of locally-sourced (AVF volcanoes) basaltic tephra layers causing large-scale disturbance in the area which is reflected in the sediment deposited at the bottom of the Orakei maar lake. Low Fe/Mn indicating oxic bottom water is recorded during massive fine sediment and overlying greyish sediment with wavy laminations. A return to calmer depositional conditions is manifested in laminated sediment overlain by coarser fluvial sediment deposited by the Pourewa creek breaching the crater rim. The upper interval of the Orakei sediment sequence consists of sediment deposited in a shallow lake overlain by peat under anoxic conditions. On top of the peat follows marine mud deposited since the post-glacial sea-level rise which breached the Orakei maar crater wall and turned the lake into a tidal basin.

**P-1471**

## **Palaeoenvironmental insights from end-member modelling of high-resolution XRF core-scanning data**

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### **Abstract**

Lacustrine and marine sediments often record a complex history of environmental change. However, disentangling the different depositional processes leading to the signals of interest in a sediment record can be challenging. Recently, X-ray fluorescence (XRF) core scanning has become a standard technique in sediment-core processing, facilitating the generation of geochemical data sets down to a spatial resolution of 200  $\mu\text{m}$ . The resulting large data sets call for the application of statistical tools to identify and analyse different sedimentary processes interacting through time.

We present a study of sediments from Lake Towuti (2.75°S, 121.5°E), one of the oldest and deepest lakes in Indonesia. We combine high-resolution (0.5 cm) XRF core scanning of Lake Towuti sediments, covering the last ~1 million years, with an end-member modelling analysis to get an objective and quantitative description of the lithologies in our sediment sequence. End-member modelling is a statistical tool to unmix data into characteristic structures of -in this case- similar elemental composition. Analogous to grain-size analysis, where end-member modelling is more frequently applied, the underlying concept is that different sedimentary processes are reflected in characteristic elemental compositions, e.g. terrestrial influx is characterised by variations in Al and Ti concentrations.

For Lake Towuti sediments, end-member modelling of the XRF data set separates processes related to climate, diatom productivity, redox processes, post-sedimentary mineral formation, and tectonics. Sediment stratigraphy across the 100-m record based on the end-member modelling results generally matches the initial visual core description, but shows more detailed variations, particularly in the central part of the record. We show that the combination of high-resolution XRF core scanning with end-member modelling can serve as a tool to adequately extract the palaeoenvironmental narrative of sedimentary systems. Particularly in complex systems with multiple distinct sediment sources and significant changes in the depositional environment through time, end-member modelling is advantageous over more commonly used statistical methods applied to XRF data sets, such as clustering or principal component analysis (PCA).

**P-1472**

## **The potential of using $\mu$ XRF records to explore climate change during the Younger Dryas period: challenges in interpreting elemental data.**

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### **Abstract**

Investigation of the late Quaternary indicates that glacial terminations typically include abrupt millennial scale climatic changes, thought to play an important role in the mechanics of how deglaciations proceed. During the last deglaciation, the Younger Dryas (c. 12.9 – 11.7 ka BP) was a partial return to more glacial-like conditions across the North Atlantic region. Both the abrupt onset and rapid termination of the Younger Dryas have been the focus of palaeoclimate studies aiming to understand the cause and nature of these abrupt shifts in climate state.

Here we focus on Scotland, where the local expression of the Younger Dryas, the Loch Lomond Stadial (LLS), resulted in the growth of an ice-cap covering much of the Western Highlands and local valley glaciation in the eastern uplands. The timing of the advance and retreat of this ice-cap is the subject of much debate, with estimates for the onset of recession ranging from the mid-stadial (12.5 ka cal BP) to the very early Holocene (11.7-11.5 ka cal BP). The early deglaciation estimates are thought to be driven by the establishment of relatively warm dry summer temperatures leading to ice recession, while the late deglaciation hypothesis argues for the predominant signal in glacier advance being driven by changes in the precipitation-bearing westerly wind systems. In order to examine these competing hypotheses, high-resolution sites that are spatially comprehensive and beyond the LLS glacial limits are required alongside a range of palaeoenvironmental proxies which provide temperature and/or precipitation data. Several such sites exist across the region and these contain one or more proxies of temperature, but also require a detailed understanding of the sedimentary context which may in turn reveal information regarding landscape stability.

$\mu$ X-ray fluorescence ( $\mu$ XRF) scans provide semi-quantitative down-core variations in a number of elements. These data have been used to understand how lake characteristics may have changed through time, with elemental variations acting as a proxy for a number of different environmental variables e.g. lake productivity, catchment erosion, and turbidity. These indicators are thought to reflect periods of stability and instability within lake systems and are ultimately linked with climatic variability particularly changes in snow melt and storminess. Here we present new  $\mu$ XRF data from 5 lake sites across Scotland to explore the propagation and variability of environmental changes during the LLS, and to further examine the rapidity of environmental changes towards the end of the Last-Glacial Interglacial Transition. These records are paired with existing palaeoecological proxies to also assess the effect of site-specific sedimentological changes and whether these clarify or obfuscate the regional expression of climatic change.

**P-1473**

## **Interpreting XRF-derived CaCO<sub>3</sub> records from the Agulhas Plateau during the past 150 ka: Surface ocean calcareous productivity vs CaCO<sub>3</sub> dissolution**

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### **Abstract**

Past variations of the Atlantic meridional overturning circulation are believed to have affected Pleistocene climate change by altering the patterns of oceanic heat transport (e.g., Lynch-Stieglitz et al., 2007, *Science*; Adkins, 2013, *Paleoceanography*) and by changing the quantity of respired carbon stored in the deep ocean (e.g., Freeman et al., 2016, *Nature Communications*). During glacial intervals, northern-sourced Atlantic deep waters are thought to have shoaled while southern-sourced deep waters expanded to fill a larger proportion the abyssal and deep ocean (e.g., Curry and Oppo, 2005, *Paleoceanography*; Marchitto and Broecker, 2006, *Geochemistry Geophysics Geosystems*). Differences in the carbonate ion concentration of northern- and southern-sourced deep waters result in changes in the carbonate saturation state of the ocean and variable preservation of CaCO<sub>3</sub> on the seafloor on glacial-interglacial timescales. Stratigraphic records of CaCO<sub>3</sub> can therefore act as a proxy for past changes of deep ocean circulation.

We present XRF core scanning data from sediment core MD02-2588 which was recovered from a calcareous contourite drift located on the southwestern flank of the Agulhas Plateau (41°19.90'S, 25°49.40'E, 2907 m water depth). Today, the core site underlies the Southern Ocean Subtropical Front and is situated within the transition zone between North Atlantic Deep Water and Circumpolar Deep Water. We examine the XRF data alongside records of bulk sediment geochemistry and stable isotopes and elemental ratios measured in foraminifera.

We find that the XRF-derived Ca record of sediment core MD02-2588 closely matches the downcore record of calcium carbonate content. Bulk sediment CaCO<sub>3</sub> content is controlled by a complex interaction between various environmental drivers, including surface ocean calcareous productivity, CaCO<sub>3</sub> dissolution on the seafloor, and dilution by other sediment components. In this study, we attempt to determine the relationship between CaCO<sub>3</sub> content, bottom water carbonate saturation state and surface ocean productivity at the MD02-2588 core site during the last 150 ka. We then examine XRF-derived Ca records from a suite of neighbouring sites to develop a regional interpretation of the temporal and spatial variability of surface ocean productivity and bottom water carbonate saturation state in the context of regional and global climate change.

P-1474

## Fe and Mn in lake sediments: spatiotemporal patterns and potential for redox reconstructions - a multicore study from Lake Łazduny (Poland)

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### Abstract

Changes in water oxygenation, especially recently emerging hypolimnetic anoxia, are potential threats for aquatic environments. Understanding past water mixing regimes is an important tool for mitigation of such human-induced changes. The utilization of geochemical proxies of past water-column oxygenation such as variations of the Fe and Mn content in lacustrine sediments is often limited due to their complex relationships with allochthonous inputs. These relations vary within different locations in the same basin. We use 31 surface cores from small and deep Lake Łazduny (Masurian Lakeland, NE Poland) to study spatiotemporal changes of selected elements to see if Fe and Mn concentrations are suitable proxies of past water oxygenation. Ongoing limnological monitoring (water column temperature and oxygen concentrations) indicates that the lake is either dimictic, monomictic or meromictic depending on the annual weather conditions. Sediment cores collected from different depths across the basin indicate that varves are preserved at depths greater than approximately 14 m. All the cores were analyzed with a  $\mu$ XRF scanner to trace their elemental composition. A Robust Principal Components Analysis (RPCA) was performed on the  $\mu$ XRF data to assess the internal relationships between elements. Additionally, material from the topmost 1 cm of the cores was used for the geochemical characterization of the surface sediments to determine spatial relationships between different components. Bulk elemental composition of these samples were measured by  $\mu$ XRF analysis and with an elemental analyzer (CNS). Additionally, biogenic silica concentrations were determined. RPCA suggests that both Fe and Mn are mostly independent from the terrestrial inputs, as correlation with erosion proxies such as Ti or K is only incidental with no apparent depth-related pattern. Accumulation of allochthonous elements (Ti, K) are highest near the lake shores, while redox-dependent elements (Fe, Mn) dominate in the deeper parts of the lake despite low oxygen concentrations. This could be an effect of sediment focusing towards the deeper parts of the lake, where even low amounts of oxygen could prevent net loss of Fe and Mn. In this study we show that the interpretation of geochemical proxies could be challenging or misleading if spatial patterns between geochemical proxies are not known.

**P-1475**

## **Disentangling climate and human factors in the settlement of the Maori in the North Island of New Zealand**

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### **Abstract**

Based on archaeological evidence, Maori landed on New Zealand around 700-800 cal BP. However, what caused Maori migration is still an open question and still has no direct evidence: was it the search of new resources brought about by human exploitation? Or was it climate induced? The cause could also be a human-climate-environment nexus.

Here we present down core leaf wax carbon and hydrogen isotopic record coupled with XRF data (Ti), Loss-on-ignition (LOI) based total organic carbon (TOC) and geophysical data (Magnetic Susceptibility) from Lake Pupuke in the North Island of New Zealand, spanning the past ~1700 years.

Ti showed an almost constant trend from 160 cm to 70 cm (~1700 to 700 yrs cal BP) then an overall varying increasing trend towards 15 cm (~200 yrs cal BP). It then showed an abrupt drop towards the top. Likewise, MS counts showed a slight overall decreasing trend from 160 cm to 70 cm (~1700 to 700 yrs cal BP) and then an overall varying increasing trend towards 15 cm (~200 yrs cal BP) similar to Ti. LOI based TOC showed an elevated concentration from 160 cm to 70 cm (~1700 to 700 yrs cal BP) compared to concentration from 70 cm (700 yrs cal BP to present) to the top of the core. LOI based TOC mirrors its overall trend of MS all through out the core.

The opposing overall varying increasing trends of Ti and MS data versus LOI based TOC from 70 cm to the top (700 yrs cal BP) may imply contributions from anthropogenic and climate-induced changes. Leaf wax carbon and hydrogen isotopic record would further our interpretation of the down-core data for the climate. These sedimentary footprints will help us to further define factors that triggered the arrival of early Polynesians on the North Island of New Zealand as well as possible implications of concurrent climatic changes.

P-1476

## **Tephra and cryptotephra in the Ross Sea, Antarctica marine deposits, correlated with rapid, non destructive magnetic susceptibility and XRF fluorescence methods.**

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### **Abstract**

Marine sediment sequences may contain deposits produced during large explosive volcanic eruptions i.e. tephra. These materials usually dispersed over regional to continental-scale areas, are isochronous marker horizons and can provide important time-stratigraphic information if geochemically fingerprinted and tied to a known, dated eruption, or used as cross-correlated time horizons between natural records, offering an accuracy difficult to achieve with other methods. Usually macroscopic/visible tephra are recognizable during the visual description of the sediment sequences by variation in sediment color or texture.

Sometimes volcanic ash is dispersed in the sediment records and does not form a continuous distinct horizon. These deposits known as cryptotephra, occur as layers of very fine ash (tens of  $\mu\text{m}$ ) and offer the opportunity to register also smaller eruptions, and eruptions from more distal sources.

Cryptotephra could be identified using several different methods, most of which are time-consuming and sample destructive. Here we present an application of rapid, and non destructive scanning techniques (XRF core scanning and Magnetic Susceptibility), in order to recognize cryptotephra in marine distal sediment sequences, from the continental shelf of the Ross Sea (Antarctica). Sediments gravity cores has been collected in the framework of Italian PNRA TRACERS Project (TephRoChronology and mArker events for the CorrElation of natural archives in the Ross Sea, Antarctica) that aims to identify, characterize in detail (sedimentological characteristics, texture, mineral phases, geochemical fingerprint) tephra as potential regional markers.

Victoria Land has been the site of intense and recurrent volcanic activity since 500 ka which resulted in the deposition of several discrete tephra in sediment sequences from Drygalsky basin off the Victoria Land coast. The volcanoes of the Melbourne Volcanic Province are considered the most likely sources for these tephra layers on the basis of volcanological, geochemical and age constraints.

High resolution Magnetic susceptibility and XRF scan of sediment cores allowed us to recognize for the first time cryptotephra layers also in more distal basin (Joides Basin). Sediment cores (ca 6-8 m long) were run through the Avaatech XRF (3rd generation) core scanner at the Italian CNR- Ismar Institute with a sample spacing of 1 cm, at 10, 30 and 50 kV to obtain semi-quantitative geochemical composition. Magnetic Susceptibility was measured with 2 cm of resolution, using a Bartington MS2 system with loop sensor to acquire the concentration of ferromagnetic component.

In particular, the ratios of light element (Fe/K, Ti/K, Ti/Ca, Mn/Ca, Cu/K and Si/Ca) proved to be the most useful to mark the cryptotephra.

P-1477

## Drilling for insight on long-term ice history and landscape evolution in Antarctica with cosmogenic nuclide depth profiles

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### Abstract

The volume of the Antarctic Ice Sheet has varied greatly during glacial-interglacial cycles and with changes in global climate over millions of years. Many nunataks exposed above the ice sheet today have been periodically buried by ice, but have not been significantly eroded by it. These surfaces are problematic for typical exposure age studies that aim to date the most recent bedrock exposure because they contain nuclides inherited from exposure prior to the most recent glaciation. However, these surfaces do offer the possibility to explore a much longer history of ice cover, exposure and erosion, which can be exploited by measurement of noble gases and radioactive cosmogenic nuclides. Here, we present results from a pilot study conducted in the Ellsworth Mountains, West Antarctica. Cosmogenic <sup>26</sup>Al, <sup>10</sup>Be and <sup>21</sup>Ne concentrations were measured at six depths within a 2 m-deep core extracted from an ice-moulded bedrock surface ~100 m above the ice margin. The data indicated a multi-cycle exposure-burial history, and so the global marine isotopic record of climate change was employed as a basis for modelling an exposure-burial history that was compatible with the <sup>26</sup>Al, <sup>10</sup>Be and <sup>21</sup>Ne concentrations. The modelling constrains a  $\delta^{18}\text{O}$  threshold for glaciation at the site, and indicates the bedrock was first exposed 3.5-5.1 Ma, and when exposed it eroded subaerially at a low rate of 1.5 m Ma<sup>-1</sup>. The data indicate the warm-based glacial erosion of the bedrock occurred before the Quaternary, rather than during more recent glacial cycles. Future applications of this approach will be discussed in light of the pilot study results, with a view to understanding the potential of the technique to constrain long-term ice volume changes and landscape evolution in Antarctica.

**P-1478**

## **Simulated land ice: latitudinal changes (0-2 Ma) and importance of CO<sub>2</sub>-glaciation divergence during times of decreasing obliquity (0-800 ka)**

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### **Abstract**

Following Milankovitch's theory the incoming insolation or summer energy at 65°N is typically analysed to predict the waxing or waning of land ice. We here use a model-based deconvolution of the LR04 benthic-d18O stack into land ice distribution (de Boer et al., 2014, Köhler et al., 2015) to verify if the latitudinal focal point of land ice dynamics has changed over the last 2 Myr or whether this choice of 65°N in orbital data is indeed well justified. We find that the 5°-latitudinal band which contributes most to land ice albedo radiative forcing ( $\Delta R_{[LI]}$ ) is 70-75°N between 2.0-1.5 Myr, which is then until 1.0 Myr gradually substituted by 65-70°N. During the last 1 Myr both 60-65°N and 65-70°N dominate  $\Delta R_{[LI]}$  and contribute approximately the same amount, while the relative importance of 70-75°N is shrinking. Our analyses illustrates that the choice of 65°N seems for the last 1 Myr to be well justified, while for earlier parts of the last 2 Myr the dominant land ice changes seems to have happened up to 10° further to the north.

Focusing on the last 800 kyr (the time for which precise data on atmospheric CO<sub>2</sub> concentration exists) we furthermore find that the multi-millennial land ice growth and proxy-based reconstruction of global cooling (= the glaciation) appear synchronously to each other and to decreasing obliquity, but diverge from CO<sub>2</sub>. This suggests that the global cooling associated with Earth's way into an ice age as deduced in the reconstructions has to be mainly caused by the land ice albedo feedback, and is not dominated by the CO<sub>2</sub> greenhouse gas radiative forcing. One way of perceiving this CO<sub>2</sub>-glaciation divergence in the reconstructions is that the reduced incoming insolation at high latitudes during phases of decreasing obliquity causes land ice growth (= sea level fall) and cooling, while there is a coexisting process that keeps CO<sub>2</sub> at a relatively constant level. Solid Earth modeling experiments have indicated that falling sea level might lead to enhanced marine volcanism (enhanced magma and CO<sub>2</sub> production) at mid-ocean ridges and at hot spot island volcanoes which might be a potential cause for this CO<sub>2</sub>-glaciation divergence (Hasenclever et al., 2017).

This CO<sub>2</sub>-glaciation divergence needs to be considered, when using paleo data to quantify paleoclimate sensitivity: periods with diverging CO<sub>2</sub> and global temperature change should be filtered out when approximating the relationship between global temperature rise and CO<sub>2</sub> concentrations (Köhler et al., 2018).

### References:

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Köhler et al. (2015). <https://doi.org/10.5194/cp-11-1801-2015>.

Hasenclever et al. (2017). <https://doi.org/10.1038/ncomms15867>.

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**P-1479**

## **A conceptual model of the causes of a varying Eurasian ice sheet size during past glaciations**

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### **Abstract**

Varying fluxes of iceberg-rafted debris (IRD), as recorded in polar-subpolar marine sediment cores from the western European margin (British Isles to Fram Strait), provide ample evidence for the large-scale waxing and waning activity of ice sheets during major glaciations of the past 0.6 Ma. These marine data of iceberg discharge rates point to significant temporal changes in ice-sheet coverage over the NW Eurasian continent. A clear, stepwise decrease in IRD delivery is noted for the last 3 major glaciations (Elsterian/MIS12, Saalian/MIS6, Weichselian/MIS2-5), which matches well the pattern recognized on land, i.e., the southern and western spatial extents of moraines. By contrast, the North Eurasian shelf edge (Barents/Kara seas) remained rather inactive for a long time starting to deliver IRD into the adjacent Arctic Ocean only during Saalian times. This latter finding is somewhat at odds with field evidence from southern and eastern Russia where the existence of several major glaciations predate both the Weichselian and the Saalian. This asymmetry in terrestrial glacial development between the Arctic and the regions farther south calls for a systematic migration of southern glaciation limits towards the north on the one hand, and with it, for a western and northern shift of major glaciation centers on the other. These spatial shifts were likely forced by major changes in oceanic heat transport which essentially influenced the pathways of atmospheric moisture transfer thereby leading to the systematic changes of the Eurasian ice sheet since mid-Pleistocene times.

**P-1480**

## **Using the history of the Antarctic Ice Sheet to reduce uncertainties in projections of global sea level rise**

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### **Abstract**

Ice sheet models are the most descriptive tools available to simulate the future evolution of the Antarctic Ice Sheet (AIS), including its contribution towards changes in global sea level. However, our knowledge of the dynamics of the coupled ice-ocean-lithosphere system is inevitably limited, in part due to a lack of observations. Furthermore, to build computationally efficient models that can be run for multiple millennia, it is necessary to use simplified descriptions of ice dynamics. Ice sheet modelling is therefore a poorly constrained exercise. The past evolution of the AIS provides an opportunity to improve the description of physical processes within ice sheet models and, therefore, to constrain our understanding of the role of the AIS in driving changes in global sea level.

We use the Parallel Ice Sheet Model (PISM) to demonstrate how past changes can be used to improve our ability to predict the future evolution of the AIS. A large perturbed-physics ensemble is generated, spanning uncertainty in the parameterisations of key physical processes within the model. A Latin hypercube approach is used to optimally sample the range of uncertainty in parameter values. This perturbed-physics ensemble is used to simulate the evolution of the AIS from the Last Glacial Maximum (21,000 years ago) until 5,000 years into the future. Records of past ice sheet thickness and extent are then used to determine which ensemble members are the most realistic. This allows us to use the known history of the AIS to constrain our understanding of its past contribution towards changes in global sea level. Critically, it also allows us to determine which ensemble members are most likely to generate realistic projections of the future evolution of the AIS. This enables us to use past changes in the AIS to reduce uncertainty in projections of future sea level rise.

**P-1481**

## **Timing and Rate of Deglaciation of the MIS 2 Cordilleran Ice Sheet in Yukon Territory, Canada**

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### **Abstract**

The northern Cordilleran ice sheet (CIS) consisted of a series of quasi-independent ice lobes that coalesced during the last glacial maximum (LGM) to form a continuous carapace of precipitation limited ice over southern Yukon. Deglaciation of the northern margin of the CIS and its rate of recession from the LGM are poorly understood. We use cosmogenic nuclide exposure dating (10Be and 36Cl) on groups of 3-4 glacial erratics to reconstruct the timing and rate of deglaciation. Our sampling concentrated on the St. Elias, Cassiar and Selwyn lobes, as well as an independent glaciers in the Ogilvie Mountains and Ruby Range.

Boulders sampled up-ice from terminal moraines show that the initiation of deglaciation varied regionally. 36Cl ages from the Ogilvie Mountains indicate that deglaciation initiated by ca 23 ka. Deglaciation of the NCIS initiated first in the Coast Mountains and St. Elias lobes at 18.2 and 17.4 ka, respectively. Deglaciation of the Cassiar lobe initiated before 16.4 ka. For the Selwyn Lobe, two sites separated by ~150 km returned ages of 15.3 and 16.5 ka.

Rates of deglaciation are best constrained for the Cassiar Lobe with two transects along different flow lines. Multiple valley bottom samples in the mid-deglaciation setting at Whitehorse yielded ages of 13.7 ka, while one boulder from the adjacent ridge top 600 m above is 15.4 ka. In the accumulation zone, ice-free conditions occurred by 12.1 ka. The other transect has higher elevation samples in a mid-deglaciation setting in the Pelly Mountains that indicate deglaciation occurred by 13.7 ka. Samples taken from high elevation and valley bottom sites close to accumulation zones of the Cassiar Lobe yielded ages of 13.4 and 10.8 ka, respectively, indicating ice persisted in valley bottoms much longer than uplands.

These results provide a chronology for the style of deglaciation interpreted from regional mapping throughout Yukon: gradual initial retreat and thinning marked by moraines, followed by rapid downwasting and regional stagnation. Thinning of the ice to expose uplands in the Cassiar lobe was coincident with margin retreat. The increase in rates of deglaciation after 14 ka fits well with mapped evidence of regional stagnation. Early animal, and possibly, human migrants could have traveled along the uplands as these became ice free first. Early deglaciation of the Ogilvie Mountains may be a result of moisture starvation due to the Laurentide Ice Sheet reaching its all time maximum in the western NWT.

P-1482

## Combining state-of-the-art ice flow and regional climate modelling to reconstruct the Alpine Ice Sheet of the Last Glacial Maximum

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### Abstract

Ice flow modelling studies targeting the last glaciation of the European Alps have so far relied on present-day precipitation and temperature pattern and seasonality. These studies yield interesting insight to the dynamics of this former ice cap. However, the modelled maximum ice extent is inconsistent with geomorphological reconstructions based on terminal moraines. More precisely, the ice flow models systematically overestimate the ice extent in the north-east of the Alps and at the same time underestimate it in the south-west. Furthermore, the modelled flow directions are inconsistent with the depositional locations of erratic boulders with known origin, in particular those carried by the Valais Glacier. Recently, output of a global climate model run for Last Glacial Maximum (LGM, 20,000 year before present) conditions has been downscaled to a resolution of 2x2 km over the European Alps with a regional climate model. This offers, for the first, time the opportunity to drive an ice flow model with a high-resolution climate forcing that is truly representative for this period.

Here we present some simulations of the Alpine Ice Sheet around the LGM utilizing this novel climate forcing. To model the ice flow and mass balance of the ice sheet, we use the Parallel Ice Sheet Model (PISM), which is a state-of-the-art ice sheet model. As only the climate at the LGM is available, we emulate a transient climate by applying a time-dependent temperature offset deduced from the EPICA ice core. We compare the modelled ice sheets with geological evidence such as terminal moraines and trajectories of erratic boulders. Preliminary results show that the new LGM climate forcing yields notable improvements between modelled and reconstructed ice extents. In particular, the ice distribution between south-west and north-east is significantly improved when compared to former simulations employing a climate forcing derived from present-day climate.

P-1483

## Plio-Pleistocene exposure histories from Dronning Maud Land, Antarctica, indicate general ice sheet thinning and dynamic decoupling across the Heimefrontfjella escarpment

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### Abstract

Dronning Maud Land (DML) represents a critical gap in the empirical data collected for reconstruction of the East Antarctic Ice Sheet (EAIS). MAGIC-DML is an international collaboration with a focus on filling this data gap and reconstructing the timing and pattern of ice surface changes on the western DML margin using field data and ice sheet modeling. The ice-sheet margin in DML is characterised by a prominent escarpment about 200 km inland from the grounding line. The near-vertical cliffs of this escarpment constitute a major barrier between the polar plateau ice (Amundsenisen) and the downstream ice (Ritscherflya), resulting in up to 500 m differences in ice surface elevations. This topographic barrier causes substantial challenges for both empirical ice sheet reconstructions and ice sheet models. Within MAGIC-DML, 35 samples were collected from stable bedrock surfaces and isolated erratics for cosmogenic nuclide surface exposure dating along a coast-inland transect running roughly perpendicular to the escarpment at its westernmost extent in DML.

Here we present <sup>10</sup>Be, <sup>26</sup>Al and <sup>21</sup>Ne results from these samples. The highest-elevation bedrock samples yield <sup>10</sup>Be and <sup>21</sup>Ne concentrations indicating steady exposure in excess of 3 Ma, indicating that the ice sheet has not overridden the escarpment edge at those sites since at least the Pliocene. The dataset also contains Holocene apparent <sup>10</sup>Be ages (6.9 ka and 4.3 ka) for erratics collected ~30 m above the present-day ice on a nunatak situated ~150 km downstream of the escarpment. We link the wide spread, and spatial variation in apparent exposure ages to the distinctly different topographic settings of our sample sites. The results highlight a decoupling of the ice sheet dynamics above and below the escarpment which has persisted throughout the Quaternary. This decoupling presents a significant challenge in the ice sheet reconstruction and highlights the need for the integration of cosmogenic nuclide results with ice sheet models in this region, and elsewhere along the Antarctic margin.

P-1484

## Timing and causes of MIS 4 and MIS 3 glacial advances in South Island, New Zealand

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### Abstract

This poster summarises information on the timing and possible causes of glaciation in New Zealand prior to the LGM (26.5-19 ka). We recognise five regionally identifiable advances in MIS 4 and MIS 3 in South Island, NZ, including one which may mark the start of the LGM, but may also precede it. These advances, all secured by CRN and/or luminescence chronologies, occurred at  $65 \pm 3$  ka,  $47.5 \pm 3$  ka,  $38.5 \pm 2$  ka,  $31.5 \pm 3$  ka, and at  $26.5 \pm 2$  ka. Not all advances have clear linkages to climate but some are coincident with periods of Southern Hemisphere insolation minima (65ka, and 31.5 ka advances), while another occurs during a notably cold phase (38.5 ka) and precipitation may play a role (65 ka and 26.5 ka advances). The timing of greatest glacial extent in the last glacial cycle is not simultaneous across New Zealand. The MIS 4 advance was the greatest in the southern South Island, while the MIS 3/2 advances (26.5-25 ka) were greatest in the central South Island. We attribute these spatio-temporal changes in the timing of maximum glaciation to precipitation changes related to a northward shift in the track of the southern-hemisphere westerlies.

Ref: Shulmeister, J., Thackray G.D., Rittenour T.M., Fink, D., Patton, N.R. 2019. The timing and nature of the last glacial cycle in New Zealand. *Quaternary Science Reviews* 206:1-20.

P-1485

## Late Pleistocene deglaciation history of the SW British Isles: New evidence from Lundy and the Outer Bristol Channel

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### Abstract

The SW British Isles was glaciated by the British-Irish Ice Sheet during the Late Pleistocene. Glacial deposits are widely preserved in the Bristol Channel and are revealed in boreholes and geophysical data. Lundy, an island in the Outer Bristol Channel, displays unique terrestrial evidence of glaciation in the Outer Bristol Channel. The evidence is dominated by erosional evidence of ice-scouring, although there are wide spreads of erratic cobbles and pebbles several of which contain evidence of striae and faceting. In addition, subsurface thick silt-clay deposits are common on the island with clay mineralogy indicating limited weathering, in contrast to occasional pockets of strongly weathered granite (growan). These deposits are interpreted as subglacial in origin. Offshore of Lundy, especially to the E and NE, geophysical data reveals the presence of thick glacial deposits and dense fields of boulders. This suggests that an ice limit occurred between Lundy and the mainland. This allowed the drainage of the proto-Severn to drain between this ice limit and the mainland in Devon, and the course of this palaeochannel can be traced in bathymetry and geophysical survey data.

Periglacial activity after deglaciation is recorded by the presence of coversands, loess, ventifacts, scree slopes and associated colluvial deposits. Luminescence ages from colluvial sands on Lundy date to 24-26 ka indicating that this island was deglaciated by marine isotope stage (MIS) 2. This is consistent with deglaciation and exposure of the island in MIS 3 following glaciation in MIS 4 or possibly earlier. Previously obtained exposure ages from ice-scoured bedrock surfaces have been recalculated using the most recent production rate models and support this interpretation. In addition, a new programme of cosmogenic exposure dating of glacially-transported boulders and displaced tors will further test the previously obtained exposure age data from glaciated bedrock surfaces. In contrast to other weathered granite surfaces in the British Isles, Lundy has not experienced a prolonged weathering history through multiple glacial cycles. Whilst the precise timing of deglaciation is undergoing further testing, the current evidence overwhelmingly indicates that Lundy was eroded by an ice sheet during the Late Pleistocene. Morphometric analysis of weathering pits in the ice-moulded granite bedrock on Lundy supports this exposure history as do the OSL ages from sands overlying the bedrock surfaces. Evidence from elsewhere around the Celtic Sea indicates that the glaciation of Lundy most likely occurred in MIS 4 with ice retreating in MIS 3. However, during MIS 2 ice reached to the continental shelf in the Celtic Sea. This apparent paradox may be explained by a highly mobile Irish Sea Ice Stream which changed its configuration in response to fluctuating marine incursions in MIS 3 before exploiting the exposed continental shelf to the southwest during MIS 2.

P-1486

## Quaternary glacial activity in Iberian mountain ranges

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### Abstract

In the Iberian Peninsula, currently there are only small glaciers in the Pyrenees, but their number and extent has experienced large changes over the Late Quaternary. The existence of a wide range of glacial landforms and deposits across different Iberian mountain ranges is indicative of the occurrence of periods in the past with extensive glaciers covering large areas. We have reviewed all available absolute dates concerning the glacial activity in the Iberian mountains during the Late Quaternary, homogenizing the surface exposure dates following the most recent standard procedures with the purpose of summarizing the current knowledge on the spatial and temporal patterns of glacial activity. The chronological framework was divided in six periods: glaciations prior to the Last Glacial Cycle, Last Glacial Cycle, Termination-1, Holocene, Little Ice Age (LIA) and present-day. The data were geographically divided considering the mountain systems where glacial evidence exists: Pyrenees, Cantabrian Range, NW ranges, Central Range, Iberian Range and Sierra Nevada. During cold phases, more or less ice was stored depending on the combination of temperatures and moisture conditions. The ice accumulated in the head valleys and glaciers flowed down-valleys, but did not reach the surrounding lowlands. In some massifs, there is evidence of Middle Pleistocene glaciations, one potentially correlating with marine isotope stage (MIS) 12 and another correlating with MIS 6 with glaciation dated to ca. 130-170 ka. However, most glacial records correspond to the Last Glacial Cycle and subsequent Termination. The maximum glacial expansion of this glaciation occurred well before the global Last Glacial Maximum (LGM) between 30 and 60 ka in the Cantabrian Mountains and Pyrenees, at ca. 30 ka in Sierra Nevada and NW ranges, and (almost) synchronously to the LGM in the Central Range and Iberian Range. A massive glacial retreat occurred in all Iberian mountain ranges at 19-20 ka. The long-term deglaciation was interrupted by two cold periods, such as the Oldest and Younger Dryas, which favoured glacial expansion in the highest mountains. Higher temperatures recorded at the onset of the Holocene favoured the melting of glaciers, which only reappeared in the highest massifs during the coldest phases, such as the LIA. However, post-LIA warming started by 1850 led to glacier disappearance in the Cantabrian Mountains, Sierra Nevada and most massifs of the Central Pyrenees, together with an accelerated shrinking of the small glaciers still existing in this range at elevations near 3000 m.

P-1487

## A cosmogenic glacial chronology of Lake Judd, southwest Tasmania and latitudinal shifts in the Roaring Forties

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### Abstract

Limited attention has been paid to the glacial history of Tasmania (40-44 S). At the northern limits of today's Westerly storm track (the Roaring Forties), it experiences precipitation changes due to shifts in the Southern Annular Mode and ITCZ. Cosmogenic dating in southwest Tasmania (Kiernan 2010) highlights the marginal nature of its glaciation where small precipitation or temperature changes cause large changes in mass balance. This makes southwestern Tasmania an excellent location to study Westerly flow through the Last Glacial Cycle. The prevailing idea is that during glacial times, Westerlies expand northward to lower Southern Ocean latitudes, delivering increased rainfall to Tasmania, whilst during interglacials, their migration polewards reduces precipitation. Somewhat counterintuitively, from a Tasmanian perspective of increased Westerly circulation and wind strength, maxima glaciation should coincide with peak global glacials. Although well preserved, extensive last glacial cycle moraine sequences are not common, a series of more than 20 terminal moraine ridges have been mapped over 3 km concentric with the southern margin of Lake Judd, in the SW wilderness corner of Tasmania. Morphologically, the Lake Judd sequence is believed to represent three phases; pre MIS-6, MIS 5-3 and MIS 2 (LGM), representing substantially different volumes of ice accumulation. Our first field campaign collected 16 dolerite samples (<sup>36</sup>Cl) from the three innermost concentric moraines adjacent to lake edge and 4 quartzite (<sup>10</sup>Be, <sup>26</sup>Al) samples from the most distal moraines. Our aim is to test correlation of the long-term glacial history with records of westerly fluctuations from NZ speleothems (Whittaker et al., 2011) to determine whether the latitudinal variation in Westerly winds in the Australasian region are zonal during glacial times as they are demonstrated to be in interglacial intervals (Fletcher and Moreno, 2012). Preliminary exposure age calculations on the full set of 20 samples are in poor agreement with Kiernan's age associations. The <sup>10</sup>Be (and <sup>26</sup>Al) ages on the distal moraine indicate a most probable MIS 4/5 affiliation (>50 ka), significantly younger than expected. In contrast, the 16 dolerite samples from the 3 innermost proximal moraines at lake edge gave a complex set of ages that ranged from MIS 3 to MIS 4 affiliation (45-25ka), somewhat older than predicted. To add further complexity, these 16 ages show no intra or inter moraine age trends with respect to their morphologic positions and ice flow direction. These results contrast with those from other Tasmanian glacial records and reveal the need for a concrete effort to apply cosmogenic exposure dating to the numerous glacial deposits already mapped throughout Tasmania.

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*Fletcher and Moreno, Geology v39(2012).*

*Kiernan, Fink and McConnell, QSR, v157( 2017)*

*Toggweiler Science, v323 (2009).*

*Whittaker et al Geology, v39(2011).*

P-1488

## Glacial advance and retreat during MIS 3 in Picos de Europa (Spain) evidenced by cave sedimentation and paleontological remains

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### Abstract

In calcareous mountains, karst caves preserve information about glacial evolution, delimiting its advances and retreats temporal and spatially. In the SW of Europe, Picos de Europa mountains with 2650 m maximum altitude is included in the Cantabrian Mountains-Pyrenees chain. Pleistocene glaciers occupied an extension of ~180-190 km<sup>2</sup> in Picos de Europa, with a local maximum around 45 ka and a subsequent general retreat after 37-39 ka, before the LGM advance. Our study aims to quantify this glacial advance and retreat based on sedimentary and paleontological record in karst caves. The study cave is located in the glaciated area around the Covadonga Lakes, a reference location for glacier research in the northern Iberian Peninsula. The study combines cave geomorphology, five OSL ages and two AMS radiocarbon dates, allowing us to define two alluvial sedimentary sequences: 1) a first sequence deposited at 84-65 ka, and 2) a second sequence deposited 36 ka ago. Both sequences present remains of fauna that is not adapted to cold environments, as those covered by glaciers. The remains corresponds to fragments of dental enamel of Arvicolinae, and bones of chamois (*Rupicapra pyrenaica*) dated in 34-32 ka cal. All this evidence allows us to conclude that: 1) after 65 ka, glacial fronts descended more than 450 m in vertical range in less than 20 ka and 2) glacier retreat began at 45-36 ka and the altitude of the glacier fronts rose more than 350 m in less than 9 ka, coevally with the second half of the MIS 3.

P-1489

## Continental sediments and the MIS-3 in mid-latitudes of South America (Uruguay): faunal records, paleoclimatic and environmental features

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### Abstract

MIS-3 evidences from continental beds in South America are few and loosely dated. Fluvial sediments and paleosoils developed in northern Uruguay (the Sopas Formation) produced a  $^{14}\text{C}$  AMS (fresh-water mollusk shells) and OSL set (15 samples) of ages encompassing the  $33,560 \pm 700$  yrs BP (cal 36,089 – 39,426 yrs) to  $39,900 \pm 1,100$  (cal 42,025 - 45,389 yrs) and OSL ages from  $27,400 \pm 3,300$  to  $71,400 \pm 11,000$  yrs (being more represented the 45-28 ka time interval). A correlation with the Marine Isotopic Stage 3 (MIS-3, 60-25 ka) seems to be confident. This unit outcrops in northern Uruguay alongside creeks and rivers with a patchy pattern of distribution. It yields medium-coarse sandy and conglomerate basal levels belonging to fluvial facies overlaid by brownish mudstones and siltstones related to floodplains deposits and paleosoils including bioturbation. The ongoing analysis of the faunal content could help to characterize this interval of time at these latitudes. It includes trace fossils, woods, fresh-water mollusks and vertebrates with mammals being the predominant taxon with more than 50 species recorded belonging to ca. 25 families. In the fossil assemblage are taxa related to open habitats, savannahs and woodlands including gallery forests and perennial rivers. Among the extinct taxa are indicators of open to semi-open environments, such as some glyptodonts, ungulates such horses, toxodontids and litopterns, among others. Living representatives of taxa indicate mostly tropical to temperate climates along with some taxa that suggests arid to semiarid environments (tapirs, coendus, coypus, capybaras, river-otters, some peccaries, some caviids, ocelots, and marsh-rats). In addition, seasonality indicators are also registered like southern bird migrants and worm aestivation chambers. This climatic and environmental pattern could have been modeled by millennial climatic changes that were prevalent in the MIS-3. The presence in the mammalian assemblage of tropical to subtropical representatives is difficult to explain under the postulated climatic characteristics of the MIS-3, which is in fact colder than the Last Interglacial and the current time. In order to explain this pattern could be invoked a replacement faunal model or alternatively a mixed faunal model, which is discussed here. The survival of these tropical to temperate mammals during the MIS-3 at this latitude could have been caused by the presence of refuge areas (perennial rivers, riparian forest and semi-forested areas) performing a mixed fauna. In fact, heterogeneous biomes in the Neotropical Region of South America have expression in the recent such as the “Cerrado” (southeastern Brazil). It is characterized by a mosaic of environments (open habitats, savannahs and dense woodlands including gallery forests alongside perennial rivers) developed in seasonal climate. In this biome forest species with non-forested species coexists and has high values of diversity. Contribution to CSIC (DT-MU) and Pedeciba-Biología.

**P-1490**

## **Early to mid-Holocene vegetation history of South Korea inferred from pollen records**

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### **Abstract**

The sedimentary cores were obtained from the Gunsan and Bigeumdo sites in west coast and Goheung site in south ones of South Korea in order to understand the vegetation changes response to the early to mid-Holocene climate changes on the Korean Peninsula. The age-controlled palynological studies associated geochemical data indicated that the riverine wetland meadow between 12.1 and 9.8 cal kyr BP changed to subtropical and temperate deciduous broad-leaved forest in 9.8–2.8 cal kyr BP. Additionally, the cold climate conditions from 12.1–9.8 cal kyr BP became warmer from 8.5–7.3 cal kyr BP. Subsequently, another relatively cool period from 7.3–2.8 cal kyr BP was prevailed. The temperature changes were mainly in response to solar factors. However, two relatively humid periods from 12.1–9.8 cal kyr BP and 8.5–7.3 cal kyr BP, which arose for different reasons, were detected. The earlier humid period resulted from strong westerlies and a rapidly rising sea level. The later humid period was produced mainly by the strong East Asian summer monsoon and may also be linked to La Niña-like activity. The cold “Younger Dryas” event (12.0–11.4 cal kyr BP) and “8.2 kyr cool” event recorded in the study area may have been produced by teleconnection with a North Atlantic meltwater pulse. This would have reduced temperatures that were already low due to weak insolation, and the strong winter monsoons would have increased the precipitation.

P-1491

## Postglacial diatom-climate responses in a small lake in the Pacific northwest of North America

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### Abstract

Understanding the variability of ocean-atmosphere interactions in the Pacific Northwest (PNW) of North America is essential for climate forecasting, particularly variations in the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). Research suggests that global warming is increasing the frequency of extreme El Niño events, which can have global climatic impacts (e.g. disrupting global weather patterns, affecting ecosystems and agriculture and extreme weather events (flood, drought, bushfires)). A diatom record spanning 14,500 Cal yr BP from Moss Lake, Washington is used to assess Holocene climate change in the PNW including evidence for periodicities related to ocean-atmosphere interactions and/or variations in solar output, and is directly compared to the Moss Lake pollen record. Three climate phases were identified: 1) the Late Pleistocene (until 11,800 Cal yr BP), with a cold climate evidenced by the low abundance of diatoms; 2) the early to mid-Holocene (11,800 – 7500 Cal yr BP), with warm climate, longer growing seasons and shorter periods of ice cover, indicated by the increase of *Cyclotella pseudostelligera* and decrease of *Fragilaria* taxa; and 3) the mid-to-late Holocene from 7500 Cal yr BP onwards, with a cooler climate reflected by a decrease in *Cyclotella pseudostelligera* and an increase in *Fragilaria* taxa. These climate shifts correlate with the regional and local pollen record. Fluctuations in *Cyclotella pseudostelligera* and *Aulacoseira* taxa suggest climatic cycles of varying amplitude throughout. RedFit and Wavelet analyses revealed periodicities of approximately 2000 years, 1300 years, and 450 years. The 2000-year cycle is attributed to solar variation; the Hallstatt Oscillation. The 1300-year and 450-year cycles are attributed to ENSO and PDO like cycles. The 1300-year periodicity is evident throughout the Late Pleistocene and Holocene and reflects shifts from El Niño/positive PDO (weak wind intensity, warm temperature) to La Niña/Negative PDO (high wind intensity, cool temperature). Between 11,800 and 7500 Cal yr BP the cycle amplitudes are reduced and frequency increased reflecting the 450 yr periodicity. Diatom data from Moss Lake provide a sensitive record of climate-related limnological responses and refine our understanding of Holocene climate change in the PNW.

P-1492

## Multidecadal variability of air temperature over East-Central Europe in the last millennium

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### Abstract

Novel simulations of past climates provide unique opportunity to separate external perturbations from internal climate anomalies and to attribute the latter to systematic changes in different types of synoptic scale circulation and distributions of high-frequency weather events. At the moment, there is a lot of information about the variability of thermal and humidity conditions on continents in the last millennium. They can be obtained i.a. from an extensive network of tree-ring, ice cores and coral records. Here we study the trends of changes of thermal conditions by employing the Last Millennium Ensemble (LME) of climate simulations carried out with the Community Earth System Model (CESM) at the U.S. National Center for Atmospheric Research, focusing in particular on decadal changes in air temperature over East-Central Europe from 850 to 1850. The forcings over this period are associated with volcanic eruptions, solar activity, the orbit of the Earth, land cover, greenhouse gas concentrations, and tropospheric ozone and aerosols. We have analyzed the occurrence of air temperature anomalies in relation to both stratospheric volcanic sulfate aerosol concentration and total solar irradiance (TSI). In addition, we compared the differences between thermal conditions in winter and summer during Medieval Warming Period (MWP) and Little Ice Age (LIA). The values of the air temperature during the two periods were also compared with the sea level pressure anomalies over the North Atlantic Ocean and Europe as well as the index of the North Atlantic Oscillation.

P-1493

## Changes in speleothem $\delta^{13}\text{C}$ through the deglaciation: a model-based study

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### Abstract

Stable carbon isotope measurements ( $\delta^{13}\text{C}$ ) on most of the speleothem records that span the end of the last glacial period and the deglaciation, both in tropical and extratropical regions, show a trend towards more negative values. At some sites the trend is marked by rapid shifts towards more negative values, and some sites also show short-lived reversals broadly corresponding to the Younger Dryas interval. Speleothem  $\delta^{13}\text{C}$  records are conventionally interpreted in terms of shifts in the relative abundance of  $\text{C}_3$  and  $\text{C}_4$  plants in the vegetation above the cave. However, the  $\delta^{13}\text{C}$  composition of  $\text{C}_3$  plants also reflects the stomatal conductance response to aridity and this should also be reflected in speleothem  $\delta^{13}\text{C}$  records. Changes in the  $\delta^{13}\text{C}$  composition of  $\text{C}_3$  plants are a reflection of climate, but shifts in the relative abundance of  $\text{C}_3$  and  $\text{C}_4$  plants can be caused either by climate change or by changes in atmospheric  $\text{CO}_2$  concentration – low  $\text{CO}_2$  can favour  $\text{C}_4$  plants even in relatively moist/cold climates. We use a process-based biogeography model (BIOME4) that explicitly simulates  $^{13}\text{C}$  discrimination to explore the causes of observed deglacial changes in  $\delta^{13}\text{C}$  at 25 speleothem sites worldwide covering the interval from 22-10 kyr from the SISAL (Speleothem Isotopes Synthesis and Analysis) database. The model reproduces the observed trends in  $\delta^{13}\text{C}$ , including rapid shifts, and also reversals. We show that the trend towards increasingly negative values is largely a reflection of  $\text{CO}_2$ -induced changes in vegetation composition, particularly in the tropics where the change in climate is muted. In the extratropics, both climate warming (and increased water stress) and  $\text{CO}_2$ -induced shifts in vegetation composition play a role in explaining the trend. Rapid shifts in  $\delta^{13}\text{C}$  appear, within dating uncertainties, to correspond to intervals when the increase in  $\text{CO}_2$  is steep. The reversal in the  $\delta^{13}\text{C}$  associated with the Younger Dryas is largely a vegetation response to climate. As this study shows, process-based modelling can be used to explore and explain the causes of changes in speleothem  $\delta^{13}\text{C}$ .

**P-1494**

## **Poleward shift of the subtropical jet linked to Heinrich Stadial 1 and future rainfall changes in China**

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### **Abstract**

Expansion of the Hadley cell and poleward displacement of the subtropical jet are two crucial features of circulation change under global warming. Connection between rain band of Asian Summer Monsoon in China and such circulation changes is very poorly studied. We use a compilation of hydroclimate records and published transient model simulation results to assess the connection of Hadley cell's width and subtropical jet to monsoonal precipitation change in China during HS1. Records documented precipitation increasing in northern China and the eastern Tibetan Plateau but decreasing in southern China during this period, indicating monsoonal rain band moved northward. The model output shows that temperature in middle and high latitudes increased in summer as a transient response to radiative forcing changes during the last deglaciation, leading the Hadley cell expanding and the subtropical jet moving poleward. Poleward displacement of the subtropical jet drove the monsoonal front moving northward during HS1 summer, therefore, precipitation increasing in northern China but decreasing in southern China as geological records documented. A very similar mechanism is also apparent in the multi model simulations under IPCC RCP 8.5, lending confidence to the projection of a wet northern China in the future.

P-1495

## Extreme climatic events in the North Atlantic-European sector and their link to modes of variability during the last two millennia

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### Abstract

Future climate change scenarios suggest an increase of extreme climatic events in southern Europe, especially those associated with anomalous rainfall conditions (i.e., droughts and floods), which often cause major negative economic and social impacts. However, climate model simulations still include large uncertainties in the reproduction of flood and drought recurrences, partly due to the large internal variability that characterises the climate of the mid to high latitudes of the Northern Hemisphere. Therefore, it is necessary the use of hydrological reconstructions to: i) establish the baseline conditions prior to the current Climate Change and ii) investigate the previous analogous warm periods (e.g., Roman Warm Period and Medieval Climate Anomaly) to infer the future behaviour of extreme climatic events and provide clues under the prevalence of which large-scale atmospheric and oceanic patterns occur these extreme events. The most prominent atmospheric pattern in mid to high latitudes of the Northern Hemisphere is the North Atlantic Oscillation (NAO). Nevertheless, the NAO is not the only mode that affects the North Atlantic-European sector climate regime. Here, we present the hydrological balance of two southern regions of the North Atlantic European sector (i.e., Azores Archipelago and Iberian Peninsula) using lacustrine sedimentary records to determine the spatio-temporal evolution of hydrological extremes and their relationship with large-scale modes of climate variability. Our main hypothesis is that large-scale climate variability other than the NAO have modulated extreme climatic events in the North Atlantic-European sector during the Common Era. Our results make evident that different interactions between the NAO and other large-scale atmospheric and oceanic patterns explain local climate conditions and spatial differences during enhanced flooding and droughts periods. These lacustrine records show that above-average rainfall conditions are linked to the negative phases of both the NAO and the Atlantic Multidecadal Oscillation (AMO), while background and drought conditions preferentially occur under positive NAO and AMO phases. These results highlight that, although the hydrological regime in this area is clearly influenced by the NAO, the low frequency AMO also plays a key role at decadal to centennial time-scales. Moreover, other climate patterns, such as the East Atlantic (EA) and Scandinavian (SCA) patterns, could also modulate the geographical position of the NAO action centres, thus affecting the strength and latitudinal position of the dominant westerlies crossing the North Atlantic sector. Our results provide an evidence of the importance of considering other patterns than the NAO to explain palaeohydrological variability in the North Atlantic European sector

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P-1496

## North Atlantic Ice-rafting and Western Mediterranean climate during the Holocene

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### Abstract

The periods of enhanced Holocene North Atlantic ice-rafting (Bond events) have climate implications over distant regions, due to their coupling with large-scale ocean circulation and atmospheric modes. However, only a few proxy records replicate all the Bond events as climate anomalies. Hence, additional paleoclimate research is required from key sites to reconstruct potential teleconnections with the subpolar North Atlantic. Here, based on robust age models, we present three high resolution isotope speleothem records from the Western Mediterranean, a region under the direct influence of the westerly winds circulation through the North Atlantic Oscillation (NAO). We demonstrate that the rainfall variability in the Western Mediterranean is in phase with negative NAO-like conditions and solar minima, consistent with modern climate patterns. Furthermore, we provide proxy evidence for wet conditions in the Western Mediterranean during the periods of enhanced ice-rafted debris (IRD) throughout the Holocene. These findings are consistent with previous proxy and model results, which describe cooling and sea ice expansion over the North Atlantic and the resulting slowdown of the Atlantic Meridional Ocean Circulation (AMOC) as a response to reduced wind stress on the ocean. The latter is caused by southward shifts of the precipitation-bearing westerly winds, which resemble negative NAO-like conditions that bring moisture to the Western Mediterranean.

P-1497

## Quantitative climatic reconstruction in China during the mid-Holocene and the Last Glacial Maximum

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### Abstract

Quantitative paleoclimatic reconstruction is crucial for understanding the operation and evolution of the global climate system. For example, a quantitative paleoclimatic reconstruction for the Last Glacial Maximum (LGM) and the mid-Holocene is fundamental to understanding the evolution of Earth's climate during the last glacial-interglacial cycle. Previous quantitative palaeoclimate reconstructions in China are generally based on statistical comparison of modern pollen assemblages and modern climate data. These methods are based on the premise that vegetation-climate interactions remain the same through time, and implicitly assume that the interactions are independent of changes in seasonality and atmospheric CO<sub>2</sub> concentration. However, these assumptions may not always be valid, which may affect the reconstructions. In this study, we present the results of a quantitative study of the LGM climate of China based on an improved inverse vegetation model which incorporates physiological processes combined with a new China Quaternary Pollen Database.

The results indicate that during the MH period, mean annual temperature (ANNT) in China were higher ~0.7°C than present, especially in the eastern China, but cooler in the northwest China. Winter temperature were generally higher ~1.0°C than today, but summer temperature only higher ~0.5°C than present. Mean annual precipitation (ANNP) were wetter ~230 mm than present, especially in the eastern China, which was due to the increase of summer rainfall. At the LGM time, mean annual temperature (ANNT), winter and summer temperature of the warmest month in China were lower by ~5.6°C, ~11.0°C and ~2.6°C, respectively, compared to today, and that the changes in ANNT were attributed mainly to the decrease of winter temperature. Mean annual precipitation was lower by ~46 mm compared to today, especially in northern China, which was due to the decrease in summer rainfall.

Comparison of our results with recent outputs from paleoclimatic modelling reveals that while the latter are broadly consistent with our estimated changes in mean annual climatic parameters, there are substantial differences in the seasonal climatic parameters. Our results highlight the crucial importance of developing seasonal simulation on paleoclimatic models, as well as the need to improve the quality of paleoclimatic reconstructions based on proxy records from geological archives.

P-1498

## Seasonal Precipitation Patterns by Superposition of Polar Jet and Monsoon Circulation in Northern China Since Last Glacial

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### Abstract

Loess-paleosol and dune sand-paleosol  $\delta^{13}\text{C}_{\text{SOC}}$  values of soil organic carbon (SOC) can be used to reflect “annual-average” changes of floral habitat and  $\delta^{13}\text{C}_{\text{SCC}}$  values of soil carbonate carbon (SCC) can be used to reflect summer habitat changes. However, variations of “annual-average” proxy of floral habitat is biased by seasonal precipitation. When summer precipitation is intense and fall/winter season is dry, the “annual-average” proxy tends to reveal more summer habitat variation. When fall/winter precipitation is persistent and summer is dry, the “annual-average” proxy tends to reflect fall/winter habitat. We argue that an equilibrium state between  $\delta^{13}\text{C}_{\text{SOC}}$  and  $\delta^{13}\text{C}_{\text{SCC}}$  values indicates wet summers and dry falls/winters and a disequilibrium state between  $\delta^{13}\text{C}_{\text{SOC}}$  and  $\delta^{13}\text{C}_{\text{SCC}}$  values indicates dry summers and wet falls/winters.

We explored this approach to a riverine dunefield that contains 10 incipient paleosol horizons formed narrowly between 10,800 and 7,500 calBP to discuss the evolution of the East Asian Summer Monsoon (EASM) circulation in the southeast Mu Us Desert in northern China. We also examined stable carbon isotopes from a loess-paleosol sequence for the last 20,000 years in the northwest margin of the Loess Plateau. We found that wet falls and dry summers more frequently dominated the early-Holocene, while wet summers and arid falls became overwhelming after 9000 calBP. We interpreted that the substantial warming in the Northern Hemisphere in early Holocene propelled the subtropical jet streams that carried heat and moisture from Indian and West Pacific Oceans in falls poleward causing northern China wet, while accelerated melting of ice sheet raised sea level and shifted Arctic Oscillation (AO) to a negative phase in summers, resulting in southern China wet and northern China dry. However, after middle Holocene the highest summer and lowest winter solar radiation and decrease of sea level rise favored a positive phase of AO, driving polar jet streams further poleward with less meridional meanders, intensifying EASM rainfall transfer aloft poleward, while colder/windier winters could extend drier/colder conditions to springs/falls. The interaction between the Rossby wave trains of polar jet troughs and ridges and subtropical jet streams that carry Indian Summer Monsoon and EASM heat/moisture supplies modulated the millennial scale climate and habitat changes in the northern China.

P-1499

## Holocene evolution of the Northern Hemisphere temperature gradient and its relation to mid-latitude net precipitation

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### Abstract

The latitudinal temperature gradient (LTG) between the equator and the poles influences atmospheric stability, jet-stream strength, and extratropical cyclones. Recent global warming is weakening the Northern Hemisphere annual surface LTG by preferentially warming the high latitudes; however, the implications of these changes for mid-latitude climate remain uncertain. Paleoclimate archives spanning the Holocene provide an opportunity to evaluate the impact of orbitally driven changes the LTG on mid-latitude hydroclimate. We show that a weaker LTG (warming of the Arctic with respect to the equator) during the early to middle part of Holocene coincided with substantial decreases in mid-latitude (30°-50°N) net precipitation. We quantify the evolution of the LTG and mid-latitude moisture in both an extensive new compilation of Holocene paleoclimate records spanning from 10°S to 90°N, and in an ensemble of mid-Holocene climate model simulations (PMIP3, 6 ka time slice). The observed pattern is consistent with the hypothesis that a weaker LTG led to weaker mid-latitude westerly flow and decreased net terrestrial mid-latitude precipitation. Currently the northern high latitudes are warming at rates nearly double the global average, decreasing the equator-to-pole temperature gradient to values comparable with the early to middle Holocene.

P-1500

## Western Pacific Ocean influences in East Asian summer monsoon since the mid-Holocene

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### Abstract

Numerous paleoclimate records on precipitation isotopes have been published to infer past hydroclimate changes in Asian monsoon region. However, there are still debates on whether or not these reconstructed precipitation isotopes can represent changes in the amount of monsoon rainfall. In this study, we report a record of leafwax hydrogen isotope ( $\delta D_{wax}$ ) for the past 5000 years inferred from a 6.67-m-long sediment core collected in Beilianchi (BLC) Lake in the Chinese Loess Plateau. To better understand the relation between precipitation isotopes and monsoon rainfall amounts in this region, we systematically analyze the modern instrumental observations on moisture sources, precipitation amounts, precipitation isotopes. We find that precipitation isotopes ( $\delta D_p$ ) show distinct negative correlation with amounts of local summer (from April to September) monsoon rainfall in the southwestern Chinese Loess Plateau, with moisture mainly transported from the northwestern Pacific Ocean through the subtropical monsoon circulation. These observation are further verified by the agreement between instrumental precipitation and reconstructed high-resolution rainfall isotopes from regional lake sediments and speleothems over the past 60 years, and climate simulations on regional atmosphere circulations. Accordingly, our ~20-year resolution  $\delta D_{wax}$  data reveal a slight long-term decrease in monsoon rainfall amounts since the mid-Holocene, with multicentennial-scale increased monsoon precipitations at 4800-4200 BP and 1100-400 BP but decreased monsoon precipitations intervals at 3900-3500 BP, 3200-2600 BP, 1700-1300 BP, and 300-0 BP. These changes agree with the published speleothem  $\delta^{18}O$  data from the nearby area and remote sea-surface temperatures in the western Pacific Ocean, and the simulated summer rainfall record from the Kiel Climate Model (KCM) which also suggests a Pacific-sourced moisture for this region. We conclude that precipitation isotopes, at least in some East Asian monsoon regions, can still represent changes in the amount of summer monsoon rainfall, and that East Asian summer monsoon likely be controlled by subtropical monsoon circulations originating from the western Pacific Ocean and connected with changes in sea surface temperatures and migrations of the ITCZ there.

**P-1501**

## **Anti-phase variation of hydrology and in-phase carbon accumulations in two wetlands in southern and northern China since the last deglaciation**

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### **Abstract**

To examine the spatial patterns of hydrological variations in the southern and northern East Asia Monsoonal (EAM) region on millennial scales as well as to investigate the relations of hydrological changes on carbon accumulation in the regions with contrasting environmental backgrounds, we performed facies-based hydrological reconstructions at two wetlands, Midiwanwetland (37°39'N, 108°37'E) and Dahu wetland (24°45'N, 115°2'E), respectively, located in a semi-arid loess-desert transitional zone and humid southern China. Our reconstructions show that there is an anti-phase pattern of the precipitation in these two wetlands on a millennial scale. However, with the different responses to the contrasting hydrological conditions, the carbon accumulations at these two sites show in-phase patterns on a millennial scale. These results indicate that the carbon accumulations in the two sites are mainly controlled by the local hydrologic conditions. The wetlands in both southern and northern China were found to be expanding during the interval from 6 to 4 cal. ka BP (ka = kilo annum), as inferred by the higher total organic carbon content. For the Mystery Interval (MI, from 17.5 to 14.5 cal. ka BP), however, both hydrological conditions and carbon accumulations in these two sites showed an in-phase pattern.

P-1502

## A high-resolution Holocene speleothem record from NE Romania: the nexus of Arctic and North Atlantic atmospheric circulation systems

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### Abstract

The Romanian Carpathians act as a geomorphological barrier between different atmospheric circulation systems over Central and Eastern Europe; the NW of Romania lies under the remote influence of the North Atlantic oscillation, while the NE is influenced by the Arctic climate. In NW Romania, previous stable isotope studies of speleothems have not yielded a clear account of abrupt climate oscillations during the Holocene. Here we present results from a stalagmite collected from the Taușoare Cave, located in NE Carpathians. The chronology of stalagmite T141 is based on 15 high-precision Th/U dates ranging between 32 and 1.1 ka with a continuous growth between ~13.3 and 1.1 ka. The portion of the record within the Holocene was analyzed for  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  at a resolution ranging between 15 to 200 years/sample. The resulting  $\delta^{18}\text{O}$  record captures the Younger Dryas (YD) event centered at ~12.9 ka, with  $\delta^{18}\text{O}$  values about 4 ‰ more depleted than those corresponding to the Holocene Climatic Optimum. The 8.2 ka event appears to be also captured in the record, although less prominent. The T141 isotope record is significantly different when compared to coeval records measured in speleothems from NW Carpathians, which do not exhibit marked changes during the YD or 8.2 ka events. This is likely due to the contrasting effect of temperature and atmospheric transport on  $\delta^{18}\text{O}$  signal in NW Romania. Within a distance of 200 km to the east, on the eastern flank of the Carpathian range, the  $\delta^{18}\text{O}$  signal of the Arctic circulation appears to be more prominent and clearly exhibits a positive relationship with temperature changes.

**P-1503**

## **Application of Avaatech X-ray fluorescence core-scanning in Sr/Ca analysis of speleothems**

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### **Abstract**

Application of X-ray fluorescence core-scanning (XRF-CS) analysis on both marine and lake sediments has achieved remarkable results. However, its application now has not been widely extended to the research of speleothems. In this study, we measure the Sr abundance and the Sr/Ca ratio of three stalagmites (two aragonite stalagmites, one calcite stalagmite) using the state-of-the-art fourth-generation Avaatech high-resolution XRF core scanner. Through comparisons among different scan paths and among different scan resolutions, as well as comparisons with inductively coupled plasma optical emission spectrometer (ICP-OES), Itrax XRF and Artax XRF results, we confirm that the Avaatech XRF core scanner could accurately, quickly and non-destructively analyze the high-resolution Sr abundance of speleothems. Furthermore, we also combine the stalagmite  $\delta^{18}\text{O}$  record to try to explain the paleoclimatic significance of the measured stalagmite Sr/Ca.

P-1504

## Pipi shells: a new high-resolution palaeoenvironmental archive for south-eastern Australia

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### Abstract

Oxygen isotope ratios from marine mollusc shells have been widely used to reconstruct sea surface temperature (SST) and seasonal shellfish foraging records from archaeological sites worldwide. However, the application of this technique to the Australian archaeological record has so far been limited to a few sites. Pipi shells (*Donax deltooides*) are common components of many archaeological sites in south-eastern Australia. One pioneering study in the 1980s (Godfrey 1988) employed oxygen isotope analyses of pipi shells to study the Holocene archaeological record of Discovery Bay in Victoria. However, this study was constrained by the technology and techniques of the time. Recent advances in mollusc shell growth increment analysis (sclerochronology) and high-resolution geochemical sampling as well as improvements in mass spectrometry technology have enabled the reconstruction of sub-monthly sea surface temperature records from intertidal mollusc shells, thus enabling more robust and reliable reconstructions. In light of these recent advances, we reassess the utility of *Donax deltooides* shells as archives for SST and seasonality information in south-eastern Australia.

To validate whether this species is a faithful year-round palaeoenvironmental recorder, we collected live *D. deltooides* from Discovery Bay, Victoria each month for a year. We analysed the intra-annual variability of  $\delta^{18}\text{O}$  in modern live-collected shells and sea water and compared  $\delta^{18}\text{O}$ -derived SST reconstructions with instrumental SST records. Shell-derived SSTs were highly correlated with instrumental SST records over the period of collection. This suggests that these shells are reliable palaeothermometers. This study demonstrates the utility of applying advanced sclerochronological techniques to Australian shell middens and shows that pipi shells hold great potential for reconstructing monthly-resolved SST records and seasonal foraging practices in south-eastern Australia.

P-1505

## Mid-late Holocene palaeoclimate reconstructions from speleothem and peatland high-resolution stable isotope records (the HOPES project)

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### Abstract

Among geological archives, speleothems (i.e. secondary carbonate deposits in caves) and peatbogs are now regarded as important continental archives of past climatic and environmental conditions, offering a number of advantages relative to other archives such as lake sediments, tree rings or ice cores. Both archives, available in Belgium, are potentially reliable environmental records of high interest due to their dating possibilities and their possibility to preserve multi-proxy records of environmental and climatic dynamics.

Here, we present a peat core and a stalagmite collected from the Clefaye peatland (Hautes-Fagnes Plateau) and the Père Noel cave, respectively, used to reconstruct Mid to Late Holocene climate. The Clefaye peat core covers 6.4 ka according to <sup>210</sup>Pb, <sup>14</sup>C datings and the Père Noel stalagmite (PN) covers the last 12.7 ka according to U/Th datings. Trace elements concentrations and stable isotopes were analyzed in Clefaye peat core and PN stalagmite to assess local and regional climate changes. To compare the two records, this study focuses on the interval from 1.5 to 6.5 ka. High spatial resolution measurements of Mg, Al, Sc, Sr, Ba were done by using Laser-Ablation Inductively Coupled Plasma Mass Spectrometry at Royal Museum for Central Africa (Tervuren, Belgium). The  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of Clefaye peat cellulose and PN stalagmite were measured by Mass Spectrometer at the Department of Geography, Swansea University (UK) and at Union College (USA). Time series of elemental and stable isotope geochemistry were established for the 2 archives. Precipitation and humidity conditions over Belgium was reconstructed by result integration derived from the two continental archives.

Even diagenesis processes influenced the peat composition (i.e. peat decomposition), the stable carbon and oxygen isotope signals preserve the hydrological conditions. The similar patterns of  $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$  in both archives suggests that they have the potential to provide high resolution insights into regional palaeoclimatic variability during the Holocene. The regional climate patterns are dominated by alternations of dry and wet episodes during the Mid-Late Holocene. Five distinct periods of wetter conditions were identified between 6000 and 5500, at 5200, 4650, 3250 and at 2100 cal. BP, along with three periods of drier conditions between 4900 and 4750, at 4150, and from 3000 to 2500 cal. BP. These climatic variations show some correlation with published records from different climatic archives studied in Europe and in the North Atlantic area. The results suggest that local and regional climate change in the mid-late Holocene has a potential to control the peatland and speleothem proxies in Belgium, although the reliability of these records will depend heavily upon the nature (quality, purity and preservation) of the sample material analysed.

P-1506

## Sub-annual multi-proxy data reveals Pacific ENSO variability during the mid-Holocene

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### Abstract

The Pacific El Niño-Southern Oscillation (ENSO) affects climate dynamics globally. A number of archives are at our disposal to gain insight into the natural variability of the ENSO system, the controls underlying these dynamics and the impact it exerts on other climate subsystems. However, only very few high-resolution time series are available to inform us about ENSO conditions during the Holocene Thermal Optimum (ca. 7-5 kyrs BP, Moy et al. 2002, Donders et al. 2008, Cobb et al. 2013).

Here we present preliminary results from a U/Th dated stalagmite from remote Niue Island in the tropical South Pacific that reveal palaeo-hydrological conditions and ENSO dynamics during the mid-Holocene (ca. 7,000 to 5,450 years BP). Caves on Niue Island are highly susceptible to environmental changes, with local infiltration being modulated by seasonal shifts in the South Pacific Convergence Zone, and at multi-annual scale by ENSO (Tremaine et al. 2016). The island receives most rainfall during austral summer, while during the austral winter and during El Niño events rainfall is significantly reduced (Rasbury & Aharon 2006).

The shallow epikarst above the study site supports a rapid response of the cave environment to infiltration changes and thus transfer of climatic signals into the cave at seasonal scale.

Stalagmite C-132 consists of calcite and is visibly laminated, with layers as thick as 800  $\mu\text{m}$ . Stable oxygen and carbon isotope analyses are combined with laser ablation multi-element profiles to illuminate past local moisture conditions at seasonal scale. Stable isotopes and X/Ca ratios vary at sub-annual scale, highlighting the rapid response of the cave system to external conditions.

Prior calcite precipitation (PCP) dynamics in the epikarst are the most likely reason for  $\delta^{13}\text{C}$  and X/Ca changes. Oxygen isotopes reflect changes in moisture source distance and amount. We use statistical analyses to extract PCP changes that are superimposed on seasonal variability in our proxies and controlled by ENSO dynamics.

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P-1507

## 20th century decreases in local effective moisture recorded by a Kangaroo Island speleothem

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### Abstract

Australian cities and agricultural areas have seen a decrease in rainfall over recent decades, with economic and social consequences. High-resolution palaeoclimate records present an opportunity to place these trends into a longer context and can shed light on the drivers of such change over time scales beyond the instrumental coverage of the 20<sup>th</sup> century. This study presents outcomes from a five-year monitoring program and a new speleothem derived palaeoclimate record from Kangaroo Island, South Australia. The site is strategically located because it is situated in a location with few palaeoclimate reconstructions, as well as being climatically 'upstream' from major population and agricultural centres.

The monitoring program reveals the primary controls on rainfall and cave dripwater  $\delta^{18}\text{O}$  as well as drip counts. Precipitation  $\delta^{18}\text{O}$  ( $\delta^{18}\text{O}_p$ ) is controlled by rainfall amount on daily and monthly time scales. However, seasonal  $\delta^{18}\text{O}_p$  values reflect seasonal changes in moisture source, with winter rainfall originating from the Southern Ocean and summer rainfall originating from the tropical Indian Ocean. Yearly  $\delta^{18}\text{O}_p$  reflects seasonality of the rainfall, with winter rainfall currently dominating the average  $\delta^{18}\text{O}_p$  values. Dripwater  $\delta^{18}\text{O}$  values reflect the yearly weighted average  $\delta^{18}\text{O}_p$  values.

Calcite  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values, in addition to a suite of trace element concentrations, were measured in a ~103-year-old speleothem from Kelly Hill Caves on Kangaroo Island. The  $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ , and trace element results (Mg/Ca, Sr/Ca, Ba/Ca) corroborate wetter conditions in the early part of the record and drying in the most recent decades. Increases in Mg/Ca, Sr/Ca, and (to a lesser extent) Ba/Ca are driven by prior calcite precipitation and are used to identify dry periods in the palaeoclimate record. Comparison of these proxies with Kangaroo Island instrumental observations supports a rainfall interpretation; however, temperature may have played an important role in decreasing effective moisture, and thus triggering the increases in  $\delta^{13}\text{C}$  and Mg/Ca since ~1970.

Outcomes of the monitoring investigation indicate that rainfall amount and moisture source influence rainfall  $\delta^{18}\text{O}$  values, but interpretation of the speleothem record suggests that temperature also plays an important role on longer time scales. Overall, this study demonstrates that Kangaroo Island speleothems can preserve records of regional climate variability, and analysis of additional, older, speleothems from Kelly Hill Cave will assist in understanding the interplay of rainfall and temperature in southern Australian hydroclimate variability.

P-1509

## El Niño variability reflected in a high resolution pollen record from a lake in the Tropical Andes of Ecuador

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### Abstract

The future frequency and magnitude of the El Niño – Southern Oscillation (ENSO) in a world with global climate change is still highly uncertain and topic of intense debate. High resolution records from sedimentary archives can aid our understanding of ENSO variability under changing climates on the true 2-7 year El Niño timescale. One of the most detailed continuous records of Holocene El Niño dynamics from a terrestrial setting is the Laguna Pallcacocha record from Cajas National Park, Ecuador. Previous analysis revealed hundreds of El Niño-driven light-coloured inorganic, clastic laminations, in the dark organic lake sediments which reflect increased frequency of El Niño events during the past 5000 years, with millennial-scale oscillations. While used worldwide as a key record of ENSO variability, it is essentially a local record with potential complexity in interpretation. High resolution pollen analyses represent a more regional source area that aid the development of our understanding of ENSO intensity through time. We present the first high resolution Holocene pollen record from Laguna Pallcacocha that reveals clear expanses of the montane forest belts to phases of high ENSO frequency. Additionally, an ultra-high resolution pollen analysis of the last century permit to calibrate interannual changes in pollen deposition to variability in regional precipitation and temperature variability forced by ENSO on the true 2-7 year timescale. Application of this approach to an interval during the early Holocene will for the first time detect annual-scale vegetation responses during a phase of proposed reduced ENSO intensity.

**P-1510**

## **Using elemental mapping of Mg/Ca ratios to cheaply screen seasonal limpet records for SST changes and vital effects**

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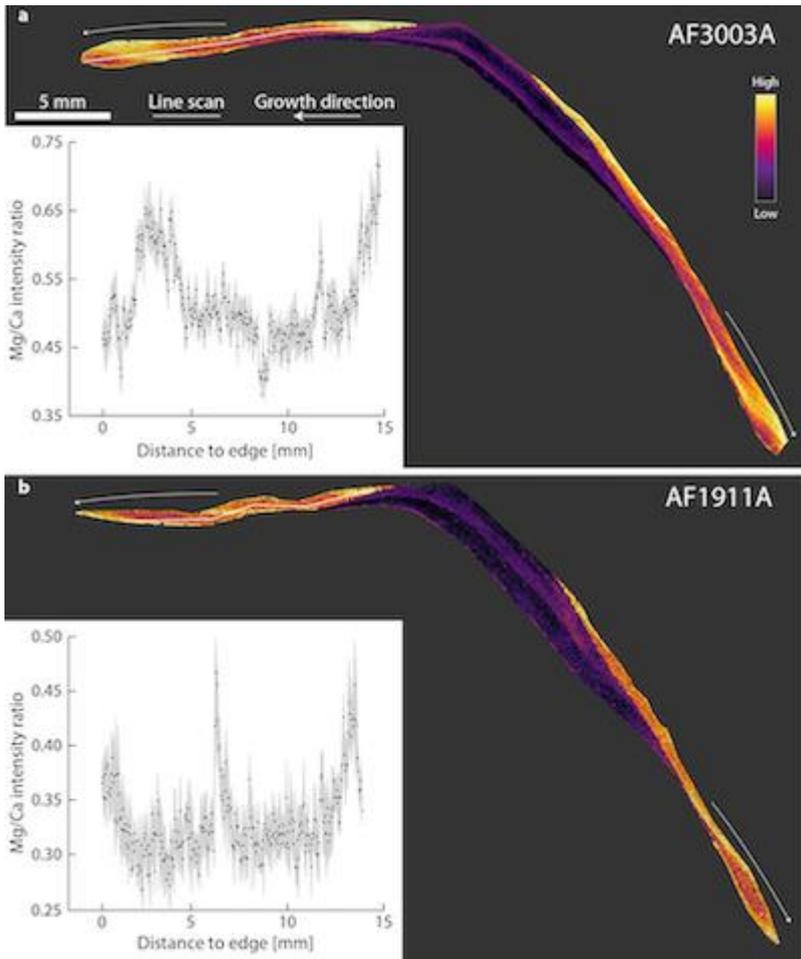
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### **Abstract**

Elemental analysis of biogeochemical archives is an established technique used to study climate in a range of applications, including ocean circulation, glacial/interglacial climates, and anthropogenic climate change.

Data from mollusc archives are especially important because of their global abundance and sub-annual resolution. Despite this potential, they are underrepresented among palaeoclimate studies, due to enigmatic physiological influences skewing the elemental record. Understanding the patterns behind these influences will improve data interpretation and lead to the development of new climate proxies.

Here, we apply extensive mapping of multiple mollusc specimens using the rapid method of Laser Induced Breakdown Spectroscopy (LIBS) across a wider region to compare and resolve enigmatic patterns within the elemental record caused by physiological influences.



Mg/Ca ratios displayed as maps and line scans for two modern limpet shells collected in spring (top) and autumn (bottom).

2D elemental (Mg/Ca) maps of whole limpet shells (*Patella caerulea*) from across the Mediterranean revealed patterns of variability within individual mollusc records as well as within isochronous parts of specimens. By registering and quantifying these patterns, we established previously uninterpretable correlations with sea surface temperature (SST):  $R^2 > 0.8$ .

We additionally found that the resulting SST equations were specimen specific and would require additional calibration using other methods (i.e.  $\delta^{18}\text{O}$ ). We thus present a combined approach of fast and cheap LIBS screening and subsequent isotopic analysis of seasonal minima and maxima only.

This approach thus presents the means to assess annual temperature ranges using oxygen isotope analysis requiring only 2 samples per shell and season of capture, important for archaeological studies, entirely without oxygen isotope analysis.

P-1511

## Revealing interannual variability in the Indian monsoon with sub-mm lipid biomarker and elemental measurements over the past 200 years

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### Abstract

Sub-decadal to annual climate oscillations are particularly relevant to human climate perception, including such well-known phenomena as seasonal tropical monsoons and the Pacific El Niño-Southern Oscillation (ENSO). To assess the variability of these oscillations in the past, proxies for climate variables that are influenced by these oscillations (e.g., temperature, precipitation) and geologic materials with a temporal resolution able to record them are both needed. However, even in settings where these two criteria are met, the sample size needed for laboratory analysis can limit temporal resolution.

Recently, a mass spectrometry imaging technique, matrix-assisted laser desorption/ionization coupled to Fourier transform-ion cyclotron resonance mass-spectrometry (MALDI-FT-ICR-MS), has been developed to measure and map distributions of climate-relevant biomarkers (e.g., GDGTs, alkenones) from intact sediment core surfaces in 100- $\mu\text{m}$  increments, unlocking the ability to reconstruct sub-annual paleoclimate (Wörmer et al., 2014, 2019; Alfken et al., 2019). The same sediment sample surfaces can also be analyzed with micro-XRF mapping, enabling congruent examination of complementary elemental- and biomarker-derived paleoenvironmental proxies at ultra-high spatial resolution both down-core and along-lamination.

Nearshore Pakistan Margin (northeastern Arabian Sea) marine sediments provide excellent, continuous archives of past climate and oceanographic conditions that can be used to reconstruct the variability of the Southwest (summer) and Northeast (winter) monsoons of India. These sediments are composed of alternating light and dark layers—laminae couplets—that together record the deposits of a single year. The sub-mm-thick layers consist of organic-poor terrigenous clays associated with river-runoff after heavy rainfall events, and organic-rich layers associated with high primary productivity.

Using the congruent micro-XRF and MALDI-FT-ICR-MS techniques, we measured elemental abundances and lipid biomarkers in Pakistan Margin sediment core SO90-58KG in continuous 100- $\mu\text{m}$  increments, resolving 8 to 14 discrete time intervals per year over the past ~200 years. We present a precipitation proxy for south-central Pakistan based on detrital, siliciclastic elemental abundances, and sub-annual  $U_{37}^{K'}$  and CCaT (a GDGT-based proxy; Wörmer et al., 2014) sea surface temperature (SST) proxy records for the northeastern Arabian Sea. Precipitation may be linked with the Southwest monsoon, and cooler winter SSTs are due to convective mixing by the Northeast monsoon. We apply spectral analysis to identify dominant cycles in precipitation and SST reconstructions and periodicity changes through time. We compare our sub-annual precipitation and SST proxies with instrumental and satellite data, and other records of Southwest and Northeast monsoon variability and ITCZ position.

**P-1513**

## **Hydrological change in subtropical Australia from 80–40 kyr**

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### **Abstract**

There are very few continuous palaeoclimate records of the period when humans first colonised Australia 60–50,000 years (60–50 kyr) ago, or during the extinction of Australia's megafauna between 51 and 40 kyr. The studies that exist primarily employ palynological techniques; however, the interpretation of terrestrial vegetation records becomes complex within the nexus of combined human, fire, climate and mega-herbivore influences. An incomplete understanding of Australian climates during this period means questions remain regarding the relative influence of Northern and/or Southern Hemisphere forcing of Australian climate variability and the role of climate in the extinction of megafauna. Here we present a palaeohydrological record from Welsby Lagoon, a wetland in subtropical eastern Australia that was recently discovered to be over 100,000 years old. We use the oxygen isotopes of aquatic cellulose preserved in the sediment – which reflect the isotopic composition of the lake water – to infer hydrological variability between 85 and 40 kyr independent of changes in terrestrial vegetation.

Our results demonstrate substantial hydrological variability occurred during this period, with apparent links to both Antarctic temperatures and North Atlantic Heinrich events. We propose that this is due to the combined influence of sea-surface temperature variability and the impacts of ITCZ migration on the prevalence of south-easterly trade winds in transporting moisture to the study region. We find evidence of a notable shift towards drier climates during the megafauna extinction window at around 45 kyr, aligning with findings from elsewhere on the continent. Though the magnitude of this shift is not exceptional in our record, it does imply that, in the subtropics at least, climatic change may have played a contributing role in the demise of the megafauna.

P-1514

## Understanding terrestrial oxygen isotope records of climate change: Insights from a 5-year, daily resolved $\delta^{18}\text{O}$ precipitation record from southern Thailand

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### Abstract

Variations in oxygen isotopes in speleothems are often interpreted to reflect variations in the amount of precipitation controlled by changes in climate phenomena such as the monsoon or ENSO. However, this amount effect has recently been questioned, favoring other mechanisms such as moisture source(s), rainout history, shifts in climate patterns or front systems, or the influence of local convection. A more than 5 years long daily resolved precipitation and  $\delta^{18}\text{O}$  record from southern Thailand allows the relationship between precipitation patterns and rainwater  $\delta^{18}\text{O}$  to be examined. Rainfall at the Krabi station was highly irregular with rain events ranging from 0.1 mm to nearly 150 mm per day. Rainwater  $\delta^{18}\text{O}$  values vary from -17.50 to 8.24 ‰, with a long-term average close to -5 ‰. We demonstrate that while daily and amount-weighted seasonal  $\delta^{18}\text{O}$  values show no correlation with rain amount, the amount-weighted monthly values display a significant correlation with monthly rainfall. Statistical comparison to atmospheric parameters reveal a strong correlation to outgoing longwave radiation, suggesting that local convection rather than precipitation amount control variations in rainwater  $\delta^{18}\text{O}$  in this region. Comparison to a short cave drip water record suggests that the atmospheric  $\delta^{18}\text{O}$  signal is recorded with a muted amplitude in the drip water, and with a lag of one to two weeks.

**P-1515**

## **The link between Asian summer monsoon, polar and tropical regions during the Quaternary**

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### **Abstract**

A long-term decreasing trend in the Asian summer monsoon (ASM) during the Quaternary has been proposed to be associated with increasing ice volume, decreasing  $p\text{CO}_2$  and global temperature based on observations of changes on glacial-interglacial time scales. However, the long-term evolution of the ASM intensity during the Quaternary is still highly debated. The debate is mainly caused by the paucity of continuous geological records that cover the Quaternary and a lack of fidelity of paleo-proxies that could faithfully reflect monsoon intensity.

To understand this question, here we use a new proxy based on oxygen isotopic compositions of pedogenic carbonates from the Chinese Loess Plateau to reconstruct the ASM intensity over the past ~2.6 million years, which shows an increasing long-term ASM intensity, rather than a weakening trend. Then, we review the current geo-biological archives from ASM region to confirm our result. Afterward, we integrate the records from polar and tropical regions to explore the inter-regional processes from a global perspective.

**P-1518**

## **Aridity timeseries for 10 selected key regions of the global climate system during the last 60 000 years**

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### **Abstract**

Teleconnections existed at least from ~ 60 000 to ~ 48 000 yr b2k and from 25 000 to 15 000 yr b2k (LGM) from North Atlantic over Central Europe, Arabian Sea to China. Strong aridity can be shown during LGM (25 000 to 15 000 yr b2k) for Cariaco Basin, Central Europe, France, Portuguese Margin, NW-Africa, Mediterranean Sea, Arabian Sea and China. Early marine isotope stage 3 (MIS3, 60 000 – 48 000 yr b2k) was warm and Humid in Cariaco Basin, NW-Africa, Central Europe, Arabian Sea and China.

Published literature on the dust content in terrestrial and marine sediment cores is synchronized with terrestrial and marine pollen data and speleothem growth phases on a GICC05 time scale for ten selected key areas of the global climate system during the last 60 000 years. Records have different time resolution and are dated by different methods, but still are brought to a synthesis for each of the regions. All regions show speleothem growth during the early MIS3, sometimes continued into the middle MIS3, but mostly confined to interstadial times only. Dust is common during the entire MIS2, but dust deflation in some regions start in the middle MIS3. It is not always apparent if the dust deflation is confined to stadial phases only, because the time resolution is often not sufficient to resolve the stadial / interstadial phases precisely. A major problem for the middle and early MIS3 are the limitations of  $^{14}\text{C}$  dating. Finally, we detect only few regions where a MIS3 synthesis of dust, vegetation and speleothem growth results in coherent pattern. With all information of the ten regions combined, a newly developed Aridity Index is estimated. This Index reveals strong aridity patterns throughout the northern hemisphere. The regions show synchronous changes in vegetation, speleothem growth and Aeolian dust and in result Aridity, which can be explained by atmospheric teleconnections of the regions.

## P-1519

### A long, discontinuous speleothem record of Pleistocene hydroclimate variability in Central Europe

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### Abstract

Speleothems, such as stalagmites or flowstones, are unique continental archives of past climate and environmental dynamics. Past climate records can be established and precisely dated by a variety of independent proxies (such as  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) and U-series disequilibrium methods, respectively.

Here we present new speleothem  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  time series from a 1.3 meter-long calcite flowstone core (BÄ-1) drilled in the Bärenhöhle, Swabian Alb, Southern Germany. The 200 m long Bärenhöhle developed in Upper Jurassic limestone in the Pliocene and Early Pleistocene under epiphreatic conditions. Cave sediments and speleothems in the Bärenhöhle can be subdivided in at least 13 periods of speleothem growth, which reveal several accumulation and erosion processes during the early and middle Pleistocene. The location of Bärenhöhle can be strategically used to reconstruct past changes of mid-European hydroclimate and associated Northern Hemisphere (NH) mid-latitude atmospheric pattern highlighting the potential of speleothems from Bärenhöhle to gain a better understanding of mid-latitude climate variability.

The morphology of the flowstone core shows a succession of several growth periods, suggesting a discontinuous formation of BÄ-1. This is for example indicated by five thin sand layers and two soda straw layers (up to 3-4 cm thick) where no flowstone formation occurred, related to a stream that flowed through the cave, possibly during deglaciation periods. A first set of U-Th ages and the correlation of the BÄ-1  $\delta^{18}\text{O}$  time series to the benthic stack  $\delta^{18}\text{O}$  time series and a benthic  $\delta^{13}\text{C}$  time series reveal that the upper half of the flowstone core grew from c. 83 kyrs to 530 kyrs. Based on these preliminary analyses we find that the flow stone core includes several glacial-interglacial cycles during the last 530 kyrs, but did not grow during peak glacial conditions during MIS 12, 10 and presumably 6.

Absolutely dating of the bottom half of the flowstone core is not possible due to the secular equilibrium of U- and Th-isotopes, but U-isotope ages, the history of cave sediments in Bärenhöhle and a first magnetic record of BÄ-1 suggest that it grew between 530 kyrs and about 1.4 million years before present. However, both  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values from the bottom half of BÄ-1 show pronounced changes of several per mil that partially follow the benthic  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  time series, which suggest that some glacial-interglacial cycles are recorded.

In summary, our preliminary set of analyses on BÄ-1 emphasise the high potential of speleothems from Bärenhöhle to reconstruct Northern Hemisphere mid-latitude climate and environmental variations on long time scales that can be compared to other climate reconstructions from high (ice cores) and low (e.g. speleothem based monsoon reconstructions) latitudes. This will allow for a better understanding of interregional relationships/teleconnections on various time scales.

P-1601

## Developing a framework for Pleistocene hominin occupations, lake level change and landscape dynamics in the Ararat Depression, Southern Caucasus

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### Abstract

Situated at the intersection between of Africa and Eurasia, the Southern Caucasus is a key region in understanding hominin dispersal and behaviours during the Pleistocene. Specifically, the occurrence of a wide range of biomes and steep topographic gradients over small geographic area create an ideal locale to examine multi-scalar models of hominin-environment interactions. The Ararat Depression is a large intermontane basin located in Armenia and Turkey, bounded by the volcanic centres of Ararat and Aragats. Presently, the basin is drained by the river Arax; however, during the Quaternary there were several intervals in which lakes persisted in the area. Exposed on the surface today are the relict shorelines and deposits associated with these lakes, in addition to at least 200m of interbedded lacustrine and volcanogenic deposits representing the basin fill. Limestone escarpments outcrop on the eastern side of the depression, in which karstic cave and springs created thick travertine deposits. Several of these caves have yielded Palaeolithic archaeological remains, with further artefact surface scatters also identified. The wide range of depositional environments in the area offers enormous potential for the development of a high resolution chronological and environmental framework in this area.

Here we present preliminary results from ongoing investigations in the Armenian sector of the Ararat Depression as part of the Fritz Thyssen Foundation funded 'Pleistocene Hunter-Gather Lifeways and Population Dynamics in the Ararat (palaeo-lake) Depression, Armenia' project. We focus specifically on the results from extensive geomorphic mapping, deposit modelling and archaeological surveys undertaken, highlighting the ongoing chronological (OSL, U-Th, <sup>14</sup>C, tephrostratigraphy) and multiproxy environmental work currently being undertaken. It is envisaged that the results of this work will significantly expand our understanding of Pleistocene hominin population dynamics and environmental change in the Southern Caucasus and enable its articulations within the wider context of Southwest Asia.

P-1602

## New loess deposits in the southern Caucasus - On the way towards an interregional loess-stratigraphic scheme

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### Abstract

In the framework of a research project funded by the German Research Foundation (DFG), much work is being conducted on the Sevkar loess record, NE-Armenia, in order to explore it as a reliable and meaningful archive of palaeoenvironmental conditions. This work includes detailed stratigraphic analyses, extensive luminescence dating, sedimentological, mineralogical, geochemical, micromorphological, and clay mineral analyses, as well as terrestrial mollusc, biomarker, and pollen analyses. Although most of the work is still in progress, we are already able to provide a local to regional stratigraphic model for the Sevkar area (Tavush region) (see Wolf et al. 2016) based on the correlation of four individual loess sections, each of them with a thickness between 22 and 42 meters.

In the most recent past, we were successful in discovering further and not yet described loess and dust deposits in the Hrazdan area (Kotayk and Gegharkunik regions) as well as in the area of Stepanakert, Maghavuz in the Republic of Artsakh (Nagorno-Karabakh). Deposits in the latter area are similar to the loess in the Sevkar area, situated at the eastern foothills of the Lesser Caucasus at the transition to the Transcaucasian depression. Contrary, deposits close by Lake Sevan are located to the west of the main ridge of the Lesser Caucasus Mountains. This fact, together with the different character of the deposits as well as differing stratigraphic appearances, suggests disparate sediment sources and probably disparate conditions of dust formation, deposition, and post-sedimentary overprinting.

On the poster, a first stratigraphic overview of the different loess sites will be given together with observed similarities and differences. In addition, we will present some key sites that will be visited in the course of the post-conference excursion following the International Symposium on "Loess deposits as archives of environmental change in the past" that will take place from September 15<sup>th</sup> to 23<sup>th</sup>, 2019 in Yerevan (Armenia).

Wolf, D., Baumgart, P., Meszner, S., Fülling, A., Haubold, F., Sahakyan, L., Meliksetian, K., Faust, D. (2016): Loess in Armenia - Stratigraphic findings and palaeoenvironmental indications. *Proceedings of the Geologists' Association 127 (1)*, 29-39.

**P-1603**

## **Evidence of long ice-free conditions during MIS 3 in northern Finland**

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### **Abstract**

Northern Finland has been repeatedly in the centre of the Fennoscandian Ice Sheet during Late Pleistocene. Till stratigraphy is composed of several till beds having stratified sand and fines inter-till layers and sometimes organic material; peat and gyttja. However, many of them were dated in 1970s and 1980s using radiocarbon method, which gave unreliable ages 45 ka or more i.e. indicating the limit of the dating method to be reached (e.g. Hirvas 1991).

From the beginning of this century, many of the earlier stratigraphical key sections were re-examined and dated by Optical Stimulated Luminescence (OSL). Many of the inter-till layers have been dated back to Eemian or Early Weichselian (e.g. Mäkinen, 2005, Auri et al. 2008; Lunkka et al. 2015), but there were also indications of the Middle Weichselian ages and ice-free conditions during MIS3 (Salonen et al. 2014, Sarala et al. 2010, Johansson et al. 2011). Particularly, several new observations of the inter-till stratified sections with OSL dates supported the idea (e.g. Sarala & Eskola 2011, Sarala et al. 2016). The best section and the key site locates in Kaarreoja, northern Finnish Lapland, where the most well-preserved and representative sedimentary deposit including organic peat and wood pieces were studied and dated (Sarala et al. 2016). It is confirmed that during MIS3, in the middle of the most recent ice age, some 30,000–50,000 years ago, birch and coniferous forests grew in Lapland, Finland.

Nowadays, there are more than 100 reported OSL ages from northern Finland. The determined ages of Weichselian age form three groups: old 115-70 ka (MIS 5), middle 53-67 ka and young 21-46 ka (MIS 3). New dating results prove that the extent of glaciers and the length of glaciations were mostly short through Weichselian in Finland. During Early Weichselian, there were three short stadials, which occurred only in the northernmost Finland. Middle (MIS 4) and Late Weichselian (MIS 2) stadials lasted longer, and according to Sarala (2005) and Salonen et al. (2008) they were probably the only stages when glaciers covered central and southern Finland. Instead, during the MIS 3 northern Finland seems to be ice-free for a long time and the OSL ages (21-25 ka) from Veskonieni, close to Inarinjärvi Lake, indicate rapid build-up of continental ice to LGM limits (MIS 2). These observations support the recently strengthened idea of a variable climate within ice ages and the relatively short duration of glaciation cycles, as well as the rapid growth and melting of ice sheets during ice ages.

P-1604

## Global chronostratigraphical correlation table for the last 2.7 million years, version 2019 QI-500

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### Abstract

This poster shows the 2019 version of a table showing chronostratigraphical subdivisions of late Cenozoic geological time, aligned to key geological records from marine, glacial and terrestrial environments around the world. As did earlier versions (Gibbard & Cohen 2008; web updates, Bern 2011, Nagoya 2015), the chart aims to provide scientists, students, professionals and the general public with a ready reference to stratigraphical terms and schemes in use in different areas for similar periods. The chart received substantial updates, comprising the status of Quaternary chronostratigraphic subdivision (e.g. Head & Gibbard 2005; Walker et al. 2018), the combined age-modelled geomagnetic and isotope records from ocean drilling records (Channell et al. 2009, 2016), and revisions in regional correlation schemes, notably for eastern Europe (e.g. Shik 2014). The chart and a description text are to be published in the celebratory issue 500 of Quaternary International, to appear in open access at the time of the Dublin congress (Cohen & Gibbard, 2019) and will be distributed via stratigraphic commission websites (IUGS' ICS SQS: [www.stratigraphy.org](http://www.stratigraphy.org); INQUA SACCOM: [www.inqua.org](http://www.inqua.org)).

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P-1605

## Coiling ratio of *Globorotalia truncatulinoides*: a robust stratigraphic tool in the North East-Atlantic during the Holocene.

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### Abstract

Coiling ratios of planktonic foraminifera are commonly used in paleoceanographic studies to build stratigraphic sequences (e.g. *Neogloboquadrina pachyderma* sinistral form). Bolli (1950, 1951) noticed that such an exercise is especially possible with the species *Globorotalia truncatulinoides* because the ratio of sinistral vs dextral shells strongly varied in time and space. In Holocene sequences of the North East Atlantic ocean, authors usually use coiling ratio of *G. truncatulinoides* to identify a warm period (between 6 and 10 ka) marked by increases of sinistral form occurrences (Pujol 1980, Auffret et al., 1996, Zaragosi et al., 2000).

In this study, we consider changes in the coiling ratio of *G. truncatulinoides* over the last 15 000 years thanks to a collection and combination of ten marine sediment cores distributed from the Rockall trough to the southern Iberian Peninsula. This regional compilation aims to improve the precision of this stratigraphic as the work done by Ducassou et al. 2018 in the Gulf of Cádiz, especially in the definition of *G. truncatulinoides* events (TE1, TE2 and TE3). Preliminary results allow us to identify a marked change in *G. truncatulinoides* populations at 10 ka, with sinistral forms reaching up to 80% (TE3). This transient event which can extend to the mid Holocene depending on the considered site is characterized by a multi-step structure. Accurate datings of this interval will allow obtaining a robust stratigraphic tool for the Holocene. The *G. truncatulinoides* events TE1 and TE2 are not observed along all cores. These results bring us to understand more finely reasons of changes of coiling ration of *G. truncatulinoides*.

As counts of the two coiling forms of *G. truncatulinoides* are quite easy and do not imply high instrumental costs, such a study demonstrates that a robust stratigraphic framework can be efficiently obtained for Holocene marine archives on this basis.

P-1606

## Chronology and deltaic development of the Nakdong River delta area, southeastern Korean Peninsula

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### Abstract

Optically stimulated luminescence (OSL) dating was performed on Late Quaternary deltaic sequences from five long cores in the Nakdong River estuary, Korea. OSL ages obtained from chemically separated fine (4-11  $\mu\text{m}$ ) and coarse (90-250  $\mu\text{m}$ ) quartz grains ranged from  $14.0 \pm 0.8$  to  $0.4 \pm 0.04$  ka, revealing clear consistency between the grain-size fractions. The  $D_e$  values from the standardized growth curve (SGC) are consistent with those from the single-aliquot regenerative-dose (SAR) procedure, which suggests that the SGC is valid for the Nakdong deltaic sediments. However, different samples from different sites did not share dose-response characteristics. The  $^{14}\text{C}$  ages of shells and wood fragments ranged from 11 to 2.9 ka, demonstrating reasonable agreement with the OSL ages, within the error range. OSL ages obtained by high-resolution sampling show down-section variations in the depth-age curve, indicating the occurrence of rapid changes in sedimentation rate. The Nakdong deltaic sediments were divided into five units based on sedimentation rate. The lowest (unit 5) shows a break in sedimentation between the last glacial maximum (LGM) and the Holocene. The sedimentation rate increased in units 4 and 3, presumably corresponding to the early to middle Holocene sea level rise and high stand. Unit 2 shows a gradually decreasing sedimentation rate following the regression of the shoreline, until about 2 ka. The progradation of the Nakdong River delta resulted in the rapid accumulation of unit 1 during the last 2000 years.

P-1607

## Tephrostratigraphy of the Middle Paleolithic (MIS5-3) in southern Italy: the Infreschi and Grotta del Cavallo records

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### Abstract

Near or beyond the limit of radiocarbon dating (~54 ka), chronology of Middle Paleolithic archeological sites is challenging. This amplifies the ambiguity in correlating archeological successions among them and with paleoclimate archives, so limiting our understanding of historical processes and of the environmental context of archeological remains. Southern Italy archeological successions are important archives to reconstruct stratigraphy and chronology of Early to Middle Paleolithic technocomplexes thanks to the presence of tephra layers mostly originated by Campanian volcanoes (Giaccio et al., 2008; Zanchetta et al., 2018). In the last years the stratigraphy, chronology and the geochemical fingerprinting of these layers have been clarified allowing detailed correlation (Giaccio et al, 2017). In this contribution, we discuss the tephrostratigraphy of two marine caves filled by sediment containing prevailing Middle Paleolithic remains (Musterian) located ca. 200 km apart in southern Italy (Grotta di Infreschi and Grotta del Cavallo). In particular, we highlight the importance of the X-6 tephra marker at regional scale for the chronology of Musterian layers.

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P-1608

## Tephrostratigraphy of the basaltic Izu-oshima volcano during last 20,000 years using radiocarbon ages and distal tephras, off Tokyo Pacific Ocean

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### Abstract

The Izu-oshima volcano (110 km SSW of Tokyo) in northern Izu-Bonin Arc, is one of the most active Quaternary volcanoes in Japan. This volcano originating from basaltic magma has frequently erupted; that is, 12 times of major eruptions occurred after 2 ka. Studies of its eruption history have been carried out by Nakamura (1964), Kawanabe (2012) and so on. However, precise ages of eruption preceding the caldera formation occurred at 1.8 ka have not been determined. Here, we re-examine the chronological framework of eruption history of the Younger Edifice of pre-caldera.

Fall-out tephras are typically exposed along so-called Great Cut of Beds in SW part of the island. Previous studies by Tazawa (1990) and Uesugi et al. (1994) have described this outcrop, numbering each tephra layer using serial numbers (O1–95 and Osb96–127). All tephras except O55 and O58 are proximal fall-out tephras composed of scoriaceous lapilli and/or scoriaceous ash. Due to the large number of tephras and lithological similarity, it is difficult to confirm each tephra defined by previous studies except several characteristic ones such as O95, O58, and O55. O55 and O58 are rhyolitic tephras from Nijima island and Omuro-dashi submarine depression, respectively (Saito et al., 2007). Uesugi et al. (1994) estimated the age of the lowest tephra to be 25 ka or older by using 15 radiocarbon ages. However, this estimation is not reliable because it was determined using two oldest conventional radiocarbon ages (non-calibration) of 14–13 ka for the same horizon (just above O64) and under the assumption that the frequency of the tephra occurrence is constant.

In this study, radiocarbon dating was performed for organic tephric loess collected from 14 horizons under O58 and 11 above O58. The oldest radiocarbon age is 18,598–18,287 cal BP, determined at the horizon 4 m below O95. The age of O95, the most prominent scoria fall deposit, is most likely to be 16–17 ka judging from several radiocarbon ages. It is 2400–3700 years younger than the estimated age (19.4–19.7 ka) by Uesugi et al. (1994). We also recognized widespread K-Ah tephra using volcanic glass geochemistry. Two radiocarbon ages determined at 45 cm above and 55 cm below K-Ah are 6882–6747 cal BP and 8167–8021 cal BP, respectively. These ages are concordant with revised age of K-Ah (7307–7196 cal yrs BP; McLean et al., 2018), indicating the age of horizon detected K-Ah is older than estimated age of 6,330±85 yBP by Uesugi et al. (1994). These results indicate that the interval between O95 and K-Ah is shorter (67–75%) than previous estimation, suggesting higher frequent occurrence of the eruptions in this period.

**P-1609**

## **Do visible Holocene tephra from Mt. Churchill, Alaska, display varying geochemistry across their distributions?**

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### **Abstract**

Mt. Churchill, located in the Wrangell volcanic field close to the Alaska/Yukon border, is the suggested source of the late Holocene White River Ashes (WRAn and WRAe). These eruptions are separated in time by ~700 years and have geographical distributions related to their dominant plume directions (north and east, with some overlap). Visible tephra deposits are found up to 300 to 1500 km from Mt. Churchill with cryptotephra correlations extending 1000 to 7000 km (distances for WRAn and WRAe respectively).

Both eruptions have been geochemically characterised using proximal material (e.g. Preece et al., 2014) but their major element geochemical data, most commonly used to correlate and/or provenance distal tephra, show the eruptions produced two very similar rhyolites with only slight differences in their range of wt.% SiO<sub>2</sub>. This considerable overlap means additional information (e.g. stratigraphy, chronology, associated mineral Fe-Ti oxide data) is required to interpret which tephra is present where only one is found. Trace element geochemical data is also similar between eruptions, with broad ranges of values measured for several elements.

While distal samples of the WRAe have relatively constrained major element geochemical data across large distances (e.g. Jensen et al., 2014) there are comparatively fewer distal samples of WRAn analysed. The little data collected over several years on a limited number of widely-distributed WRAn samples at the University of Alberta show a more complicated geochemical picture for this older eruption - samples have variable wt.% SiO<sub>2</sub> ranges, some have bimodal rhyolitic populations. It is not clear if this relates to the eruption of a heterogeneous/zoned magma column or, potentially, multiple closely spaced eruptions.

Here, new samples collected from Haines Junction (YT) to Tok (AK) on a transect of 460 km moving from east to north of Mt. Churchill are geochemically characterised to investigate any variation with sample location/distance from source and to improve mapping of the known visible limits of each eruption/plume. Samples were analysed at the University of Alberta, Edmonton, producing major and trace element glass analyses and Fe-Ti oxide analyses of magnetite and ilmenite.

### References:

Jensen et al. (2014) Transatlantic distribution of the Alaskan White River Ash. *Geology* 42: 875–878.

Preece et al. (2014) Chemical complexity and source of the White River Ash, Alaska and Yukon. *Geosphere*, 10: 1020-1024.

P-1610

## Two new regional tephrostratigraphic markers from West Timor, Indonesia

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### Abstract

Timor, a southerly island east of Wallace's Line in SE Asia, preserves extensive Quaternary gravel deposits that have yielded fascinating fauna remains such as the highly dwarfed *Stegadon timorensis* and a larger *S. trigonocephalus*. The age of the older fossil-bearing gravels remain in question, with only one age determination of >130 ka derived from six <sup>230</sup>Th-<sup>238</sup>U dates on a tusk fragment found in the Raebia area. However, two tephra deposits were found bracketing these gravels near Raebia, a *S. timorensis* fossil locality 8 km northeast of Atambua city. Here we present the full geochemical and age characterization of these two tephras. Both tephras are high-silica rhyolites, but trace-element geochemistry suggests they originate from different regions in the Sunda-Banda volcanic arc north of Timor. The upper tephra (Raebia Tuff 1; RT1) has a greater enrichment in LREE and a steeper La/Yb profile, suggesting this unit is from a larger island in the arc (i.e. thicker crust), while the lower tephra (RT2) has a notably flatter profile. Biotite and zircons for <sup>40</sup>Ar/<sup>39</sup>Ar and laser ablation U-Pb dating were extracted from RT1, and zircons from the lower unit RT2. RT1 had zircons with two distinct age populations, but the youngest yield a <sup>230</sup>Th deficiency corrected <sup>206</sup>Pb/<sup>238</sup>U age of 665 ± 19 ka, (2s, n = 23, MSWD = 0.81), consistent with the <sup>40</sup>Ar/<sup>39</sup>Ar age 614.9 ± 16.4 ka (2s, full external precision). Preliminary zircon dates on RT2 are more problematic, providing a large range that suggests inheritance by xenoliths and/or locally-sourced detrital zircons. However, a single zircon yielded <sup>230</sup>Th deficiency corrected <sup>206</sup>Pb/<sup>238</sup>U age of 708 ± 66 ka (2s, n=17, MSWD = 0.41). RT2 has now also been correlated to a tephra at IODP Site U1483 on the northwest Australian margin, which offers an independent age verification. The identification of RT2 in U1483, and the geochemistry of RT1, shows that these two newly described tephras are regionally distributed and will likely be important stratigraphic horizons for this portion of Southern Wallacea and into the Indian Ocean. They also push the age for these fossils back by ~500,000 years.

**P-1611**

## **Tephra evidence for the explosive eruptions of Changbaishan volcano**

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### **Abstract**

Changbaishan volcano is known for its Millennium eruption (ME, AD 946; VEI 7) and the ME tephra has been detected in Greenland ice cores ~9000 km from the vent. However, the pre-Millennium (pre-ME) and post-Millennium (post-ME) eruptions are still poorly characterized. Combining field exposures with tephra layers recorded in lake sediments, detailed explosive eruptions of Changbaishan volcano were characterized. A pyroclastic fall deposit (more than 1 m thickness, and well sorted pumice lapilli) with an age older than 31 ka was found at its eastern flank. Tephra layers from Yuanchi lake ~30 km to the east of Changbaishan volcano illustrate that the tephra Qixiangzhan eruption can be traced from this lake to Suigetsu lake in central Japan, and the age of the controversial Qixiangzhan eruption (dated to 88 ka to 4 ka previously) can be constrained to ~8100 cal a BP. There are no tephra at around 4 ka in Yuanchi lake, which implies that the age of Tianwenfeng eruption should be more older than previous thought. Tephra from ME can be found about 700 km north to Changbaishan volcano, and the geochemical composition of glass shards from this eruption is different between south (east) and north (west) directions. Tephra from those historical documents recorded eruptions referred as post-ME eruptions (e.g., AD 1668, AD 1702) can be found at eastern flank of Changbaishan volcano, and even in the Sihailongwan lake sediments from Longgang volcanic field ~120 km west to the Changbaishan volcano.

**P-1612**

## **Converging tephra community effort to establish best-practices for data collection, analysis, and reporting**

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### **Abstract**

A renaissance in tephra research, involving volcanology, petrology, geochemistry, tephrochronology and tephrostratigraphy, is motivated by studies of environmental/climate change, sediment transport and deposition, archaeology, anthropology and natural hazards. During workshops in 2014 and 2017, the tephra research community concluded that it is crucial for future progress and advances in tephra studies to develop unified requirements for tephrochronological data collections. Proposed best practices in tephra data collection and reporting aim to establish a new research philosophy that is necessary to coordinate, simplify and broaden data contributions from various scientific disciplines. Using common, accessible mechanisms for tephra data archiving and retrieval, major advances are expected. By standardizing protocols for the collection, analysis and reporting of tephra field and laboratory data across and within disciplines, all relevant tephra information will be more easily shared through common databases while maintaining data uniformity and completeness.

An important aspect of data sharing is related to open access for standardized data and metadata. This element is remarkably well aligned with major data sharing initiatives and requirements that research and funding agencies are trying to establish (e.g., NSF, USGS).

While the community understands the value of open data access, it is important to develop mechanisms to ensure that original investigators receive credit, and that data users comply with data sharing licenses and policies established by the users. A similar framework is well established in the open source software community, but is often misused or misunderstood by the scientific community.

We present the latest community vision and initiative that will help to:

1. consistently collect and share data produced by various disciplines using tephra,
2. discuss basic and comprehensible metadata requirements,
3. train members of the research community from students to journal editors and reviewers.

In the future, machine learning tools will further broaden the benefits of standardized tephra sample data collection, analysis, and visualization that are not invasive to the end user. Assisted by advances in field and laboratory data collection software, digital checklists should ultimately take correlation and identification of tephra across geographically large areas to a new level that will clearly benefit all collaborative tephra research fields.

This project is partially supported by NSF and USGS.

**P-1613**

## **Identifying environmental records held within tephra layer morphology**

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### **Abstract**

This PhD project aims to develop the use of tephra layer morphology as a proxy for past environments and as a tool for environmental reconstruction. Tephra layers that are incorporated into the surface stratigraphy form isochrones which can be used to define a moment in time. Based on this, tephrochronology has made significant contributions to understanding the timing of change in past environments. This project seeks to develop aspects of direct environmental reconstruction from tephra layers themselves because variation in the thickness and morphology of tephra layers reflect Earth surface processes and the surface vegetation communities present at the time the tephra was deposited and stabilised as an enduring stratigraphic layer. Therefore, the morphology of the tephra layer itself can provide valuable insights into past land surface conditions, environmental processes and land management activities. Using tephra layers as a proxy in this way can provide a novel means for interpreting past environments and allows long-term human-environment interactions to be assessed, thus further developing uses of tephra layers in a stratigraphic context.

However, post depositional alterations by surface processes, for example cryoturbation or solifluction are also captured in the morphology of tephra layers, highlighting areas in the landscape that are dynamic, less resilient and sensitive to environmental change. Such processes can erase the initial form and thickness of the tephra layer created as it was deposited and incorporated into the stratigraphy, making both traditional tephrochronological studies and novel interpretations of layer morphology more challenging. Field-based study and experimentation in Iceland are used to assess these alternative sources of environmental information held within tephra layers, in order to create a new approach to the application of tephra layers in environmental research. This will both contribute to proxy development for past environments and also improve the interpretation of tephra layers to better understand volcanic eruptions, creating more accurate eruption parameter reconstructions and isopach maps of past tephra eruption volumes.

P-1614

## Post-depositional alterations of tephra layers as indicators for paleoenvironmental conditions

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### Abstract

The investigation of tephra layers in terrestrial sediment sections such as loess-paleosol-sequences is frequently used to temporally correlate archives on a regional, supra-regional or even continental scale. This study, however, concentrates on other aspects of tephrostratigraphy, such as the depositional milieu and the post-depositional alteration of the volcanic ashes. In that sense, the polygenetic sediment sequence of Bodoc north of Sfântu Gheorghe (Transylvania, Romania) at the bank of the Olt River was investigated. In this 15 m long section volcanic ashes are intercalated by sediments of fluvial, aeolian, and colluvial origin. The sequence covers the last glacial cycle, and the several, partly thick tephra layers originate from the dacitic Ciomadul (Csomád) volcanic dome complex (CVDC). The CVDC is known to host the youngest volcanic eruptions during the late Quaternary in the Carpathian-Pannonian region, occurring ca. 29 ka BP. Due to the polygenetic characteristics of the Bodoc section, the deposition of tephra differs between subaqueous and subaerial. In the course of this study, granulometric, geochemical and spectrophotometric analyses were conducted as proxies for the paleoenvironment. Additionally, magnetic parameters were measured in order to investigate diagenetic alterations, pedogenesis and to detect cryptotephra. The chronostratigraphy is based on OSL dating as well as stratigraphic correlation and geochemical comparison of tephra deposits. Field observations and preliminary results show that the tephra deposits were altered by redoximorphic and soil forming processes. Most striking are periglacial features such as block rotations at the contact between solifluction layers and persistent permafrost as well as ice-wedge casts. These features rank among the first reported strongly developed permafrost features in the Transylvanian Basin and indicate a harsh periglacial environment following the tephra fall out. The investigations about the post-depositional alterations of the tephra is presented within the context of the sedimentation dynamics controlled by the Late Pleistocene environmental evolution.

**P-1615**

## **The potential of cryptotephra in a volcanic environment.**

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### **Abstract**

Sumatra hosts at least 30 active or potentially active volcanoes close to highly populated areas and lies in close proximity to global transportation and trade routes. Despite these facts and the high humanitarian and economical hazard potential of these volcanoes, very little is known about the eruptive history of the Sumatran Volcanoes.

The Sumatephra Project aims to establish a tephrostratigraphic framework for Sumatra's volcanic activity during the Quaternary, which will help to quantify the eruptive activity and to identify the sources of these eruptions. To address this task, we are combining tephra and cryptotephra records from marine, lake and peat sediments, with classical on-land records. Combining proximal, medial and distal archives provides the opportunity to not only reveal the history of highly explosive eruptions in the region, but also to reconstruct the volcanic activity within certain areas in more detail. Which will lead to a better understanding of the eruption frequencies and their spatial distribution.

Within this project we adapted methods typically used to identify cryptotephra of highly explosive eruptions in distal to ultra-distal settings at higher latitudes to tropical peat swamps located within the volcanic arc in Central Sumatra. Given the sampling locations the clastic proportions within the peat is dominated by volcaniclastic material. This requires additional characterization of the glass shards to distinguish between primary (cryptotephra) and secondary deposits (background sediment input).

The goal is to not only identify deposits of widespread highly explosive eruptions, but also evaluate the potential of using these methods to reconstruct the eruptive history of volcanoes or volcanic areas including smaller explosive eruptions ( $\leq$  VEI 4). This is of particular interest in a highly vegetated tropical region with low preservation potential for moderate to small eruptions on land and limited historical record like Sumatra.

We will present peat core data from the vicinity of active and potentially active volcanoes from Central Sumatra.

P-1616

## **The Avellino event: a Bronze Age environmental reconstruction from the Pontine plain and the Fondi basin, southern Lazio, central Italy.**

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### **Abstract**

The major Early Bronze Age (EBA, about 2000-1650 BC) Avellino eruption of the Monte Somma Vesuvius has had an enormous impact on the landscape and inhabitants of the Campania region. This eruption buried the EBA landscape to the north and south of the volcano in a deep layer of volcanic ash. However, a small initial eruption had probably allowed the population to flee the area before this devastating event, heading inland rather than towards the sea. A multi-disciplinary research involving geology, palaeo-botany and archaeology has been set up to unravel the hypothesis, that a significant percentage of the refugees must have decided to resettle in the nearest coastal plains to the north - the Pontine Plain and Fondi Basin of South Lazio, and that it should therefore be possible to prove this by tracing the ecological, demographic and cultural impacts that this immigrant population must have had. This was further encouraged by the already established presence of distal AV-tephra within Holocene stratigraphy of these basins. This paper discusses the palaeogeographical and –ecological results needed to be able test the hypothesis. A detailed palaeogeographical reconstruction was made of these coastal plains to identify the AV-tephra layer within diverse EBA lake-marsh settings. Results show termination of marine influence, the presence of multiple lacustrine basins with different genesis and diachronous terrestrialization around the time of AV-tephra deposition. The palaeobotanical research has focused on reconstructing the vegetation in this area before and after the AV eruption, to detect the environmental impacts that should have been brought about by the influx of possible immigrants from Campania. High quality profiles of eight peat locations in the Pontine plain and the Fondi basin have been chosen. In addition, macro botanical research has been conducted in four of these case studies, to provide information on the local vegetation and environment around the profile locations. Where possible, plant macrofossils from terrestrial plants were extracted to obtain accurate radiocarbon dates allowing the construction of a precise chronology for the profiles. Palaeo-ecological analysis of peat in the Fondi basin shows that tephra deposition might have had a local effect on vegetation, but a limited effect on regional vegetation, while the overall human signal in the pollen record is weak. This suggests that the area was thinly populated during and directly after the Avellino event. During the project, an unexpected discovery was the presence of more than one tephra layer within the Holocene peaty sediments, opening the potential for an even more detailed palaeogeographical and –botanical analysis. New tephra characterisation studies have disclosed their origin and new radiocarbon datings have improved age control.

P-1617

## Establishing a tephra- and luminescence-based chronology for glacial lake outburst flood deposits in the Channelled Scablands of North America

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### Abstract

The largest known freshwater floods in Earth's history scoured the north-western USA from the late Pleistocene catastrophic drainage of ice-dammed glacial Lake Missoula. The resulting floods covered more than 7500 km<sup>2</sup>, leaving behind an impressive and dramatic landscape. Besides large-scale erosional features, the floods also deposited extensive sediment sequences. During these floods, eruptions from the Cascade volcanoes Mt St Helens (MSH) and Glacier Peak deposited volcanic ash over large areas of the Pacific Northwest, some of which, remarkably, were preserved as tephra layers within and overlying the flood sediment sequences.

The aim of this project is to develop a clear understanding of the nature, frequency, and timing of the cataclysmic glacial lake outburst floods by establishing a high-resolution chronology of these deposits by both optically stimulated luminescence (OSL) dating and tephrochronology. The magnitude of these floods, high sediment loads, and the depth of the water column diminish the likelihood that the OSL signals from the suspended sediment load were fully reset ('bleached') on deposition, making OSL dating challenging. Robust, independent age control is therefore of key importance. In this study, tephrochronology will serve as the independent age control for OSL dating; additionally, in some settings the OSL dating of sediment bracketing a tephra layer may be able to further constrain the timing of the corresponding eruption.

We use a combination of major and trace element chemistry to chemically fingerprint the tephra layers preserved in the flood deposits by comparison to reference samples of proximal deposits from Mt St Helens and well-characterised Glacier Peak deposits. Forty tephra samples collected from ten sites in Washington State were prepared and examined in the laboratory. This sample suite includes several occurrences of two closely spaced tephra layers, referred to as a couplet, and generally assigned to MSH set S on the basis of their stratigraphic position, field characteristics and major element chemistry. The clear geochemical correlation provided by this study of these distal tephra deposits preserved in flood deposits and the link to those of source-proximal tephra deposits offer a more robust correlation of different flood deposits across the region and greater insight into flood magnitude and frequency. When combined with OSL dating, the tephra-based evidence from these flood deposits provides insight into the timing of the deposition of flood sediments in the Channelled Scabland and potential links to loess deposits in the Palouse.

P-1618

## Determining possible controls on Icelandic volcanism during the last glacial period: an examination of the Greenland Ice-core tephra framework

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### Abstract

A link between increased volcanic activity in Iceland following the deglaciation has been suggested for some time ([Sigvaldason et al., 1992](#); [MacLennan et al., 2002](#), Kutterolf et al., 2019) and more recently studies have suggested a possible climatic control on Icelandic volcanism during the Holocene (Swindles et al., 2018). This poster will examine the relationship between Icelandic volcanism and climatic controls over a section of the last glacial period (25-50ka BP) using tephra data from the Greenland ice-cores. The Greenland ice-core records provide a master record of past climate changes through the last glacial period and also act as a repository of past volcanism with both volcanic aerosol (ice acidity and sulphate records) and tephra particulate matter (or glass shards) preserved in the ice. However, only the volcanic glass shards allows a geochemical link to specific Icelandic volcanic sources. The majority of deposits are preserved in cryptotephra form and continuous sampling of the NGRIP ice-core between 25-50ka allows an initial assessment of volcanic frequency during the last glacial period. A total of 88 individual volcanic events are recorded during this time period. Basaltic composition tephtras dominate the records and indicate frequent eruptions from the Grimsvötn, Katla and Kverkfjöll volcanoes in Iceland. An assessment of the eruptive frequency of different volcanic centres will be presented and links to any climatic forcing discussed.

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**P-1619**

## **Finding source: Integrating proximal and distal tephra records to obtain more complete volcanic histories, examples from the Cascade arc**

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### **Abstract**

At Summer Lake, Oregon, USA, an ~200 kyr outcrop record contains at least 90 tephra beds (Kuehn & Negrini, 2010) yielding an average frequency of one tephra per 2,200 years. Surprisingly, less than one quarter of these beds have been correlated to proximal deposits in the Cascade arc. This indicates that our understanding of the frequency and impacts of pyroclastic volcanism from Cascade arc volcanoes based on proximal records is woefully incomplete. By integrating proximal and distal records, this situation may be improved. Recent work in the Three-Sisters–Tumalo volcanic region, associated with a relatively active segment of the Cascade volcanic arc, has obtained stratigraphic and geochemical information on numerous proximal tephras and silicic lavas. To date, more than 50 field locations have been studied, yielding more than 180 samples. Statistical clustering suggests at least 30 and perhaps more than 40 geochemically and stratigraphically distinct populations. This adds substantially to a known catalog of several small late Holocene (e.g. ~2.2 ka Rock Mesa tephra) to much larger late Pleistocene (e.g. ~0.4 Ma Bend Pumice/Tumalo tuff, and ~0.65 Ma Desert Springs tuff) eruptions from this area. At least six tephra beds (II1, JJ, JJ0.2, G, F, and E1) at Summer Lake are newly correlated with their proximal equivalents near Three Sisters. Summer Lake bed F is the ~30-35 ka Wono tephra, a key regional time marker in Oregon, California, and Nevada, which forms a visible tephra bed as much as 500 km distant. The ~200 ka bed JJ has previously been correlated (Coleman et al., 2006) to Bear Lake, Utah/Idaho about 850 km distant. At least two Three Sisters tephras correlate to Carp Lake, Washington, about 200 km to the north-northeast. Carp Lake also contains an excellent record of the early (pre set C) tephra history of Mount Saint Helens. Geochemical and age relations suggest that Summer Lake beds I (~80 ka) and W (~190 ka) correlate with coarser deposits at Carp Lake and thus likely originate from Mount Saint Helens.

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P-1620

## The importance of grain size and shape in controlling the dispersion of the Vedde cryptotephra

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### Abstract

Volcanic ash is dispersed in the atmosphere after a large eruption according to meteorology and the physical properties of the particles, including size and shape. However, there are multiple definitions of size and shape for non-spherical volcanic ash particles. This affects our ability to use physical particle properties to understand tephra transport. It is generally assumed that large particles ( $> 100 \mu\text{m}$ ) fall out close enough to the volcano to be excluded from ash dispersion models. However, ash in tephra deposits that are hundreds, and even  $>1000 \text{ km}$ , from source can exceed  $100 \mu\text{m}$  in size, and its transport distance is often difficult to explain using numerical models of ash dispersion. Here, using X-ray computed tomography (CT) and optical microscopy, we measure the shape and size of samples of the Vedde ash from Iceland, an exceptionally widespread tephra layer in northern Europe. We find that ash that travelled further is lower sphericity, showing that shape is an important control on tephra dispersion. Shape also impacts particle size measurements, as size for non-spherical particles can be defined in several ways. We find that particle long axis, the parameter often reported by the cryptotephra community, is on average  $2.3 \times$  greater than geometric size, used by dispersion modellers. By using geometric size and quantifying shape, we can explain how Vedde ash particles of up to  $190 \mu\text{m}$  were transported  $> 1200 \text{ km}$  from source. We define a set of best practices for measuring the size and shape of cryptotephra shards and discuss the benefits and limitations of using physical particle properties to understand cryptotephra transport.

**P-1621**

## **The origin of ocean-rafted pumice found in Mesolithic to Medieval archaeological sites across the North Atlantic**

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### **Abstract**

Ocean-rafted pumice has been found at sites across the North Atlantic, from Arctic Canada, Greenland, Iceland, the British Isles, Scandinavia and Svalbard. The majority of finds were reported from Scottish archaeological sites dated from early Holocene to the second millennium CE, representing Mesolithic, through Neolithic, Bronze and Iron Age to Norse-medieval contexts.

We have investigated frequently found, yet hitherto largely unexamined, pumice pieces from archaeological sites along the North Atlantic and Barents Sea coasts of Northern Norway. The overall aim of the study was to explore spatiotemporal patterns of pumice deposition at a distal coastline and its prehistoric human use. This paper focuses specifically on establishing the origin of the pumice and on comparing the results to other North Atlantic finds. A set of 38 new samples were selected from 19 well-controlled, spatiotemporally diverse archaeological contexts dated to between 10,100 to 587 cal. years BP, and crucially, from sites of variable isostatic uplift. The samples were subjected to geochemical and use-wear analysis. The pumice pieces exhibit high variability in kinds of use-wear; most show evidence of being used as an abrasive tool on wood, bone, antler, or hide, with marks ranging from one or more grooves and furrows to flattened, polished surfaces, some of which created a faceted appearance. The shape of the largest piece suggests use as net floater for fishing. From a volcanological perspective, the pumice samples vary macroscopically in colour, vesicularity, phenocryst assemblage and proportion, roundness and degree of alteration.

Microprobe glass analyses conducted to identify the source of the pumice revealed that most are dacitic in composition with some being rhyolitic and two plotting in the field of trachyandesite. Similar to most of the pumice found in Scottish archaeological sites and on raised shorelines in Southern Norway, the majority of pumice from Northern Norwegian sites was produced by silicic eruptions of the Katla Volcanic System in Iceland. While some could be correlated to distinct, well-dated eruptions such as the 7,000-7,200 BP SILK-B tephras and the early Holocene Vikurholl pumice, the bulk displayed a compositional range that overlaps with the SILK-A tephras. These tephras were produced by several eruptions from Katla between 6,600 and 1,676 BP and show similar major element concentrations, although further trace element analyses might allow correlation to specific eruptions.

Our pilot study provides additional albeit mostly coarse-grained age control for pumice-bearing archaeological context in the North Atlantic and sheds new light on the availability, use and curation of natural pumice resources throughout the Holocene. Furthermore, these results contribute to a better understanding of ocean-circulation patterns and the nature and frequency of Holocene silicic eruptions from Katla with implications for the potential distal impact by ocean-rafted pumice from future Icelandic eruptions.

**P-1622**

## **Holocene tephrochronology of west Iceland**

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### **Abstract**

Emerging lake sediment records are rapidly improving Iceland's Holocene tephra stratigraphy and chronology. Here, we expand upon these recent developments with a securely-dated tephrochronological record from the lake Haukadalsvatn in west Iceland. We capitalize on the existing paleomagnetic secular variation (PSV) age model, which uses 54 ties points to synchronize Haukadalsvatn's high-resolution lake sediment record to a well-dated PSV master chronology from marine core MD99-2269 on the North Iceland Shelf. Major element composition permits the identification of 38 tephra layers over the last 10,500 years. Of these total 38 tephra, 13 can be traced to tephra found on the Vestfirðir peninsula and represent a series of well-dated key tephra markers for western and northwestern Iceland. By comparing Haukadalsvatn's tephra record to other well-dated lake sediment tephra records across Iceland, we hypothesize that the early Holocene demise and mid-late Holocene nucleation of ice caps over the most productive volcanos may have at least partially controlled the tephra layer frequency in Icelandic records. We argue that Haukadalsvatn serves as an important template for the tephrochronology of western Iceland and for future studies investigating the tephra records in more distal regions of the northwestern North Atlantic, such as Greenland.

P-1623

## The effect of volcanism on the submontane rainforest vegetation composition: palaeoecological evidence from Danau Njalau, Sumatra (Indonesia)

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### Abstract

Volcanic processes might have played an important role in the vegetation history of Sumatra, one of the largest and most tectonically active region in Southeast Asia. Palynological and macro-charcoal analysis results from Lake Njalau in the Kerinci Seblat National Park (KSNP) in Sumatra (Indonesia) provide an understanding of interactions between the volcanic deposition and vegetation in the past 5000 years. The deposition of volcanic material in the depression of the Lake Njalau (5100–4400 cal. yr BP) led to the dominance of pioneer species of *Casuarina* and *Myrica*, which grow in deforested land and volcano slopes (volcanophile taxa). The formation of the modern forest composition took several centuries after the volcanic deposition in the soil ended (ca. 900 years at ca. 2400 cal. yr BP). This suggests that the vegetation changes were not driven by a successional pattern, and soil formation was the most important environmental factor explaining this slow change in composition. The palynological records show no evidence for prehistoric human–landscape interactions in the area despite the close proximity to known megalith sites. The local fire regime reconstructed using macro-charcoal analysis indicates that fire was rare for the last 5000 years, and the average fire return interval was ca. 500 years. Phases of increased fire frequency could not be linked to either any of the vegetation phases or regional climatic changes, suggesting that fire occurrences were stochastic events. Our results overall suggest that volcanism has acted as one important driver of changes in the rainforests of the KSNP

**P-1624**

## **An important sedimentary archive adjacent to the Taupo Volcanic Zone, New Zealand: Volcanic activity and landscape evolution**

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### **Abstract**

Large caldera-forming rhyolite eruptions from the Central Volcanic Region have shaped New Zealand over the last c. 12 Ma. During the Quaternary the Taupo Volcanic Zone (TVZ) has been the most frequently active and productive Quaternary silicic system on Earth. Voluminous ignimbrites, many exceeding 100 km<sup>3</sup>, and at least two exceeding 1000 km<sup>3</sup>, have periodically spread over hundreds of km<sup>2</sup> of New Zealand's North Island, whilst related airfall deposits can be found over 3000 km from source.

Deposition and subsequent long-term remobilisation of vast volumes of pyroclastic material from these mega-eruptions cause abrupt, dramatic environmental changes. In adjacent river and coastal systems, the sudden influx of volcanic sediment result in valley aggradation, river avulsion, infilling of coastal embayments and coastal progradation. These large-scale sedimentary processes represent some of the most catastrophic, landscape-altering mechanisms in the world, particularly well preserved in the Whanganui Basin, in the southwest North Island of New Zealand.

Whanganui Basin is a 40,000 km<sup>2</sup>, Late Miocene-Pleistocene sedimentary basin located 200 km south of the active TVZ. It occupies a back-arc position with respect to the current Pacific-Australia plate boundary, located west of the main axial range composed of Mesozoic greywacke-argillite. Subsidence migrated southeast through time, facilitating preservation of a 4.5 km dominantly marine succession. Throughout the Quaternary, sedimentation has broadly matched subsidence resulting in deposition of shelf muds through to nearshore or coastal sands and occasional terrestrial deposits on a low-lying, broad coastal plain. The sedimentary record is preserved as 58 cyclothem resulting from Quaternary climatic fluctuation on 41 k (2.58 – 1Ma) and then 100 k timescales (1Ma – 0.125Ma). Late Quaternary uplift has exposed magnificent coastal and river valley sections through the basin fill, revealing one of the most complete Quaternary stratigraphic records of climate change exposed onland anywhere in the world.

Silicic volcanism and associated volcanoclastic processes are key drivers in the landscape evolution due to their magnitude and thus extensive, long-term impact. Ignimbrites from the TVZ flowed into the catchment areas draining into the Whanganui and other peripheral sedimentary basins. The unwelded parts of these ignimbrites were easily eroded and only fragmentary records remain. However, volcanoclastics preserved as river alluvium, coastal progradation fills, deltas and nearshore deposits are conspicuous. Silicic tephra are also common in both terrestrial and marine environments.

By 1 Ma, the coastline was moving rapidly south-west towards its present position, punctuated by glacial periods of low sea-level. By 0.5 Ma, preserved marine terraces were forming in interglacials and river aggradation terraces in glacials as uplift and subsequent dissection ensued.

P-1625

## A refined chronology of the Biały Kościół loess key section (Silesia, Poland) and comparison with other sections in European Lowlands

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### Abstract

The loess-paleosol sequence (LPS) at Biały Kościół (Silesia, Poland) has been recognized since many years as a regional key section in the northern branch of the European loess belt, spanning the last glacial-interglacial cycle. In spring 2017, a new and more complete profile was excavated immediately adjacent to the former section, and was sampled for several sedimentological and pedological investigations. 12 well-selected samples for optical dating (OSL, pIR-IRSL) were taken from the bottom of the section to the top.

From the previous section 21 OSL ages from coarse grains of quartz (90-125µm) were published by Moska et al. (2012), but for loess older than the Upper Pleniglacial results showed some inconsistencies and problems such as apparent age underestimates which were supposed to be induced by saturation effects. Some preliminary OSL ages from the previous profile on quartz fine grains (Zoeller, unpublished) partly agree with the ages by Moska et al. (2012) but tend towards somewhat higher ages ( $\geq 10\%$ ).

The present study tries to overcome these problems by applying the pIR-IR method using polymineral fine grains, complementary to OSL of quartz. The suitability of the pIR-IR method to avoid OSL age underestimates due to saturation effects was basically demonstrated by Moska et al. (2015) at the Złota LPS near Sandomierz. The optical sensitivity of the pIR-IRSL signal is, however, much less than of the OSL signal from quartz, eventually leading to significant age overestimates for young loess. We therefore intend to check the risk and the amount of pIR-IR age overestimation for young loess samples from Biały Kościół (<30 ka) for which quartz OSL ages are regarded reliable. As a pIR-IR age overestimation derives from a residual dose unbleached at deposition and is a numerical value expected in the range of very few ka only we expect that it becomes insignificant (<10%) for Middle or Lower Pleniglacial loess. Luminescence ages which are reliable within error bars will improve the chronostratigraphy of at least the complete last glacial cycle in Silesia.

Latest results from the ongoing research into the new profile will be presented and serve as a base for well-founded correlations with other key sections on a regional and continental scale.

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P-1626

## Local, regional or global climatic signal? A multiproxy analysis of complex loess-palaeosol sequences from the Bulgarian Middle Danube

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### Abstract

Due to their completeness and location loess-palaeosol sequences in Europe provide an opportunity to investigate in detail the last glacial-interglacial cycle. Most of the investigated records in Central and Eastern Europe fall into the typical “loess” sequence, with thick glacial loess units, broken up by a small number of well-developed interglacial and/or interstadial palaeosols. Despite a number of studies investigating short-term pedogenesis and embryonic soils in Western European loess belts, not many of these features have been described in Central and Eastern Europe. Yet these sequences have the potential to provide a detailed picture of short-term local, environmental, geomorphological or climatic conditions.

Here we present the results of a multi-proxy examination of two nearby loess-palaeosol sequences in northern Bulgaria. These sites differ from other sites investigated in the region as they preserve many embryonic soil horizons. We present the results of magnetic susceptibility, grain size, luminescence dating, and tephrochronology. The results show that sediment accumulation at the sites during the Last Glacial Maximum is almost equivalent to a full glacial-interglacial cycle recorded at sites further downstream, further highlighting the differences between the upper and lower reaches of the Lower Danube. Additionally, this work uses single grain provenance as a new tool to help understand and reconcile complex sedimentary histories. The results of U-Pb zircon dating combined with sedimentological analysis show that the two sites either experienced different depositional histories or there was a switch in the sediment delivery mechanism to the sites. We suggest that these complex loess-palaeosol sequences may hold the key to a better understanding of the Quaternary in Central Europe.

P-1627

## Is it possible to disentangle sedimentary and post-depositional processes in loess sequences? – Experiences from the loess sequence Krems-Wachtberg, Lower Austria

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### Abstract

Loess-paleosol sequences (LPS) are sensitive terrestrial archives of past aeolian dynamics and paleoclimatic change. Numerous paleoenvironmental reconstructions from loess records have traditionally depended on the analysis of grain size (GS) distributions. A number of GS based statistical approaches are widely used. However, the GS distribution of a loess sample is not solely a function of aeolian dynamics, but rather of complex polygenetic depositional and post-depositional processes.

At the well-differentiated LPS Duesseldorf Grafenberg (Lower Rhine Embayment, Germany), the  $\Delta\text{GSD}_{\text{clr}}$  was identified as promising indicator for post-depositional alteration processes in LPS (Schulte and Lehmkuhl 2018). It is based on two different optical models to calculate GS distributions from laser diffraction data. We apply the  $\Delta\text{GSD}_{\text{clr}}$  on the weakly differentiated last glacial LPS Krems-Wachtberg (Lower Austria) in order to evaluate its use in a loess record without distinct paleosols. The 8 m thick LPS records paleoenvironmental fluctuations between 40-20 ka in a sequence of loess sediments, reworked horizons and incipient paleosols, mainly of tundra gley type. A Beckmann Coulter LS 13320 measured GS from samples taken in 2.5 cm resolution along the whole LPS.

$\Delta\text{GSD}_{\text{clr}}$  values range around zero in the entire dataset. Nevertheless, the vertical variation of the  $\Delta\text{GSD}_{\text{clr}}$  signature is directly related to post-sedimentary processes and reflect zones alternated by chemical weathering processes. The degree of pedogenesis detected by the  $\Delta\text{GSD}_{\text{clr}}$  is markedly lower than suggested by colorimetric data.

We conclude that detailed grain size information (e.g.  $\Delta\text{GSD}_{\text{clr}}$  values) can be used as a reliable proxy for past aeolian dynamics. In combination with a robust color-based stratigraphy the comparison of LPS Krems-Wachtberg to the LPS Nussloch and the NGRIP dust and oxygen isotope records is possible.

P-1628

## Last Glacial environmental changes in Loess-Palaeosol-Sequences of the Schwalbenberg (Middle Rhine, Germany) - combining in-situ sensing techniques and mutli-proxy sediment analyses

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### Abstract

Loess deposits in Europe extend from the maritime North Atlantic-influenced climatic zone of northwest Europe, to the Mediterranean-influenced southeast and the long, thick deposits influenced by Eurasian continental climate in the East. Western Central Europe sits at the core of these deposits; its location has ensured variable influence through time by both maritime and continental climate subsystems, as well as experiencing strong climatic gradients between glaciated areas in the north, and the Alps in the south. In this context, the Schwalbenberg in the Middle Rhine valley in Germany is a key area for understanding terrestrial system response to North Atlantic Climate Oscillations within the western part of Central Europe.

Previous studies indicate that loess deposits in the Schwalbenberg area are particularly thick, resolving especially the interpleniglacial period (OIS 3) in detail. However, these studies were bound to one available outcrop located in slope position enabling the creation of a local stratigraphy, which was used for a correlation to regional and supra-regional records of environmental and climate change.

Following the catena principle from downslope to interfluvial position, we conducted systematic non-invasive geophysical prospection, followed by the application of Direct Sensing techniques using the Hydraulic Profiling Tool (HPT) and Cone Penetration Testing (CPT) and subsequent sediment coring in order to obtain detailed information on the variability of the sedimentary composition along the transect. Stratigraphical data were complemented by sedimentological and geochemical analyses and the determination of rock magnetic parameters. The chronostratigraphical framework is based on radiocarbon dating of earthworm calcite granules, luminescence dating using the quartz OSL and feldspar pIR IRSL signals, palaeomagnetic time series and intercalated volcanic ashes.

We are able to demonstrate that investigated novel Loess-Palaeosol-Sequences from the Schwalbenberg area yield the thickest and most complete non-aquatic record of environmental change in Western and Central Europe for the entire Last Glacial Cycle. Furthermore, the combination of direct sensing techniques and geophysical measurements allows for accurate mapping of stratigraphical marker horizons (e.g. soil horizons, tephra layers), significant layer



boundaries (e.g. transition from loess deposits to fluvial and colluvial sediments) and erosional events along the geomorphological transect. Thus, the combined approach allows for the detection of variations between different coring and sensing locations, which enables us to decouple local, regional and supra-regional processes acting on the deposits and to elucidate the nature of loess deposition and formation through the Last Glacial Cycle.

P-1629

## Superposition of paleosol horizons in the last 350 ka: a case study from the Hévízgyörk loess-paleosol sequence (Hungary)

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### Abstract

#### Abstract

A multi-proxy analysis, including grain size, magnetic susceptibility, diffuse reflectance and soil geochemistry, the examination of stable isotopes of hypocoatings, was performed on the loess-paleosol succession at Hévízgyörk (Hungary). Field investigations suggested a continuous record of sedimentation and pedogenesis at first sight. However, after the identification of the Bag Tephra (Horváth, 2001), a characteristic late Middle Pleistocene marker horizon in the Pannonian Basin, it was getting clear that paleosols and loesses are missing from the section. In contrast to the field observations, fluctuations were identified in the measured proxies in the upper paleosol, potentially indicating the presence of more than one paleosol, merging into a single paleosol.

Presumably, paleogeomorphological processes supposed to be responsible for the superposition of the paleosols, alongside of the differences between the paleoenvironment and local geomorphological position. Erosional processes could be more intensive during the beginning of interglacials along the slope, when vegetation was sparse but precipitation increased. On the other hand, it is presumed that sedimentation decreased locally, during dry, cold glacial periods, because the strong winds carried away the deposited dust. These paleoenvironmental features may well have led to the partial erosion of paleosol horizons and the lack of or entire alteration of thin loess formed during the glacials, therefore the superpositioning development of successive paleosols.

Based on their pedogenic characteristics, the investigated paleosols presumably developed during intensive interglacials and thus can be correlated to global interglacial intensities (Past Interglacials Working Group of PAGES, 2016), and gives an opportunity to define key units of the Hungarian loess stratigraphy (Thiel et al., 2014; Újvári et al., 2014).

According to the interpretation about the superpositioning, the upper paleosol could contain the MIS 7e, the MIS 7a and the MIS 5 paleosols or at least two of them, while the intercalated loess (MIS 6), and possibly the MIS 7a paleosol, were totally eroded.

The case study shows that although the superposition of paleosols disrupts the clear chronostratigraphical subdivision of the section, it can nonetheless provide valuable information about the sequence evolution.

### Acknowledgement

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P-1630

## Paleoclimate change record in the Dejvice loess-paleosol sequence (Prague, Czech Republic)

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### Abstract

#### Introduction:

Loess-paleosol sequences often record information useful for the reconstruction of paleoenvironmental processes such as periods of increased dust accumulation, erosion or landscape stability (soil formation) triggered by climate changes. This study is focused on a loess-paleosol sequence exposed in Dejvice, located near downtown Prague, Czech Republic, which was investigated during a rescue research.

**Methodology:** The loess-paleosol sequence was studied using a multi proxy approach. Magnetic susceptibility and magnetic fabric (anisotropy of magnetic susceptibility) methods and geochemical approaches (total organic carbon, XRF elemental analyses, XRD mineralogy, <sup>13</sup>C and <sup>18</sup>O stable isotopes) were used to interpret the paleoenvironmental record. Optically stimulated luminescence (OSL) dating was used to determine the chronology of the section which is essential for understanding the link between climatic shifts and depositional and post-depositional regimes.

**Results and Preliminary Conclusions:** The loess-paleosol sequence is 15 m thick and includes loess and colluvial deposits, representing cold stages, and at least 4 different paleosol horizons, developed during warmer periods. The section records the climatic oscillations during the last two glacial stages. The Dejvice sequence contains a partly eroded weakly developed paleosol classified as PK I (MIS 3), a Chernozem and a Luvisol of PK III (MIS 5e). The oldest detected paleosol is a Luvisol of PK IV. The Dejvice sequence was highly affected by several erosion events. There is a hiatus of approximately 50 ka corresponding to the Early Weichselian. Gravel and colluvial deposits are present in a number of layers in the section. The record preserved in the section corresponds well to other sections exposed in central Bohemia and shows significant paleoclimate changes.



Figure 1: The Dejvice loess-paleosol sequence Prague, Czech Republic.

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P-1631

## Mineral analysis (QEMSCAN® method) of the loess-palaeosol sequence in Złota (Sandomierz Upland, Poland) – preliminary results

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### Abstract

The mineralogy of the five loess samples from the Złota loess-palaeosol sequence (LPS) was analysed by the QEMSCAN® - Quantitative Evaluation of Minerals by Scanning Electron Microscopy. Each sample was placed into silicon cup and covered by Epofix (cold mounting). Samples were then treated by a low vacuum to remove air vesicles. The hardened surface was grinded, polished and carbon-coated. The final samples were transferred to the sample holder dedicated to the QEMSCAN® analysis.

The used QEMSCAN® combines an automated scanning electron microscope (SEM) with two energy-dispersive X-ray spectrometers (EDS). The backscattered scanning electron signal (BSE) controls the acquisition of EDS spectra identifying the chemical composition of the sample surface. The measurements are compared against a database of known mineral phases and classified into hierarchically-grouped mineral list. Mineral identification, mapping and data analysis are performed by the iDiscover® software.

In Złota LPS the dominant rock-forming mineral components are quartz, feldspars, carbonates (calcite and dolomite) and micas. In heavy minerals group there are zircons, tourmalines, garnets, pyroxenes, automorphic titanium-rich minerals (ilmenite, titanite, and polymorphic forms of TiO<sub>2</sub> e.g. rutile), etc. Furthermore, gold and electrum were found. The preliminary results reveal also that in Złota there are present rare REE-bearing heavy minerals e.g. Allantite-(Ce) and Xenotime-(Y), which are characteristic for "NYF" granitic pegmatites. For each sample QEMSCAN® provided quantitative mineralogy data, textural information in form of mineral maps of the scanned sample surface, and mineral-specific size and shape attributes. The mineralogical analyses confirmed earlier results of chemical composition analyses e.g. clear distinction between L1LL1 and L1LL2 loess units.

P-1632

## Grain size variation of loess in Poland

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### Abstract

Loess in Poland occupies the central area of the northern zone of occurrence of loess in Europe - one of the largest loess areas in the world. Because of their characteristic transitional location, they are among the most interesting on the continent. Their granulometric diversity is the main subject of this study.

The analysis was based on the grain size distribution of L1LL1 loess units of three loess-soil sequences that represent the three most important loess areas in Poland. Loess-soil sequences are well suited for studying past changes, although in most cases sediment properties can't be associated with only one process. An important condition for pre-separation of signals coming from sediments and further reconstruction of parameters is to examine the contemporary spatial variability of sediment characteristics and apply appropriate models. Observable sediment properties are the result of the interaction of many processes. Several statistical methods have been used to diagnose them well. One of them is the flexible end-member modeling algorithm (EMMA). This algorithm calculates the so-called "end members" which represent sources and processes affecting the lithological features of loess. The statistical *k*-median method was also used in the granulometric analysis. This method allowed the separation of several groups in the L1LL1 loess structure.

These groups were characterized by different grain characteristics and suggest different features of the loess sedimentation environment between western and eastern Poland. The western part of Poland has many features related to the loess of Western Europe deposited in the marine climate. Loess in eastern Poland had more features related to the deposit in the continental climate. The results of the analysis show the dissimilarity of granulometric features of SW Poland loess represented by the sequence in Biały Kościół (Strzelin Hills) in relation to the loess of the eastern part of the country. Loess at this place is characterized by a different composition and structure, which is confirmed by the results of *k*-median analysis. It is confirmed by enrichment of fine dust fractions. The results of grain-size analysis of Złota and Tyszowce sections show a lot of similarities and differ to a small extent. Within all analyzed L1LL1 units *k*-median analysis suggests the presence of three different subpopulations which may suggest a differentiation of the loess formation processes. Subpopulations are reflected in the number of calculated particle-based "end members".

The obtained results confirm that the process of forming the L1LL1 unit was not continuous. The subpopulations separated by statistical methods indirectly inform about climatic conditions prevailing in the sedimentation environment, i.e. with different sedimentation coefficient, as well as factors affecting the pollination from various sources.

**P-1633**

## **Colorimetric variations of loess-paleosol sequences in SW Poland**

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### **Abstract**

Loess-paleosol sequences (LPS) are terrestrial records of paleoenvironmental changes in the Pleistocene, which develop in the interplay of aeolian sedimentation, pedogenesis, slope processes and erosion. Color variations along the stratigraphic sequence of LPS result mainly from pedogenic overprinting during sedimentary pauses. Brownish to reddish colors reflect different degrees and conditions of oxidation, whereas grey colors can be attributed to reduction (tundra gleys). Color variations are complex, indirect proxies for paleoclimatic changes and increasingly recognized in loess research.

This poster studies the colorimetric variations of two last glacial LPS in SW Poland. The LPS Zaprężyn is located at 165 m a.s.l. at the southern margin of the Trzebnickie Hills, where loess sediments have a thickness of about 4-6 m. The LPS Biały Kościół is located 60 km further south on the west slope of the Oława river valley at an altitude of approximately 185 m a.s.l. The profile is located in an old loam pit and exposes 9 m interfluvial and slope loess.

An overall number of 1500 samples were collected with 1 cm intervals from both profiles. A Konica Minolta 600d spectrophotometer quantified their color variations objectively, reproducibly and non-destructively. The results are presented in the CIELAB color space and then converted to the RGB color scale. The measured color values were the basis for the differentiation and classification of profile units using widely established pedological standards (e.g. A, B, C master horizons). This classification has sufficient sensitivity in detecting stratigraphically significant changes in the intensity of pedogenesis processes.

The analysis of colorimetric variation of the loess-soil sequences in SW Poland allowed for several conclusions:

- \* Colorimetric studies confirm the presence of major lithostratigraphic units.
- \* Color measurement and their vertical differentiation allowed to separate new subunits even in seemingly homogeneous loess units.
- \* High resolution colorimetric studies play a significant role in clarifying the stratigraphic division of LPS.

P-1634

## Chronostratigraphy of Late Pleistocene loess-palaeosol sequences in Poland – record of discontinuous sedimentation

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### Abstract

Loess covers in Poland are situated in the southern part of the country, along the northern margin of the central part of the European loess belt. Their location and origin are clearly connected with the Pleistocene glaciations.

In the 1991 book entitled “Main Sections of Loesses in Poland” about 50 loess profiles were characterized that represented all loess areas in Poland. According to Maruszczak’s chronostratigraphic scheme, the Late Pleistocene loess-palaeosol sequences (LPS) consists of four main loess deposition stages: Early Weichselian and lower, middle and upper Pleniglacial age (Marine Isotope Stage - MIS 5b, 4, 3 and 2). Maruszczak claimed that the Late Pleistocene loess sedimentation process in Poland was almost continuous and very well correlated with the marine record. At the end of the 20th century most of the questions concerning Late Pleistocene loess in Poland (stratigraphy, age by means of the TL method, rate of deposition, periglacial record and others) seemed to be well explained and documented.

To verify previous chronostratigraphic scheme of the Late Pleistocene LPS in Poland new research was performed during the last 10 years, using a new methodological approach. Several representative loess successions were chosen along the latitudinal transect from western to eastern Poland. These LPS were sampled in vertical continuous sections at close intervals (5 cm) and comprehensively documented. Grain-size distribution, carbonate and organic carbon contents, geochemical composition and magnetic susceptibility were determined.

To emphasize the global nature of loess sedimentation a slightly modified labelling system elaborated for the Chinese Loess Plateau was used. High resolution optically stimulated luminescence (OSL) dating was performed: Post-IR IRSL method for the polymineral fraction (4-11  $\mu\text{m}$ ) and OSL method for medium quartz fraction (45-63  $\mu\text{m}$ ). Radiocarbon dating was conducted for chronostratigraphic modelling.

The results of the investigations allow drawing some conclusions. The research results obtained to date, indicate that Late Pleistocene loess sedimentation in Poland was not a continuous process. Aeolian dust was deposited mainly during MIS 4 and 2. No evidence was found to confirm the significant deposition of loess in the middle Pleniglacial (MIS 3). In warmer Late Pleistocene stages (MIS 5 and 3) the rate of loess deposition was reduced almost to zero. The results of high resolution dating indicate short but very intensive processes of aeolian dust deposition which took place in very harsh climatic conditions with very sparse plant cover. Confirmation of this interpretation is the common occurrence of the primary loess lamination - especially characteristic for L1L1 loess.



The research was performed under the National Science Centre project No. 2011/01/D/ST10/06049 entitled “Establishing the chronology of Late Pleistocene loess formation in Poland on the basis of high resolution luminescence dating and litho-pedological studies of selected loess-soil sequences”.

**P-1635**

## **Refining the chronology of the Balta Alba Kurgan loess (Lower Danube, Romania) using a multi-method dating approach**

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### **Abstract**

The loess-palaeosol sequence of the Balta Alba Kurgan profile is located in the steppe landscape of the Lower Danube Basin (Romania). The stratigraphic sequence encompasses an interglacial soil complex at the base, as well as interstadial soil horizons and a tephra layer as chronological markers. The latter has been identified as the 39-40 ka old Campanian Ignimbrite (Y5) tephra. The flank of a Neolithic to Bronze Age tumulus intercalated in the Holocene soil which developed during continuous dust input forms the top of the sequence.

Optically stimulated luminescence (OSL) dating has frequently been used to date loess deposits. This method is well suited, because it directly determines the time of sediment deposition. For this study we compared sand-sized quartz and potassium feldspar samples as well as polymineral fine-grained samples using blue stimulation for quartz minerals and infrared stimulation (IRSL) as well as post-infrared infrared stimulation (p-IR IRSL) for potassium feldspar and polymineral samples, for a comprehensive luminescence chronology and to identify the best dating technique for these sediments. However, luminescence age estimates are limited, when investigating short term palaeoenvironmental fluctuations. Therefore, we apply a multi-method dating approach to refine the chronology of the Balta Alba Kurgan profile. This approach includes investigating the potential of radiocarbon dating of earthworm calcite granules in the sediment and palaeomagnetic dating of the section.

P-1636

## Environmental magnetic and colorimetric screening of a last glacial loess profile from Lower Silesia: evidence for a harsh periglacial environment

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### Abstract

Central European loess-palaeosol sequences (LPS) are valuable recorders of Late Pleistocene climatic change, especially in areas where other geoarchives are rare or absent. However, in the vicinity of the ice margins mid latitude last glacial loess sequences are strongly influenced by periglacially controlled humidity variations. Deep seasonal frost and permafrost cause periodic waterlogging, which in turn is responsible for pervasive redoximorphy, leading to reduction and mobilisation of iron (Fe) and re-precipitation of Fe-minerals. These processes alter colour and magnetic properties in LPS. Here we present preliminary results from a multidisciplinary study on a Late Pleistocene LPS from Lower Silesia (Poland), strongly effected by redoximorphy.

The Biały Kościół (BK) section is situated in Lower Silesia, approximately 130 km south of the last glacial maximum ice extent. The profile is considered as one of the most complete LPS in SW-Poland covering the last glacial cycle. Previous studies provide numerical ages by optical stimulated luminescence and radiocarbon dating, as well as grain size analysis, pointing to a time-span ranging from the latest Pleistocene down to the last interglacial.

Preliminary environmental magnetic and colorimetric data show the strong influence of secondary alteration, largely caused by redoximorphy of variable degree. In general, in the dry steppe loess of Eurasia, pedogenesis leads usually to brunification and to so-called magnetic enhancement which is caused by the neoformation of superfine magnetic minerals in the course of silicate weathering. At BK, magnetic enhancement is only realized in the Holocene soil, whereas the remaining sediments show solely a strong depletion of magnetic signals.

Quantitative magnetic susceptibility measurements display distinct and consistent units, with their highest values in the Holocene soil and in the lower third of the sequence, whereas qualitative parameters detect increasing alternation of the materials' magnetic composition with increasing depth. In contrast to most Eurasian dry loess areas, BK does not display any magnetic enhancement except for the Holocene soil. We assume, that the primary detrital signal is overprinted by early diagenesis and simultaneously modulated by complex redoximorphic processes. Interestingly and so far not explainable by physics, but stratigraphically consistent, intervals of negative frequency dependence of magnetic susceptibility are restricted to intervals of most intense redoximorphy. It is telling, that this phenomenon has already been observed in southern Siberian LPS.

Combined environmental magnetic and colorimetric results show distinct features of a profile close to the last glacial ice margin with fundamental differences to characteristic steppe loess of Eurasia. Based on the completeness of the profile, its geographic location, previous analyses, and newly obtained results, the loess profile of BK has great potential to become a key profile for periglacial loess in Silesia and beyond, hopefully improving our understanding of the impact of harsh periglacial environments on LPS.

**P-1637**

## **Late Pleistocene loess deposits and palaeoenvironmental conditions in Iskitim district, Novosibirsk Ob region, West Siberia**

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### **Abstract**

Late Pleistocene loess deposits are widespread in the Iskitim region. Its thickness varies from 1 to 10 meters mostly depending on geomorphological settings. Loess and loess-like deposits of MIS-2 and MIS-3 are most common. The farther from Ob Loess Plateau (up to 8-9 m; Lozhok section) to the east to the foothills of the Salair (Prisalair plain), the lower the cover thickness (up to 4-5 m, Ust'-Chem and Koen sections, MIS2-MIS4). The fullest and the most representative sections are Lozhok (MIS2-MIS-6) and Mramornyi (MIS-2-MIS-4). Sand quartz grain morphoscopy of all studied sections revealed the aeolian processes during the sedimentation and traces of cryogenic processes. As it was shown by high-resolution grain size distribution (interval 5 cm and 2 cm) the dynamics activity increased from the Tulino loess (MIS-4) to the Bagan loess (2<sup>nd</sup> half of MIS-2). Frequency-dependent magnetic susceptibility increases in paleosol horizons, while in loess layers its value is lower. Detailed bulk chemical composition (Sizikova, Zykina, 2015) and elemental ratios (Ba/Sr, Sr/Ca, Mg/Sr, Mg/Ca, with interval of 5 cm in Lozhok section) determine several peaks that seems to indicate paleoclimate humidification. During the latest field investigations of the Lozhok profile, some traces of weekly developed soil formation were noted, which had not previously distinguished as a separate horizon. They are marked above two horizons of paleosols (MIS-5e and MIS-5c) of Berdsk pedocomplex. At this stage of the study, we cannot unambiguously attribute this layer with soil formation of the substage MIS-5a, which is practically not found in this area before. Further research will help to understand whether there is a connection between its formation and the events of MIS-5a.

Multi-method data show that in the second half of the Sartan Glaciation (MIS-2), the environmental conditions in the area was apparently the driest and the coldest, being favorable for aeolian processes.

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**P-1638**

## **Cryogenic features in loess of Pleistocene periglacial zone (Volga region, Russia)**

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### **Abstract**

Loess-soil formations within the Pleistocene periglacial zone are widely spread. Most researchers believe that cyclical climate variations in the Pleistocene are fixed in the structure of loess-soil formations. This work presents the results of complex cryolithological analysis for sediments of sections of the left bank of the Akhtuba River (the southern periphery of the loess European area, Russia).

A cryolithological analysis of mineral matter was conducted to assess the paleogeographic conditions of their formation. The analysis was performed by using scanning electron microscope (SEM), particle size analyzer and X-Ray diffractometer to assess the degree of influence of cryogenic processes on the formation of loess lithological features.

It was shown that processes of cryogenic transformation of deposits took place in the conditions of seasonal freezing in the Pleistocene, which contributed to the formation of the high thickness loess. Researches showed prospects of the cryolithological analysis of mineral matter to estimate the paleogeographic conditions.

This study has been supported by Russian Foundation for Basic Research (Grant №18-35-00619).

P-1639

## Paleogeography, stratigraphy and geochronology of loess-soil sequences of the Lower Volga (Russia)

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### Abstract

Paleogeographic development of the Caspian Sea in the Late Pleisocene is characterized by alternation of transgressive and regressive stages. Unlike transgressive periods, the paleogeographical environment during regressive periods is less understood. The main reason is the lack of paleontological and paleobotanical remains (fauna and pollen) in continental deposits of various genesis.

The longest period of a Caspian Sea low level stand in the Late Pleistocene is the Atelian regression. During this period a thick sequence of continental deposits was formed. This formation is widespread within the Northern Caspian Depression and represented by subaqueous and subaerial deposits, including alluvial and aeolian. In the southern part of Lower Volga most of this strata is eroded by more active abrasion during Caspian sea minor transgressions of Hirkanian time and the first part of Khvalynian period. But in the north, in the series of sections around the Volgograd city, Atelian strata reach up to 10-12 m in thickness. In this area continental sedimentation was longer, the abrasion during the high-stand of Early Khvalynian transgression was relatively small (~1-3 m, depending on the geomorphological position) due to very rapid sea-level rise in a short time (Kurbanov et al., 2018). Four sections reveal the structure of Atelian formation: Srednyaya Akhtuba, Leninsk and Batayevka on the left side of the Volga valley and Raigorod on the right side.

Described stratigraphy and chronology of the loess-paleosol sequence of the Atelian formation allows us to better understand the main stages of environmental evolution of the Lower Volga region and the whole Northern Caspian lowland during the Late Quaternary.

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P-1801

## Characteristics of black carbon in the topsoil of the central and southeastern Qinghai-Tibetan Plateau, China, and their environmental significance

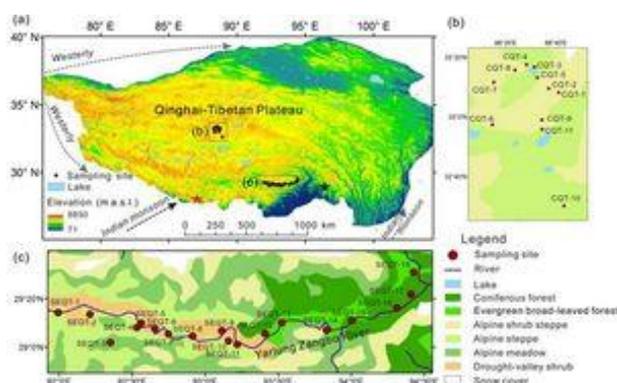
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### Abstract

**Abstract:** The Qinghai-Tibetan Plateau (QTP), known as the ‘roof of the world’, is the largest elevated landscape in the world with an average altitude of over 4000m above sea level (m a.s.l.). To date there is still a lack of investigation into topsoil BC at the high-altitude regions of the QTP, where alpine vegetation changes dramatically with the altitude gradient and responds sensitively to climate changes. In order to establish the relationship between BC, contemporary vegetation and climate at the high altitudes of the QTP, we investigated the carbon concentration and carbon isotope composition of BC and soil organic carbon (SOC) (%BC, %SOC,  $\delta^{13}C_{BC}$  and  $\delta^{13}C_{SOC}$ ) in 29 topsoil samples from the central QTP (CQTP) and southeastern QTP (SQTP) (Fig. 1). In general, the %SOC (CQTP: 0.20%-1.58%; SQTP: 0.35%-13.07%) and %BC (CQTP: 0.02%-0.14%; SQTP: 0.03%-0.74%) of topsoil show generally similar variations, indicating a common controlling factor for SOC and BC production, i.e., vegetation. The relatively small BC/SOC ratios (CQTP: 4.75%-19.29%; SQTP: 5.62%-18.77%) fall in the range of BC/OC for pyrogenic particles from biomass burning, indicating a minor contribution of BC from fossil fuel combustion. The  $\delta^{13}C_{SOC}$  of topsoil (CQTP:  $-24.1\text{‰}$  to  $-21.5\text{‰}$ ; SQTP:  $-26.5\text{‰}$  to  $-17.4\text{‰}$ ) can effectively indicate local vegetation in the QTP. The  $\delta^{13}C_{BC}$  and  $\delta^{13}C_{SOC}$  are positively correlated, whereas the  $\delta^{13}C_{BC}$  values (CQTP:  $-27.5\text{‰}$  to  $-25.3\text{‰}$ ; SQTP:  $-29.7\text{‰}$  to  $-20.7\text{‰}$ ) are more negative than those of  $\delta^{13}C_{SOC}$  ( $\Delta^{13}C_{SOC-BC}$  of  $-0.3\text{‰}$  to  $+5.1\text{‰}$ ). This could due to fire season and fractionation processes during post-deposition, but not carbon isotope fractionation during combustion or exogenous BC input. Therefore, BC in topsoil of the QTP mainly records ‘local’ environmental information, and the  $\delta^{13}C_{BC}$  can be used in paleovegetation reconstruction in combination with the local climate.

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**Key words:** topsoil; black carbon; organic carbon; vegetation; Qinghai-Tibetan Plateau

**Fig. 1.** Locations (a) and vegetation types (b and c) of topsoil samples in the QTP.

(a) Elevation data set provided by the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (<http://www.resdc.cn>); the black star is the location of the Zuoqiupu Glacier and the red star is the location of the East Rongbuk Glacier. (b) and (c) vegetation maps share the same legend of vegetation types.

P-1802

## Calibrating charcoal preserved in marine sediments to reconstruct paleofire regimes: Iberian Peninsula case study

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### Abstract

Projected warming scenarios suggest fire risk increases in certain regions, in particular in the Mediterranean region. However, large uncertainties remain because fire is a complex process, which is difficult to integrate into global modelling. Moreover, because climate is changing rapidly, models must be tested not only with modern observations, but also with observations from climate conditions very different from today. Marine sediments are a source of past fire history data that can provide such information. However, charcoal (the fire proxy) in marine sediments must be calibrated, i.e. linking the amount of charcoal found in sediments to fire regime metrics in order to benchmark quantitative models. Microcharcoal concentration was quantified in several interface sediment samples from the Atlantic Ocean margin off the Iberian Peninsula. Microcharcoal concentration was compared with parameters linked to the microcharcoal production source area (burnt area, net primary productivity, type of burnt plants, watershed size), and to the transport/deposition (wind, currents, bathymetry, distance to the river's mouth, sedimentary discharge). Our results show a great heterogeneity in the spatial distribution of microcharcoal concentrations. However, the south of the Iberian margin is characterized by higher mean concentration than the northern region. Burnt area and the numbers of fires partially explain this pattern. Our results suggest that the high winter net primary productivity of grassland and dry shrubland and the hot and dry climate observed in the southern region explain high microcharcoal concentration values in the south of the Iberian margin. Additionally, the bathymetry and the distance from the river's mouth influence the distribution of concentration within this area.

**P-1803**

## **Holocene fire history in the forest zone of European Russia: climate change or human impact?**

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### **Abstract**

Fire frequency was reconstructed on the base of macro- and micro-charcoal concentration in peat cores from five key areas, located in different landscape zone of European Russia: Ustyanskoe plateau in Archangelsk region (middle taiga), southern part of Valdai Upland (the Central Forest Biosphere Reserve, south taiga), Meshchera lowlands and Mordovia State Natural Reserve (Polesie-type landscape, mixed coniferous-broadleaf forests) and Mid-Russian Upland (Kaluzhskie Zaseki State Natural Reserve, broadleaf forests). The obtained results showed that the beginning of human occupation of the areas is clearly marked by increased fire activity. Medieval time (at about 1000 cal yr BP) and Modern Period (the last 300 years) were marked by high fire frequencies allover the East European Plain. In the model area "Kaluzhskie Zaseki" a significant increase in fire frequency was revealed around 2000 cal yr BP (Early Iron Age) and the maximum frequency of fires (8 fires per 1000 years) was reconstructed for the last millennium. However, periods of increased fire activity occurred prior to the occupation of these areas by human. The highest frequency of fire in all model areas was determined for the periods 9000-6000 cal yr BP and 3500 – 2500 cal yr BP. According to data available, the influence of anthropogenic factor during these time interval was low. Archeological findings were not revealed in vicinity of the peat cores and no pollen or plant macrofossil indicators of human impact were detected. Evidently forest fires were caused by climatic reason. According to regional climatic reconstruction inferred from pollen and testate amoebae data these periods were characterized by high temperatures and dry summer conditions. Even in the areas of spruce taiga forests (Ustyanskoe plateau and Valdai Upland) where fire events were rare entire the Holocene until the Modern Period, most of them occurred in 9000-6000 and 3500-2500 cal yr BP. In contrast to the taiga area the Polesie-type landscapes (Meshchera lowlands, Mordovia, vast fluvio-glacial plains with pine forests) were affected by repeated fires throughout the Holocene, nevertheless fire frequencies increased during the same periods as in other model areas. Fire-free interval determined for the periods 9000-6000 cal yr BP and 3500 – 2500 cal yr BP ranged from 15- 20 to 120 years.

This study was supported by the Russian Science Foundation (Grant 16-17-10045).

P-1804

## Late Cenozoic fire enhancement response to aridification in mid-latitude Asia: evidence from microcharcoal records

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### Abstract

Fire provides an important indicator of paleoclimatic change. However, little information of late Cenozoic fire history has been gathered in mid-latitude Asia (including Inner Asia and East Asia), a key region for understanding the development of the arid-monsoon climate system as well as the driving forces behind it. Here we first report the records of microcharcoal concentrations (MC) covering the Holocene (10-0 ka) and late Pleistocene (0.8-0 Ma), which we use to analyze the fire patterns in orbital time scale; then we compile the late Cenozoic MC record to investigate the long-term fire history by analyzing four cores from the Yangtze River Delta (YRD) area, East Asia (coupled with 8-0 Ma) and three sites in the Inner Asia (coupled with 18-2 Ma). The results show that the MC (i) remained higher during the relatively dry late Holocene/glacial stages than during the humid middle Holocene/interglacial stages at individual sites; (ii) became denser with time in both Inner Asia and East Asia after 18 and 8 Ma, respectively; and (iii) always remained higher in the dry Inner Asia than in the contemporaneous wet East Asia. All these characteristics imply that late Cenozoic fire in mid-latitude Asia experienced a gradual increasing trend along with the global temperature/ice volume change, and represented a continuous aridification trend across the mid-latitude Asia. The global cooling rather than the Tibetan Plateau uplift might have played a key role in it.

P-1805

## The impact of climate and vegetation on fire activity over the past 2000 years in the Daxing'an Mountains, China

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### Abstract

It is very important to understand the causes and consequences of fire activity as global warming is likely to increase the risk of fire. The region around the Daxing'an Mountains known as a high incidence area of fire in China is an ideal sites to explore the fire history and the interactions between fire, vegetation and climate change. Four peat profiles in the Daxing'an Mountains was sampled for pollen and charcoal analyses. Compared with the synthesis charcoal records of Global and Northern Hemisphere<sup>1</sup>, four peat profiles in the Daxing'an Mountains showed that regional fire activity had obvious fluctuation characteristics during the past 2000 years. Three periods of greater frequency of fire with different climates were detected over the past 2000 years: MWP (AD 680-1300, warm and dry), early LIA (AD 1300-1500) and late LIA (AD 1700-1900) (cold and dry). Our results confirm that the occurrence of fire depends on both fuel availability and climate conditions. More intensive fire activities coincide with phases of drier climate demonstrated by drought-tolerant pioneer taxa, such as *Pinus*, *Betula* and *Quercus*. Fewer fires have been identified in the middle LIA (AD 1500-1700) due to the cold and wet climate evidenced by *Sphagnum* spore. Warm climate related to the higher total PAR<sup>2</sup> (pollen accumulation rate) is suitable for the growth of vegetation, which would produce abundant fuel accumulation for burning. However cold climate with the lower PAR restrains litter decomposition and increases the combustible loads on the surface litter layer, which provides sufficient fuel for burning. Wet climate would promote plant growth, but could also restrain the break-out of fires. Our study suggest that temperature is less important than humidity in determining whether there is frequent fire activity in our study area.

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P-1806

## Fire activity in northern Poland along the west-east oceanic-continental climatic gradient – a summary of latest palaeoecological studies from Sphagnum bogs

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### Abstract

Compared to other areas of Europe (e.g. Mediterranean, Alps or Carpathians), fire activity in central European lowlands is not well recognized and only few new charcoal records have been published from palaeo-archives in this region in the recent years. The poster will present a summary of microscopic charcoal records based on seven Sphagnum-dominated peatlands located in northern Poland along the oceanic-continental climatic gradient (from west to east): Pawski Ług, Bagno Kusowo, Głębozec, Linje, Gązwa, Mechacz Wielki and Jaczno. The records cover up to the last 6000 years. We recognized a general trend of increasing fire activity along the gradient from west to east, with significantly higher charcoal influxes recorded in peatlands influenced mainly by continental climatic conditions. Charcoal peaks recorded in the last 2000 years were often connected with increased human activity, including agricultural activity (decrease in arboreal pollen and higher number of open land and agricultural indicators), drainage, and military events (for example higher charcoal influxes during the Thirty Years' War in western Pomerania). As fire activity is predicted to increase in the near future also in central and eastern Europe, the information about long-term fire activity and biomass burning in European lowlands is essential for further predictions.

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P-1807

## Late-Holocene fire activity in the New Jersey Pine Barrens and correlation with historical fire records of a managed ecosystem

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### Abstract

The New Jersey Pine Barrens is the largest area of pine-oak forest on the Atlantic Coastal Plain and is located in one of the most densely populated areas of the United States. The Pine Barrens are a fire dependant ecosystem, and prescribed burning has been routinely used as a tool to manage the landscape in order to protect local communities, and reduce wildfire related impacts (such as air quality) upon nearby centres of habitation including Philadelphia and New York City. When evaluating the impact of management, it is important to consider the long-term fire regime of the landscape. Our research presents the first regional charcoal dataset from a sedimentary record in order to reconstruct fire activity prior to historical records of fire and the more intensive ecosystem management of the 20<sup>th</sup> Century.

A ~ 3400 year sediment core from a wetland basin within the central Pine Barrens was dated using <sup>210</sup>Pb and <sup>14</sup>C. Charcoal concentrations for macro (>125 µm) and micro (15 – 125 µm) particles were determined on contiguous samples at up to 0.5 cm intervals providing a sub-decadal sampling resolution on historical timescales. Alongside charcoal data, pollen was analysed from the same samples to identify long term vegetation change.

Whilst our evidence shows correlation between recorded fires during the 20<sup>th</sup> Century and peaks in charcoal concentration, there is also evidence to show far greater levels of fire activity prior to historical records. We identify a substantial increase in charcoal concentrations around 1800 years BP. Following this increase, there is evidence to suggest a ~400 year cyclicity in micro-charcoal concentrations and a ~300 year cyclicity in macro-charcoal. Furthermore, there is an apparent increase in regularity of peaks in macro-charcoal concentration following European settlement of the region (last ~400 years).

**P-1808**

## **Holocene paleofire history and responses to climate change in the northern Greater Khingan Range**

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### **Abstract**

Natural fire is one of the important indicators of climate and environment change. The northern Greater Khingan Range (GKR), in the northernmost part of northeast China, is located on the eastern margin of the Eurasian continent and contains cold-temperate coniferous forest. It lies on the margins of the East Asian Summer Monsoon region and is extremely sensitive to changes in temperature and moisture. It accounts for 29.9% of the total forest and is a concentrated major forest fire distribution area in China.

Over the past decades, temperatures in the GKR region have increased, while precipitation has decreased, profoundly affecting the vegetation type and the forest fires. However, the prediction of short-term fire evolution simulation has relatively large uncertainty. Therefore, a longer paleofire history is needed to verify the natural fire responses to climate change in this area. The Holocene environment in this area has been principally affected by natural factors, with relatively weak human influence. Therefore, it is the ideal area to study paleofire succession and its response to climate change.

Sediment pollen and charcoal samples from the Huola Basin in the northern GKR were analyzed to reconstruct accurately the historical response of paleofire and vegetation to climate change during the Holocene. AMS<sup>14</sup>C dating and Bayesian chronological method-Bacon age-depth model were conducted. CharAnalysis technique was used to reconstruct fire regimes. Results indicated that vegetation experienced a transformation from early-mid Holocene warm-cold mixed vegetation to late Holocene cold-temperate vegetation. The paleofire succession showed a changing trend: mean fire frequency (MFF) was very low during the relatively warm period in 10000-3000 cal yr BP; however, after 3000 cal yr BP, the MFF increased markedly. Besides, the fire activity has a quasi-500 year period according to Redfit spectrum analysis. Based on the comparison of paleofire history with the vegetation succession and other paleoclimate proxy records, we found that the cooling events at high latitude might lead to the increase of fire frequency and intensity during the Holocene in this area. Consequently, the warm period in northeast China could have resulted in a strengthening of precipitation in northern GKR and encourage the development of broadleaved forests, with the fire events falling down.

P-1809

## Did recent wildfires increase metal deposition to lakes of the Canadian Shield and Taiga ecoregions, Northwest Territories, Canada?

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### Abstract

Wildfires are a natural part of Boreal ecosystems but severity and frequency of wildfires is increasing in northwestern Canada, with possible links to climate warming. Wildfires have the potential to release metal(oids) stored in plant biomass, organic soils and upper mineral soils and gaseous and particulate emissions from wildfires are recognised as a major source of certain metal(oids) to the atmosphere on a global scale (e.g. mercury). Depending on atmospheric transport and smoke plume strength, a fraction of atmospheric emissions will be redeposited at close distance to the fire area. These elements can reach freshwater ecosystems via direct deposition or watershed transport following deposition. The extent to which wildfires contribute to the metal(oid) loading of aquatic ecosystems has yet to be accurately quantified.

We sampled sediment and peat from 10 small lakes and 5 peatlands in the Canadian Shield and Taiga Regions of the Northwest Territories. We used lake sediment and peat cores to evaluate the impact of the atmospheric deposition of metal(oid) from wildfires on the flux of mercury, lead, arsenic, cadmium and antimony to these environments. Cores were dated using lead-210, wildfire occurrences were identified macroscopic charcoal analysis, and metal concentrations were analyzed by ICP-MS and DMA. The impact of wildfires was evaluated by measuring the synchronicity between metal fluxes and charcoal particle fluxes using paired statistical testing and Superposed Epoch Analysis.

The impact of wildfire on metal(loid) deposition was generally low and dependent on the metal(loid). Mercury fluxes in lakes were largely unaffected by wildfires. Sediment concentrations of lead, arsenic, cadmium and antimony were also not significantly greater following most fire events. Sedimentation rates were largely unaffected by the deposition of wildfire ash in most lakes. However, some fire events were associated with higher sedimentation rates, indicative of large ash input in the lakes from direct deposition and catchment transport. These fire events were also associated with increased concentrations of arsenic, antimony and cadmium in the sediments, leading to a higher flux of these elements for a brief period following fire events. Events that did cause a significant increase in metal(oid) concentration and flux could be related to particularly severe fires or fires occurring in areas polluted by point-sources of metal(oids) from local gold mining in the nearby City of Yellowknife. These results suggest that overall wildfires play a minimal role in metal(loid) loading to lakes but large wildfires that deposit substantial ash to a lake can increase metal(loid) input to aquatic ecosystems.

**P-1810**

## **Fire-vegetation dynamics during the Holocene in the Central Pyrenees (Spain)**

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### **Abstract**

Landscapes are dynamic entities, exposed to continuous changes as a result of long-term climatic and human processes which have been shaping them through time. Particularly, alpine ecosystems have been proved to be extremely sensitive to past environmental changes and are currently facing important transformations due to current global change. The long-term relationship between vegetation changes and fire activity is one of the most critical features transforming mountain ecosystems, and as fire risk is expected to increase in the future, understanding the long-term fire-vegetation dynamics is essential for current conservation of forests in alpine areas.

Over the last few years, several records of Holocene vegetation change in the Central Pyrenees have provided important results in relation to vegetation dynamics and treeline fluctuations. There is still a lack of knowledge in understanding the role of fire as a disturbance agent in mountain landscapes and whether fires were naturally or anthropogenically produced over the Holocene.

We present here two Holocene high-mountain lake sequences; Marboré (2612 m a.s.l.) and Basa de la Mora (1914 m a.s.l.) both located at the Central Pyrenees. We have characterized fire activity and vegetation dynamics on both of them, identifying and quantifying sedimentary microcharcoal using automated image analysis and comparing it with pollen data.

The results show an increasing fire activity during the mid-Holocene (ca. 7000-6000 cal yr BP), concurring with the highest recorded summer temperatures over the Holocene and well-developed deciduous forests. We suggest that increasing fuel availability would have fostered more active fires. Burning agency decreased as shown in both sequences, concurring with the Neoglacial period and the expansion of a nearby glacier, indicative of a cooler period, which suggests that climatic control is still dominant in promoting fire occurrence during the mid-to late Holocene transition. Interestingly fire activity increases quite abruptly at the beginning of the late-Holocene (ca. 4000-3000 cal yr BP), coinciding with an increase in herbaceous taxa, showing an opening of the landscape. This could be related to both increasing human impact and an aridity trend observed in other Pyrenean sequences. From 3000 cal yr BP until very recent times, fire activity remains low but a remarkable Holocene maximum over the last 200 years in both sequences is observed, likely related to increasing human pressure.

**P-1811**

## **Holocene savanna fire history in the seasonal tropics of northern Australia**

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### **Abstract**

Savannas are environmentally and socioeconomically important environments, and fire is an important agent of disturbance in savanna ecosystems. North Australia consists largely of relatively intact savanna ecosystems, with high plant diversity. Understanding Australian savanna dynamics requires a long-term perspective, however very few records are available from which to gain insight on long-term change. We present a pyrogenic carbon record from a 5-meter sediment core from Girraween Lagoon, Darwin region of the Northern Territory, Australia, spanning the last 12,700 cal BP. We compare a novel technique for the isolation of pyrogenic carbon, hydrogen pyrolysis (hypy), with more traditional charcoal counting method. Hypy uses catalyst-assisted pyrolysis under high hydrogen pressures (> 10 MPa) to remove labile organic matter leaving only 'stable polycyclic aromatic carbon' (SPAC) derived from biomass burning. Quantification yields robust interpretation of fire history, and the stable carbon isotope composition indicates what source material has burnt.

In general, charcoal counts compare well with SPAC accumulation rates where highest values occur between 4000 and 10,000 cal BP, with lower values before and after this time period. However, some differences are apparent. SPAC accumulation is highest at the top of the core and rapidly decreases to lowest values between 2,000 and 3,000 years, whereas charcoal values start low and generally increase to peak values from 0 to 4000 years. Moreover, the charcoal counts indicate rapid changes occurred, whereas SPAC indicates more gradual change to fire regimes in this region, although this observation might change with increased sample resolution. If such a difference holds, it might be that charcoal counts incorporate more local burning, whereas SPAC may be representative of a larger area, and more representative of trends associated with regional climate change. It may also be that some differences reflect changes in fire intensity, as this is a key variable controlling SPAC production. Stable carbon isotope values indicate the source of the burning was largely tropical grasses from early in our record until about 4,000 BP, when a gradual increase in woody sourced pyrogenic carbon is evident. This is also consistent with an increase in grass pollen evident at Girraween over this time frame.

Understanding the long-term dynamics of Australia's extensive tropical savannas are key to defining appropriate management of these ecosystems. The past has played a major role in shaping savanna systems, and the historical role of fire, as a major driver of disturbance, needs to be understood on a longer than observational timescale. As one of a handful of records from this region, our data will serve to fill a current gap in our understanding of savanna dynamics in Australia.

P-1812

## The Mid- and late Holocene fire history at the southern boundary of the forest vegetation zone (European Russia)

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### Abstract

The present study aimed to the reconstruction of forest fire history for the area of the Mordovia State Nature Reserve (European Russia). This area is located at the border between mixed forest and forest-steppe vegetation zones and particularly sensitive to environmental changes including forest fires. The Quaternary deposits in the study area is represented by fluvioglacial sands which contribute to the increasing the role of pine in the forest composition due to the edaphic factor. High pine abundance determines the relatively high activity of forest fires. Two main methods were used for reconstructions of the fire history: analysis of the macrocharcoal (particle size >125 µm) concentration in the peat and pedoanthracological analysis. The rate of macrocharcoal accumulation and identified peaks of fire activity were calculated on the base of macrocharcoal analysis and radiocarbon dating of 3 peatbogs using the CharAnalysis software. Also we compare this data with results of other proxy methods (pollen analysis, LOI, peat humification). Pedoanthracology analysis included radiocarbon dating of charcoal fragments from soil (70 samples), their species identification and the study of anthropogenic impact traces in the soil morphology.

The obtained results show that the frequency of fires was caused by both climatic and anthropogenic factors. The study area was characterized high-fire activity during the in the first half of Holocene thermal maximum (9–7 ka BP), obviously due to the relative warmer and drier climatic conditions. No evidences of human impact were detected for this period. Frequent fires (4-5 local fire events per 1 ky for each peatbog) during the Holocene thermal maximum may have led to the persistence of birch and pine forests in the study area. The subsequent decreasing of the forest fire frequency could contribute the expansion of broadleaved forests (*Quercus*, *Tilia* and *Ulmus*) and *Picea*, which reached their maximal role between 2.3 and 1.5 ka BP. The second peak (2-3 local fire events per 1 ky) of increased forest fires activity occurred in 1.2 – 0.2 ka BP and probably coincided with the beginning of intensive human-induced change of the area. Most of the charcoal fragments from soil are dated in the range of 0,2-1.5 ka BP. The presence of plowing traces in the most soil pits also confirms the fact of active human impact during the last 1.5 ka BP. The identification of species composition of the soil charcoal showed that more than 80% of all charcoals fragments are represented by *Pinus*. Remains of *Picea*, *Quercus* and *Betula* were also found. The evidences of active human influence during the last 1.5 ka BP are consistent with the data on archaeological findings and historical studies in this region.

This study was supported by Russian Foundation for Basic Research (Grant 18-04-01329).

**P-1813**

## **Holocene fire history of the British Isles**

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### **Abstract**

Fire is part of the natural disturbance dynamics of many systems. Understanding of fire history and the key drivers of fire are increasingly important for those involved in conservation and management, including sites in the British Isles. There are many records from across the British Isles which record fire activity throughout the Holocene, however limited work has been done to assess if there are any spatio-temporal trends and the implications these may have for our understanding of fire as a natural disturbance mechanism. This study uses existing sedimentary charcoal records from across the British Isles to reconstruct Holocene fire history. This reconstruction will seek to address a key question asked by palaeoecologists and archaeologists about the nature of fire in the Holocene environment, specifically whether it is driven by anthropogenic activity or climatic change. Spatio-temporal analysis of this data provides evidence of a changing fire regime, with limited burning in the early Holocene, likely to have been driven by climate. The mid- to late Holocene reveals an increase in burning across much of the British Isles, followed by a marked decline in the last 500 years, indicative of anthropogenic influence.

**P-1814**

## **The interaction between climate, vegetation and fire history during the last 250 ka at Lake Van, Turkey**

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### **Abstract**

Regionally variable interaction between climate, composition of vegetation and the non-neglected role of natural fire is not yet fully understood. The investigation of the last two interglacial-glacial cycles at Lake Van (ca. 0-250 ka, MIS 1-7) contributes significantly to the picture of long-term climate variability, vegetation changes and fire history in a climatically sensitive region, which is not influenced by human activity.

A unique multi-proxy study, derived from pollen and microscopic charcoal data, black carbon analysis (BC), stable oxygen isotopes, and XRF measurements, provides the opportunity to examine different paleoenvironmental indicators, e.g., vegetation communities, fire activity, erosion processes, evaporation rates, and moisture availability in the catchment area. We additionally used geochemical traces to reconstruct fire temperature, which relies on the oxidation of fire residues in sediments to benzene polycarboxylic acids (BPCAs). We are able to evaluate how climate triggers the activity of vegetation fires in a long continental sediment record.

The integration of all proxies shows three warm-temperate intervals, the penultimate interglacial complex (MIS 7; ca. 193-242 ka BP), the last interglacial (MIS 5e; ca. 111-131 ka BP), and the current interglacial (MIS 1; present-11.7 ka BP), characterized by the predominance of an oak steppe-forest, higher moisture availability and lower erosion processes in the catchment area. At Lake Van, intensive fire events (max. BC concentration) were recorded mainly during dry summers within temperate/humid climate conditions (large biomass production) rather than within colder/dry periods with overall sparse vegetation (low BC production). Finally, periodic variability in the vegetation composition and fire activity followed climate changes, hence are related globally to orbital forcing, with a cyclicity of ~100.000 years.

**P-1815**

## **A 'dates as data' approach to understanding anthropogenic fire trends over multi-millennial timescales; a case study from the British Isles**

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### **Abstract**

Disentangling the roles of human vs climate as primary drivers of fire regimes is one of the biggest conundrums in palaeofire research, and often comparisons between various archives and evidence are hampered by the accidental nature of the archaeological record. This is perhaps one reason why the majority of Quaternary charcoal records that cover multi-millennial timescales come from lake or peat bog sequences, where relatively straight forward depositional histories allow the use of charcoal statistics, such as CHAR alongside regional-to-global syntheses.

Much less attention has been focused on understanding fire occurrence over long multi-millennial timescales directly from archaeological datasets, from which evidence of burning is often manifest. In order to attempt to understand and explore the role of humans as an explanatory factor of fire, here we utilise part of one of the largest amalgamated archaeological radiocarbon databases in existence (taken from Bevan *et al.*, 2017). The data extracted here covers the British Isles from c.10-4 ka BP and contains over 3,500 radiocarbon determinations from material which has directly undergone at least partial charring.

In order to interpret these data, the 'dates as data' approach (Rick, 1987) is utilised, where the frequency and distribution of radiocarbon dates can be used as a proxy of intensity. This method has been most commonly used to assess changes in past human population intensity and demographic trends. A recently published method of kernel density estimation (KDE) plots (KDE\_Plot & KDE\_Model functions in OxCal; Bronk Ramsey, 2017) is used, which can help retain signal whilst also suppressing noise; a common issue with the more typically used summed probability distribution methods.

The resultant data is presented for 1) the whole of the British Isles, and 2) as national curves for Scotland, Ireland, Wales and England allowing the migration of anthropogenic fire across the Early to mid-Holocene to be assessed and compared to major archaeological cultural shifts (e.g. the Mesolithic-Neolithic transition). Finally, data is also compared from low- and high- habitability areas, based on access to freshwater resources, altitude, and flatness of land (Vahia *et al.*, 2016).

This method is not without a number of caveats, yet despite these, this approach has many advantages; not at least the ability to directly compare anthropogenic 'fire intensity' curves against more traditional lake and peat charcoal records, allowing the formation and testing of new hypotheses.

P-1816

## History of fire regime shifts during the last 1600 years in North Eastern Mongolia

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### Abstract

Global warming-induced permafrost thaw is the important source of enormous amounts of organic carbon to the atmosphere. Therefore, it is important to understand the dynamic of the process and controlling factors responsible for permafrost degradation, as well as their variability in time. For this purpose, we studied two peatlands Khar Zurkhonii Khukh Nuur in the Khentii mountain range (Mongolian: Хэнтийн нуруу) in North Eastern Mongolia. This part of Mongolia is characterized by the occurrence of the forest-steppe mosaic in the area of discontinuous permafrost. We aimed to reconstruct dependence between vegetation composition and fire regime shift during the last 1600 years from two peat archive. Two profiles: 36-cm (KH-1) and 55-cm (KH-2) have been extracted from two nearby peatlands, which are only 1 km away. Chronology of the KH-1 core was based on 6 AMS <sup>14</sup>C dates, <sup>137</sup>Cs, and <sup>210</sup>Pb analyses, while the second core KH-2 was based on 11 AMS <sup>14</sup>C dates. Respectively, the core KH-1 covers the last 250 years and the core KH-2 covers the last 1600 years. We applied the multi-proxy approach (pollen, plant macrofossils, testate amoebae, Cladocera, macro-charcoal, and geochemistry) to reconstruct changes in the ecosystem. Our first results indicate a strong relation between droughts, vegetation forest-steppe mosaic composition and fire regime shifts, which caused intensified erosion in the catchment. Palaeoecological and geochemical data allowed tracing the dynamics of degradation permafrost and fire regime shifts of the ecosystem triggered by recent and past climate change.

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P-1817

## Holocene fire history in a mid-mountain Mediterranean landscape: The Toledo Mountains (central Spain)

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### Abstract

Fire has been a major driver of landscape transformation throughout the Mediterranean basin since at least the early Holocene, modelling its ecosystems, determining species distributions, and conditioning the biodiversity of this territory. Furthermore, humans made fire an essential tool for environmental management long time ago, as it assisted the transformation of the natural landscapes to meet their need for natural resources. Indeed, many studies have shown that the frequency of fire episodes increased linked to anthropic activities such as agriculture and livestock raising and that there was a striking regional variability in human-fire relationships depending on human circumstances and the environmental setting. Eventually, in recent times, not only farming intensification but also land-use abandonment are leading to significant changes in fire regimes.

The Toledo Mountains is a mid-elevation mountain range that separates the Tagus and Guadiana basins in the heart of the Iberian Peninsula. Current climate in this mid-mountain area is mostly mediterranean, with some oceanic influence towards the westernmost section, and the vegetation mainly consists of sclerophyllous evergreen woodlands. The Toledo Mountains have acted as a prominent reservoir of natural resources for human communities, with wood, charcoal or wax as the most important products obtained directly from the local woodland. Additionally, hunting and livestock husbandry have traditionally been the main activities developed in these survival landscapes.

In this study, we reconstruct the fire history of the Toledo Mountains during the mid- to late Holocene by combining several charcoal records (charcoal accumulation rates = CHAR) from peatlands. The obtained CHAR composite curves allow us to understand the relevance of fire in building the landscape across different cultural periods, and to check for differences in the trends observed at the study sites located on the southern and northern slopes of these mid-elevation mountains. Likewise, it will be possible to determine whether fire played a role in the historical development of the landscape for livestock raising and big game hunting.

**P-1818**

## **Investigating the effects of different deflocculants on charcoal area**

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### **Abstract**

An increasing need to better understand past wildfire expression, and especially its controls, has, in the recent decades, driven extensive research into the reconstruction of past wildfire regimes. The most commonly employed proxy for this purpose is charcoal, with fragments classified as microscopic ( $<125\ \mu\text{m}$ ) or macroscopic ( $>125\ \mu\text{m}$ ) charcoal. The latter, in particular, is widely used to reconstruct local wildfire frequency. However, no standardized laboratory method currently exists. Various chemical treatments are being used in varying durations/concentrations, both prior and post- wet sieving of the charcoal from unconsolidated sediments, even though the effects on charcoal are not known. Furthermore, variously produced charcoal records are often numerically combined in order to produce regional composites of wildfire activity.

Here we systematically assess the effect of these various treatments on both modern and ancient charcoals. Fresh charcoal was produced from both softwood and hardwood species at  $400\ ^\circ\text{C}$  and  $800\ ^\circ\text{C}$ , as well as grass at  $400\ ^\circ\text{C}$ . The charcoal was broken down with a mortar and pestle, and waterlogged. Approximately 5 pieces, ranging from  $125\text{-}250\ \mu\text{m}$ , of each of the five types of charcoal were placed in 90 petri dishes, and then one of the following chemicals was added at the specified concentrations: peroxide ( $\text{H}_2\text{O}_2$ ; 8% and 33%), Sodium Hypochlorite ( $\text{NaClO}$ ; 3% and 12.5%), Potassium Hydroxide ( $\text{KOH}$ ; 10%), Sodium Hexametaphosphate ( $\text{Na}_6\text{P}_6\text{O}_{18}$ ; 20%) and Nitric Acid ( $\text{HNO}_3$ , 50%), along with two sets of control treatments ( $\text{H}_2\text{O}$ ). The samples were digitally photographed under the microscope as a series of overlapping pictures, instantly after the addition of the chemical and then in four pre-determined time steps (8 hours or 12 hours depending on the chemical). Image analysis software was used to quantify the area of the fragments ( $\text{cm}^{-3}$ ).

Each chemical had a markedly different effect on the area of charcoal, at different time steps. Mixed ANOVA tests showed that the area significantly varied from the water control treatment when submerged in  $\text{HNO}_3$  and  $\text{NaClO}$ . However, significant differences were also found in between the remaining chemicals. These findings have implications for charcoal-based paleofire reconstructions and highlight the need for a standardized methodology in the field. They also suggest that  $\text{H}_2\text{O}_2$  is probably the most effective chemical whilst use of  $\text{NaClO}$  should probably be avoided as this was found to markedly decrease the area of the charcoal.

To evaluate these laboratory findings within a “real world” context, a sedimentary sequence, with 9 replicate cores, from Sluggan Bog, Northern Ireland was used. Layers that were known to contain charcoal were treated with  $\text{H}_2\text{O}_2$  (33%),  $\text{NaClO}$  (12.5%), and  $\text{HNO}_3$ , (50%). The differing effects of these treatments on the fossil charcoal fragments will be outlined and compared to that of the modern charcoal samples.

P-1819

## The Role of Fire in the Late-Glacial Decline of Spruce Forests Across the Great Lakes Region of the United States

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### Abstract

As temperatures rise and the frequency, size, and severity of wildfires increase across North America, there is an increased risk of intensified disturbance regimes driving abrupt ecosystem conversions from forested to open vegetation. A potential model system for understanding these processes is the last deglaciation, when spruce forests and parklands rapidly declined across the Midwest and were replaced by mixed forests. These vegetation changes were primarily driven by rising temperatures (perhaps as high as 6C locally) and increasing seasonality of temperature and insolation. The role of fire during the late-glacial decline of these spruce forests and parklands, however, has not been explored. This study presents a synthesis of deglacial vegetation changes and fire activity using fossil pollen and charcoal records from 5 sites in the Great Lakes Region: Triangle Lake Bog, Bonnett Lake, Stotzel-Leis, Silver Lake, and Appleman Lake. These records have established radiocarbon chronologies, high resolution pollen data, and contiguous charcoal data, enabling a newly-detailed study of the linkages between biome-scale vegetation change and fire dynamics.

Pollen analysis shows a common trajectory of vegetation change across sites, where *Picea* (spruce) experienced a significant decline between 16,000 and 12,000 years ago, which coincided with an increase in *Pinus* (pine) and hardwood taxa like *Fraxinus* (ash), *Ulmus* (elm), and *Ostrya/Carpinus* (hop-hornbeam/hornbeam). This indicates that spruce forests and parklands were replaced by mixed coniferous and deciduous vegetation across the Great Lakes Region. During the deglacial period, the Silver Lake and Stotzel-Leis records show a similar change in fire regime, with significant fire events (top 20<sup>th</sup> percentile of charcoal peaks identified in analysis) increasing in frequency leading into a rapid spruce decline. The Triangle Lake and Bonnett Lake records show more gradual spruce declines, with one or two significant fire events occurring as spruce starts to decline, though the Triangle Lake record also shows frequent fire events toward the end of the spruce decline. The Appleman Lake record shows no significant fire events before the spruce decline and two significant events at the end of the decline. At all sites, some of the major fire events were followed by spikes in the rate of change in community composition, though the rates of change following fire events were not significantly different from the rates of change in non-fire intervals. Overall, these results suggest that individual fire events alone may not cause a large change in community composition, but increasing frequency of fires may cause communities to reach a tipping point and experience a state-change, as seen in the rapid replacement of spruce by mixed forest at sites like Silver Lake and Stotzel-Leis.

P-1820

## The *paleofire* R package: analyzing charcoal records from the Global Charcoal Database

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### Abstract

The analysis of charcoal records stored in the Global Charcoal Database (GCD) has been proven useful for reconstructing millennia trends in regional to global biomass burning. The synthesis of charcoal series poses nonetheless several challenges related to the spatial or temporal representativeness of data or to the various sedimentary charcoal units and associated laboratory methods available within the GCD. In order to provide a set of tools and a common research framework to analyze these records the *paleofire* R package has been developed as an initiative of the Global Paleofire Working Group (<http://paleofire.org>). The *paleofire* package is now in its 1.2.3 version and freely available for the R platform. Since its inception in 2014, numerous methods and tools have populated the initial capabilities of the package. The basic functions embedded within the *paleofire* package enable to: (i) select charcoal records from the GCD, (ii) transform charcoal data in order to produce statistically comparable records, (iii) synthesize temporal charcoal trends to reconstruct biomass burning. In addition to these basic functions, several tools have been incorporated enabling to quantitatively analyze temporal trends in biomass burning or to produce spatial analyses. In this presentation, I will demonstrate the principles of the *paleofire* package and present the latest improvements on spatiotemporal analyses of biomass burning from the GCD. I will also briefly present the latest version of the GCD (v 4.0.4) and how the GCD and the *paleofire* package communicates in order to provide paleofire researchers updated and freely available charcoal data and associated methods.

**P-1821**

## **Fire regimes in *Araucaria* forests ecosystem during the last 1800 years in southern South America.**

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### **Abstract**

To understand the climate-vegetation-fire dynamics, associated with anthropic influence, in the millennial scale fire regimes, a large part of the studies have been based on charcoal records. These archives document the magnitude and frequency of local fire events, as well as the fire-free interval for a period. Fire-scarce records have been able to evaluate and refine the detection of fires, which would help to reduce the error in the detection of false events and / or the non-detection of a real event.

In the present work, we present the fire regimes in *Araucaria* forests ecosystem during the last 1500 years in two main areas based on the comparison of pollen, charcoal records and a series of fire-scars records. i) Laguna Escondida (39.5 °S, 71.5 ° W) located in Villarrica National Park, and ii) Laguna Verde from Tolhuaca National Park.

Laguna Escondida covers 2017-1400 CE, while the chronology of fire-scars covers 2000-1696 CE. Both records coincide in an increase in the frequency of fires since 1890 CE, however, the charcoal record detect 4 fire events compared to 13 fire-scars. The low fires detection during the 20th century would be related to lake taphonomic processes (eg. sediment resuspension) and the high frequency of fires associated with greater human activity since 1880 CE, resulting in a relative homogenization in the accumulation of charcoal during the last century. Vegetation is dominated by *Nothofagus* forests, while the last century appears the exotic species and Poaceae taxa, the bamboo *Chusquea* is also associated with fire events recorded in lake sediments.

Laguna Verde covers 2018-150 CE, while the chronology of fire-scars covers 2001-1519 CE. Fire events are not recorded in sediments for the last centuries, however 33 fire-scars are observed between 2001-1800 CE. On the contrary, major peak magnitude and frequency is observed between 150-1500 CE indicating a major fire activity, previous the European colonization. Vegetation is dominated by *Nothofagus* and *Araucaria* forests, while the last century appears the exotic species and Poaceae taxa, the bamboo *Chusquea* shows constants values during the entire pollen record.

Despite the differences on fire regimes observed in both areas, during the settlement of southern Chile, historical fire regimes were often altered by either burning vast areas to create farmland or reducing fire frequencies by suppressing fires or by eliminating aboriginal populations that formerly set fires. These preliminary results suggest a complement between both archives to evaluate fire regimes at higher temporal scales, however, it is necessary that the chronologies are robust in terms of the number of dates used and the number of scars that sustain a fire event.

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**P-1822**

## **DiverseK: integrating fire ecology, traditional knowledge and stakeholders**

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### **Abstract**

Both frequency and intensity of fires are expected to change in many areas under future climate changes, but with different trajectories depending on the biome considered and region-specific land-use changes. Over the last years, The Global Paleofire Working Group (GPWG2) promoted new collaborations and methodological approaches to improve our understanding of fire variability across ecosystems. Central to this mission is the knowledge transfer from palaeofire research to stakeholders and policymakers, with the common goal to implement more sustainable management strategies for conserving biodiversity resources and ecosystem services. The Diverse Knowledge framework (DiverseK), developed within the GPWG community, combines long-term ecology, traditional knowledge and conservation challenges prioritized by stakeholders, and represents a novel and alternative approach to improve existing fire policies counteracting the effects of catastrophic fires in a future warmer world. Integration of ecosystem science and applied research in ecosystem management is a high priority and key challenge for the science-policy interface. The GPWG's will continue to promote the development of community tools for data analyses and new projects across the Quaternary Sciences that merge interdisciplinary ecological knowledge with our understanding of Quaternary climate variability.

P-1823

## The interaction between vegetation, megafauna and fire regimes at Lake George, southeastern Australia.

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### Abstract

The Lake George basin on the Southern Tablelands of New South Wales, in southeastern Australia, contains the longest known quasi-continuous sedimentary record of any Australian lake basin. The published spore-pollen record of Singh and Geissler (1985), obtained from Lake George, spans the entire Brunhes Palaeomagnetic Chron (ca. 780 000 to the present) and provides a record of glacial-interglacial cycles indicated by altitudinal shifts in vegetation. An ongoing multi-coring campaign funded by an Australian Research Council Linkage Project LP140100911 is examining the tectonic, sedimentary, hydrological, vegetation, climatic and archaeological history of Lake George. A multi-proxy palaeoecological record covering the last 130,000 years is being developed to both refine and provide a more robust chronology of this iconic record with initial results broadly supporting the findings of Singh and Geissler. The presence of dung fungi, *Sporormiella*, indicates that large herbivores were a key component of the environment. Furthermore, unlike more northern Australian sites, such as Lynch's Crater, fire is present prior to 40 ka, suggesting it may be more directly linked to changing vegetation patterns due to climate variation, rather than to human activity. The increased values for both micro- and macrocharcoal across the time-period 30 – 40 ka which also correlates with reduced *Sporormiella* values, suggests that there was a complex interaction between, vegetation, megafauna and fire regimes.

### Reference

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**P-1824**

## **Reconstructions of Fire Activity in North America and Europe over the Past 250 Years**

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### **Abstract**

Fire both affects and responds to vegetation changes, climate variability and human activities; a robust understanding of fire thus requires diverse spatiotemporal data and a multidisciplinary approach. This study compares historical fire reconstructions, paleofire records, and simulated land-use changes over the past 250 years to understand the role of fire in North America and Europe during the transition into the Industrial Era. Paleofire data are from the Global Charcoal Database (GCD) and historical fire reconstructions are from diverse sources, including government records and dendrochronological studies. Comparisons of the trends in fire from the GCD and the historical reconstruction show broad agreement, with some regional variations as expected. Western USA and North America show the strongest agreement, with departures in the GCD and historical reconstruction fire trends that may reflect limits in the data itself. Eastern North America shows agreement with an increase in fire from 1750 to 1900, and a strong decreasing trend thereafter. Patterns of burning in both fire history datasets often correlate positively with rates of land-use changes. Through the careful consideration of uncertainties in the data, these results can be used to constrain Earth System Model simulations of both past fires, which explicitly incorporate historical fire emissions, and the pathways of future fire on a warmer planet.

P-1825

## Pedoturbations defining charcoal stratigraphy for reconstruction of the forest ecosystem history (the Ryazan region, Russia)

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### Abstract

Pedoanthracological methods are widely used for analysis of the local ecosystem history. We propose the additional using of analysis of patterns of soil profiles to interpret the data on soil charcoal stratigraphy. We present results of the first study on soil charcoal stratigraphy, taxonomy, and radiocarbon dating combined with morphological analysis of soil profiles performed for sandy soil (Podzols and Arenosols) in the Ryazan region in Russia (55.2N, 40.2E).

Charcoal samples from the specified soil patterns with a visually high concentration of charcoals were taken from 19 soil pits located in four forest sites. Besides charcoal concentration, which has been defined for all samples, taxonomic identification of charcoals was performed for 24 samples and 12 charcoal samples were radiocarbon-dated. We specifically focused on soils that bear marks of pedoturbations, which included three distinct soil patterns: ancient arable layers, root channels, and pits formed after treefalls with uprooting. We compared samples selected from the specified soil patterns with randomly selected samples. For this, we randomly collected 90 soil samples from different soil horizons in 7 soil profiles located in the same sites. Charcoal concentration in randomly selected soil samples was identified. Results of soil charcoal analysis were compared with pollen and microscopic charcoal analysis of the cores taken in the surrounding peats.

Taxonomic composition of trees in charcoal samples was very poor. Pinus charcoals of various age prevailed in all samples. Charcoal of Betula and Sorbus rarely occurred. The oldest charcoals were 2610 cal. BP; the remaining samples were mainly grouped into three clusters: about 2200, about 900–1000, and later 500 cal. BP.

Charcoals were unevenly distributed both horizontally and vertically in the soil profiles. Mean charcoal concentration in randomly selected samples was  $1.2 \pm 0.4 \text{ g} \cdot \text{kg}^{-1}$ , whereas mean charcoal concentration in ancient root channels originated from artificial tree uprooting (grubbing) was  $12.44 \pm 3.48 \text{ g} \cdot \text{kg}^{-1}$  and charcoal concentration was up to  $30.92 \text{ g} \cdot \text{kg}^{-1}$  in the ancient arable layer. The largest and most abundant charcoals were located at the greatest depths of ancient pits formed after treefalls with uprooting: mean charcoal concentration was  $55.1 \pm 23.15 \text{ g} \cdot \text{kg}^{-1}$  and the highest one was  $133.36 \text{ g} \cdot \text{kg}^{-1}$ .

Periods of charcoal accumulation in soil and in surrounding peats have not coincided. Since 2000 cal. BP the supply of charcoal in the peats had decreased, but translocation of charcoal into mineral soil had widely started due to the pedoturbations as a result of plowing after tree burning and cutting for clearing. These human activities had provided the upper soil layer (arable layers and sometimes root channels) with charcoal fragments. Analysis of ancient pedoturbations allowed us to explain causes of charcoal stratigraphy in the soil and to interpret history of the local sites.

This study was supported by the RFBR project 18-04-01329.

P-1826

## **New perspectives on an old landscape: Utilizing Unmanned Aircraft Systems for rapid high resolution data acquisition to enhance geomorphological research.**

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### **Abstract**

The increasing availability, relatively low economic expenditure and user-friendly off the shelf capabilities, mean unmanned aircraft systems (UAS) have become a transformational technologic tool for geomorphologists. Over a two-day period UAS were employed to survey a remote upland palaeo-periglacial landscape located within the Bear Rocks Preserve (BRP), Central Appalachians, West Virginia, USA. The preliminary results from the low altitude high resolution aerial survey (LAHRS), when combined with ground based observations, enabled the development of a model of landscape evolution for the BRP. During the aerial survey 2000+ images were captured, and following processing the photogrammetric data, provided a high resolution digital dataset (HRDDS) of the entire BRP. Using the BRP HRDDS a procedure for easier targeting of areas of special interest for ground based data collection, including XRF and clast form analysis was produced. Using the BRP HRDDS lead to improved time and resource management of days spent in the field, which is an ever present pressure for geomorphological researchers. Scrutiny of the LAHRS data aided the identification of landforms and analysis of palaeo-processes that were hitherto unrecognized or published for the BRP. Combining the LAHRS and ground-based investigation of the BRP facilitated the production of a digital map illustrating the variation in the frequencies, compositions, geochemical characteristics and locations of palaeo-periglacial landforms; including but not limited to felsenmeer, tors, ventifacts and patterned ground. The preliminary model for landscape evolution of the BRP site indicates a relative consistently open and exposed environment, with disintegration and accumulation of lithologies being significantly influenced by underlying geologic structural controls. UAS are an exciting and rapidly growing toolkit for future geomorphological mapping and research. Within the USA recent updates to FAA regulations have eased the obstacles for UAS deployment for professional uses, resulting in a more widespread adoption of this technology as an enhancement to remote field-based research activities. An unforeseen positive consequence of UAS technology is the potential and rapidity for engaging and enabling undergraduates, K-12 students and the general public in accessing the geomorphology of their own region. For faculty at institutions with a teaching focus, and available dedicated research time is limited, this emerging technology presents some unique educational challenges and opportunities. The establishment and development of a UAS laboratory at FSU has faced the challenges of integrating specialized new technology into an infrastructure that is oriented toward support of more generalized instructional needs, while under pressure to conform to standards of operational efficiency and cost-effectiveness.

P-1827

## Analysis of Late Quaternary deposits for evaluation of land subsidence in an actively subsiding basin, the Echigo Plain, Japan

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### Abstract

The Echigo Plain, central Japan, is an actively subsiding sedimentary basin with its tectonic subsidence rate to be ca. 3 mm/yr at the coastal areas. In addition, anthropogenic activities such as over-abstraction of groundwater accelerate compaction processes, which results in the formation of accommodation space for sedimentation. In this study, we analyzed the latest Pleistocene to Holocene sequences using spatially high-density borehole data. We also estimated the temporal and spatial variations of paleo-water depths based on boreholes with calibrated radiocarbon dates obtained by previous studies to understand the trend of the subsidence. Several geological cross-sections were drawn and analyzed by applying the sequence stratigraphy and new “Shazam stratigraphy” concepts. The depositional sequences of the Echigo plain mainly consist of lower sand and silt deposits (estuary system), middle clay and silt deposits (marine deposits and barrier-lagoon system), sand and silt deposits (dune or bar), and upper sand and silt deposits (modern floodplain, channel, pond deposits). Spatial distribution maps of sediments during the early transgressive stage (ca. 9000 cal y BP), the maximum transgression (ca. 6000-5000 cal y BP), and the high-stand and regression (ca. 3000 cal y BP) were created using GIS based on the analysis results of cross-sections. Paleo-water depth distribution maps of the three time periods were also created based on the estimated paleo-water depth value. In the whole Niigata plain, clay and sandy silt were distributed at ca. 9000 cal y BP. During ca. 6000 cal y BP, the water depths reached a maximum (ca. 10 to 50 m). The clay along the shores and the sand and silt in the inland area were mainly deposited. After ca. 3000 cal y BP, the water depth became shallow. The sand and the silty sand were widely distributed. The variations in paleo-water depth differ regionally. At the river mouth of the modern Shinano River, the water depths were deepest, indicating its environments to be seafloor until very recently. In contrast, the water depth in the region near the western margin fault zone of the Niigata plain was relatively shallow. In the coastal areas and the river mouth where the amount of land subsidence observed by leveling and GNSS is relatively large, thick clay and silt layers, attributed to marine clay during the transgression, are distributed at a depth of ca. -60 to -100 m. While, in the inland area where subsidence is also observed, clay and silt layers attributed to lagoon deposit are also recognized at a depth of ca. -20 to -50 m. In particular, the Shinano river mouth area, where the paleo-water depths were deep and clay and silt layers deposited might be related to the observed land subsidence in the shallow layer through sediment consolidation.

P-1828

## Mapping distinct geomorphic units using a convolutional neural network

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### Abstract

Accurate geomorphological maps are essential tools for tackling environmental challenges. However, current geomorphic mapping techniques are often time-consuming and difficult to reproduce (e.g. field surveys and manual mapping), or are sensitive to man-made objects such as buildings or roads (e.g. digital terrain analysis). Recent advances in spatial data collection, new software libraries and improved computing power enable the use of more advanced data driven methods such as deep learning, for geomorphic mapping.

We explored the use of convolutional neural networks (CNNs) to map distinct geomorphological units, such as periglacial depressions, drift sand dunes and blowouts, in the north of the Netherlands. CNNs are tools which use pattern recognition to classify input images. In our case, the input consisted of elevation and relief maps of the study area. CNNs often demand large amounts of input data for correct classification. However, the CNN we selected, U-Net, has been shown to be tolerant to a relatively limited amount of data, in the form of manually classified geomorphological units. The training dataset was augmented by deforming and rotating the training data, which ultimately provided a robust model for recognizing the landforms on the input data.

U-Net was successful in locating the periglacial depressions and dune complexes in the study area. The model identified almost all depressions that were manually mapped on the current geomorphological map, and identified additional, previously unidentified, depressions. However, the delineation of the shapes was not always correct and the similar shapes of periglacial depressions and blow outs caused mix-ups of those landforms in the classification. Nonetheless, these first results show the potential of CNNs for robust and time-efficient geomorphic mapping.

**P-1829**

## **The application of high-resolution structure-from-motion photogrammetry and digital field-mapping systems to interpret glaciated landsystems in the Keady region, Northern Ireland**

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### **Abstract**

High-resolution (0.4 m) Structure-from-Motion (SfM) Digital Surface Models (DSMs) created from aerial imagery allow for detailed, high-accuracy mapping of glaciated landsystems. This study demonstrates the advantages of using these techniques compared to previous low-resolution (50 m) digital terrain models and satellite imagery.

Geological fieldwork is resource intensive and heterogenous glaciated terrains, typical of Ireland, can be time consuming to interpret. Techniques that reduce time in the field through more accurate remote interpretation allow resources to be used more effectively. In the Keady region, Northern Ireland, the authors have used photogrammetric DSMs and digital field data capture systems to augment existing field mapping strategies. Geomorphological landforms and surface stratigraphic units captured digitally in a desk study using ArcGIS SIGMA toolkit were verified and updated during field work on the ground.

Compared to interpretations of the terrain undertaken using lower resolution datasets, the accuracy of remote mapping checked in the field using SfM DSMs was markedly higher. Significantly less time was required adjust the boundaries of sediment-landform associations, allowing a wider area to be covered. This allowed operators to focus on remaining areas of uncertainty, e.g. those under dense vegetation cover.



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<h3>Digital Mapping...</h3> <p>We digitally map superficial deposits more accurately by using high-resolution terrain data.</p> 	<h3>Why?</h3> <p>Data informs developers, researchers and asset owners. Digital data provides best value.</p>  
<h3>How?</h3> <p>Structure from motion derived terrain used in the office to interpret landforms and geomorphology beforehand.</p>  <p>In the field the geologist is free to record information about sediments and rock types without having to draw in all the changes in slope.</p> 	<p>A tablet PC based field mapping system is used to ground truth the office data. It has a GPS, camera, structural tools and GIS within a map workflow.</p>  <p>The map data is in the same GIS package throughout, and cartographically attributed by the geologist when the data has been finalised. This reduces duplication.</p> 
<h3>Results</h3> <p>Structure from motion photogrammetry in Armagh provided a high level of detail for field mapping to add to. Drumlins, Rogen and glacial sediments were newly identified.</p>  <p>SfM technology can be used to map areas that might be difficult to access. Keeping the data in the hands of the geologist means less potential for error in data transformation.</p>  <p>The next step in development is to enable crowd sourced data to be input by users in the field on an app. Smartphone ubiquity puts this tech in reach of the majority.</p>  	

**P-1830**

## **Operational framework for rapid, very-high-resolution mapping of glacial geomorphology using low-cost unmanned aerial vehicles and structure-from-motion**

Marek Ewertowski<sup>1</sup>, Aleksandra Tomczyk<sup>1</sup>, David Evans<sup>2</sup>, David Roberts<sup>2</sup>, Wojciech Ewertowski<sup>1</sup>

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### **Abstract**

The ongoing glacier retreat has resulted in the continuous exposure of proglacial areas. Such areas contain essential information about the glacial process–form relationships that manifest themselves in specific landform assemblages (glacial landsystems). However, the preservation potential of freshly exposed glacial landforms can be very low, as proglacial terrains are one of the most dynamic parts of the glaciated landscapes. Rapid mapping and geomorphological characterisation of such areas are important from a glaciological and geomorphological standpoint, for a proper understanding and reconstruction of the glacier–landform dynamics. Recent advances in technology have enabled the development of low-cost alternatives for traditional aerial surveys. Small unmanned aerial vehicles (UAVs) can be used to acquire high-resolution (several cm ground sampling distance), low-altitude images. The UAV-based images can subsequently be processed using structure-from-motion (SfM), to generate detailed orthomosaic and digital elevation models.

This study aimed to demonstrate an operational framework for using low-cost UAV and structure-from-motion photogrammetry for the rapid mapping and monitoring of the glacial geomorphology, in front of retreating glaciers. The proposed operational framework incorporates various organisational and technical aspects related to mission preparation, mission execution, and data processing; and consists of seven stages: (1) Preparation and selection of the appropriate platform; (2) transport; (3) preliminary on-site activities (including optional ground-control-point collection); (4) pre-flight setup and checks; (5) conducting the mission; (6) data processing; and (7) mapping and change detection. Operational procedures were developed from several years of application of different types of consumer-grade UAVs over a wide range of case studies representing ice margins of glaciers in Svalbard, Iceland, and Peru.

We illustrated the application of the framework by a mapping case study on the glacial foreland of Hørbyebreen, Svalbard, Norway. A consumer-grade quadcopter (DJI Phantom) was used to collect the data, while images were processed using the structure-from-motion approach. The resultant orthomosaic (1.9 cm ground sampling distance—GSD) and digital elevation model (7.9 cm GSD) were used to map the in detail fine-resolution glacial-related landforms. It demonstrated the applicability of the proposed framework to map and monitor specific changes in a rapidly evolving proglacial environment, using a low-cost approach. The coverage of multiple aspects ensures that the framework is universal and can be applied in a broader range of settings. The proposed approach opens up new perspectives on detailed mapping and monitoring of modern glacial land-systems and the development of models of process-form regimes in glacial geomorphology.

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**P-1831**

## **Reconstructing historical outburst floods of the Kotá valley, SE Iceland.**

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### **Abstract**

The high magnitude and low frequency occurrence of outburst floods (jökulhlaups) makes them very difficult to measure directly. In Iceland, jökulhlaups are predominantly triggered as a result of volcanic activity, either directly through volcanic eruptions, or indirectly through geothermal activity, with many volcanoes under icecaps. Iceland is therefore in a unique location for such a study, providing the opportunity to constrain the age (based on tephrochronology, historical records and recent observed events), character and distribution of past jökulhlaup events, using a combination of techniques.

We focus on the Öræfajökull eruptions of 1362 and 1727 CE and the resulting jökulhlaups in the Kotá valley, in SE Iceland, which caused fatalities and significant damage to farmland. We use a LiDAR DEM, field data and satellite imagery to create a geomorphological map of the palaeoflood events. In addition, we use unmanned aerial vehicle remote sensing, to create a 3D model of a section of the fan using structure-from-motion. This allows us to analyse the topographic features (<10m scale) of the fan surface that are otherwise not apparent in the Lidar DEM. These data allow us to forensically reconstruct the sequence of events in terms of flow routing and timing. Finally, we undertake palaeofluvial modelling using a combination of geomorphological and sedimentological evidence to reconstruct flood hydraulic parameters (regime and competence), based on palaeoflood palaeostage and competence approaches.

The 1362 eruption was very explosive and distributed light-coloured rhyolitic tephra over a wide area that serves as a valuable time marker. The 1362 jökulhlaup deposits consist predominantly of eroded fluvial valley-fill, scree slopes and “plucked” large boulders of tillite and palagonite. The 1727 deposits are typically darker-coloured, reflecting a dominantly mafic eruption. Based on mapping of these deposits, the 1727 jökulhlaup appears to have been almost as extensive as the 1362 event. Primary routing of this flood event appears to have been towards the western part of the valley, forming a large dark-coloured fan. The 1727 flood event transported large blocks of glacial ice, which persisted for decades after the event according to historical records, littering the landscape and forming kettle holes. The UAV acquired imagery reveals a complex network of kettleholes and palaeochannels. Palaeoflood modelling indicates that the 1727 event was slightly lower in magnitude than the 1362 jökulhlaup.

P-1832

## Configuration and Chronology of the Postglacial Marine Incursion on the Eastern Ungava Peninsula (Quebec, Canada): Implication for Deglaciation Models

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### Abstract

Deglaciation of the Laurentide Ice Sheet on the Ungava Peninsula was complex and led to the development of glacial lakes that are difficult to integrate into current paleogeographic frameworks due to large uncertainties on the ice margin configuration and sparse chronological constraints on the ice retreat pattern. The final deglaciation of the Ungava Peninsula was marked by the incursion of the Iberville Sea into the isostatically depressed coastal areas of Ungava Bay. Previous studies show large spatial variations in the elevation of the maximum extent of the marine limit as well as a wide range of radiocarbon ages for this limit, while uplift gradients show no consistent pattern throughout the region. These inconsistencies may reflect the isolation of different ice masses late in the deglaciation and/or inadequate elevation measurements linked to low-resolution mapping techniques. Here we characterize the maximal extent of the Iberville Sea and document the regional pattern of deglaciation through detailed mapping of raised marine beaches, terraces, deltas and other deglacial landforms. Mapping was carried out using high-resolution satellite imagery (Rapideye, 5m), aerial photographs and DEMs, and observations were subsequently validated through fieldwork. We also measured the elevations of 133 landforms associated with the maximum marine limit using high-precision DGPS. Elevation measurements were focussed on a 230 km-long N-S transect along the western Ungava Bay coast, in addition to two E-W transects extending inland along the Payne and Leaf rivers. Our results indicate that the elevation of the maximum marine limit shows a gradual increase from north to south along the Ungava Coast, going from 100 m to 155 m. The calculated E-W uplift gradients yield a uniform dip towards the east, suggesting the presence of a late deglacial ice mass located on the center of the Ungava Peninsula. Our mapping also outlines geomorphic features that refine the position and configuration of the ice margin at the time of the marine incursion. The geometry of the water plane associated with the maximum marine limit can also be used to identify the origin of raised shorelines that might belong to the Iberville Sea or glacial lakes, which may be difficult to differentiate far inland. We also present an inventory of <sup>14</sup>C ages available for the region, which will be compared to upcoming cosmogenic (<sup>10</sup>Be) ages obtained on boulders sampled from marine shorelines and deltas. The <sup>10</sup>Be ages will refine the timing of the opening of Ungava Bay to marine water, thereby providing minimal time constraints on meltwater discharges from glacial lakes that drained into the Iberville Sea. Overall, these mapping results should refine regional sea-level curves and improve paleogeographic reconstructions depicting the deglaciation of the Ungava Peninsula.

**P-1833**

## **Methodology for the predictive mapping of flat terrains within a catchment, by semi-automatic analysis of the Digital Elevation Model**

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### **Abstract**

The knowledge of surface geological formations over the metropolitan French territory is very much heterogeneous: sometimes well represented for their contours and descriptions, sometimes absolutely absent when they can be observed on the field. The implementation of systematic and continuous acquisitions programs at appropriate scales all over the territory cannot be intended considering vastness of the country. Therefore, finding solutions to help the mapping of subsurface geological objects in order to increase the knowledge is likely to be a relevant strategy in which the BRGM has been committed for some years.

One of the research approach consists in defining methodologies for predictive mapping by image processing and analysis with validation through field feedbacks. As part of the cartographic identification of alluvial formations, we developed a methodology based on the Digital Elevation Model (25m precision from IGN (French geographical service)) and its declinations (curvature, slope, its difference with base level etc.). The implemented workflow provides a predictive map representation of morphological terrace levels as well as the colluvium from the valley bottom or lower hillside.

We developed this methodology of semi-automatic mapping by topography analysis on a selected test area in the Pyrenean foothills (sub-watershed of the Gave de Pau). A field campaign on the basins of Baise and Ousse rivers allowed us to compare the results of the predictive cartography and the geological reality. The first results show that the proposed analysis is relevant at the scale of a multi-kilometer catchment, not affected by faults. The methodology provides valuable support for the mapping of these superficial formations, in particular by significantly saving time when drawing the map. It was noted that the estimation of the alluvial system base level was a key point in our modeling, then several interpolation methods were compared.

The development of a graphical interface allowing all the catchment analysis to be carried out in a single application will make it possible to produce predictive maps quickly and to help with the cartographic identification of alluvial stepped formations

**P-1834**

## **Accuracy assessment of using cost-effective PPK in direct georeferencing of UAS photogrammetry**

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### **Abstract**

This study presents a self-made and cost-effective post-processed kinematic (PPK) system for the direct georeferencing in the unmanned aerial system (UAS) photogrammetry. Contrast to the traditional UAS photogrammetry, PPK survey has many advantages: no need of Ground Control Points (GCPs), faster processing and field preparation, safer field work and cost-effective. Especially without the need of GCPs placement, this extends the application of UAS photogrammetry, such as large-scale landslide, steep sea cliff monitoring and high mountain survey, where the survey area is not accessible.

This paper presents an experimental investigation on the four repeatability of UAS photogrammetry. Four control configurations were designed and executed in the same flight plan: no-GCPs and PPK-disabled, 12 GCPs only, PPK only, PPK+1GCP. 15 check points (CPs) and 98 independent check points (ICPs) were used to evaluate the RMSE of UAS photogrammetry by using total station. The Z RMSE of CPs is 2969cm (no-GCPs and PPK-disabled), 2.45cm (12 GCPs only), 3.32cm (PPK only), 2.51cm(PPK+1GCP).

P-1835

## 3D-modelling of Charlemagne's summit canal – merging remote sensing and geoarchaeological data

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### Abstract

The Fossa Carolina is the first hydro-engineering construction that bridges the Central European watershed in the Early Medieval. The canal was built in 792/793 AD by order of Charlemagne with the aim to connect the drainage systems of the Rhine-Main-catchment and the Danube catchment. At that time, navigable waterways played an important role for itinerant kingships, economic exchange and communication across powerful elites and religious institutions in Europe. Hence, this hydroengineering project was of high geostrategic relevance. Current studies show, that the canal was built as a summit canal with several ponds of different levels. The canal trenches were deepened into sandy to loamy valley fills between the Rhine-Main and Danube catchments. In this poster, we show for the first time, the integration of Airborne LiDAR and (geo)archaeological datasets with the aim to create a 3D-model of Charlemagne's summit canal. We develop an approach for handling with geoarchaeological data of different resolution. The canal trench geometry is derived from three archaeological excavations and four high-resolution direct-push transects. We produced a purged Digital Terrain Model (DTM) by removing all anthropogenic structures (Schmidt et al. 2018). This pre-modern DTM reflects the Carolingian topography that deals in this study as basis for the modelling approach. By means of several core drillings we interpolate the ditch floor and the adjacent dams along the entire canal. As a result, we are able to create a 3D-model that reflects the maximum construction depth of the entire Carolingian canal. Furthermore, we calculate the excavation volume of the most important hydro-engineering construction in Early Medieval Europe. As a result, we compute an excavated volume of c. 287,000 m<sup>3</sup>. The excavated volume is not equally distributed over the whole canal length. On the contrary, approx. 87 % of the entire volume corresponds with just 45% of the canal length. The present remnants of the massive dams are much smaller and reveal only a volume of approx. 120,000 m<sup>3</sup>. This difference reflects the erosion and overprint since the 8<sup>th</sup> century AD. According to current information to the construction time by dendrochronological and historical data, we finally calculate the number of workers (c. 1725 persons) that were needed for the earthwork construction.

P-1836

## Spatial variation in till texture and clay mineralogy across the Saginaw Lobe terrain, Great Lakes region, USA

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### Abstract

We present a spatial/mapping approach to the study of the glacial history of the Saginaw lobe of the Laurentide Ice Sheet. The Saginaw Lobe flowed into southern Michigan, forming modern-day Saginaw Bay and leaving behind a series of small moraines in down-ice locations. Upon its retreat – and likely also during its advance – a large proglacial lake (Glacial Lake Saginaw) formed in the northeastern margins of the this “Saginaw terrain”. The Saginaw lobe advanced to the southwest, out of this lake basin and onto thinly mantled, sandstone and shale bedrock of the Michigan Paleozoic Basin. Although the Late Pleistocene deglacial chronology of this lobe has been generally assumed for decades, few numerical ages exist that could help constrain a better defined timeline. Indeed, as luminescence ages slowly emerge for terrain of the Saginaw Lobe and nearby areas, it seems clear that the lobe retreated from the region considerably earlier than is generally assumed, adding to the potential for large areas of ponded water in proglacial settings, all of which are as yet unmapped.

In this mapping project, we sampled tills on uplands across the terrain of the Saginaw Lobe, avoiding (1) areas that were affected by the lake, and (2) outwash plains. In all, we obtained 334 samples of calcareous till, by bucket auger. Sample locations were sited generally uniformly across >20,000 km<sup>2</sup> of the Saginaw terrain. Additionally, we recovered 17 samples of lacustrine clay from two areas on the former lakebed of Glacial Lake Saginaw. Grain-size analyses on these samples, by laser diffraction, revealed that the majority of the samples are texturally bimodal, with a mode in the clay-fine silt fraction and one in the very fine to medium sand fractions. Samples with a larger “fine” mode were typically in locations that were either (1) immediately down-ice from what would have been ponded by Glacial Lake Saginaw as the ice advanced into the region, and (2) areas which would have been trapped between the Saginaw ice and the large, preexisting West Branch Moraine. Down-ice, tills become sandier, which we attribute to the increasing influence of sandstone bedrock, as well as increasing distance from the clay source (the lakebed).

Our data highlight the tremendous spatial variability that can exist across a till sheet that, until now, was considered to have been comprised almost entirely of loam-textured till. Maps and grouping algorithms in ArcGIS helped us to identify natural groupings of these till textures, and in so doing, better elucidate the workings of the Saginaw Lobe as it advanced onto, and receded from, the landscape of southern Michigan.

**P-1837**

## **New insights into the glacial history of the eastern Cobequid Highlands, Nova Scotia, Canada as revealed by lidar-based surficial mapping**

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### **Abstract**

Surficial geological mapping based on the interpretation of LiDAR data has led to new insights into the Wisconsinian glacial history of the eastern Cobequid Highlands, where local ice-flow centres (the Appalachian Glacier Complex) prevented the incursion of Laurentide ice and produced regions of complex ice-flow chronologies associated with five phases of ice-flow and a multitude of surficial deposit types. New glacial geomorphological features have been identified and include eskers, flutes, kame and kettle features, meltwater channels, moraines, colluvial and alluvial deposits, many of which were not observed in previous lower resolution datasets (DEMs and aerial photographs). This surficial mapping project is one component of a joint surficial and bedrock mapping program conducted by the Nova Scotia Geological Survey to evaluate the mineral exploration potential (epithermal gold); guide geochemical sampling of till and stream sediments; and determine mineral dispersal patterns, which are discussed in this presentation.

The identification of new surficial landforms and deposits in the Eastern Cobequid Highlands allows us to update the Quaternary knowledge in this region and further our understanding of the glacial history, patterns of ice flow, and their associated landforms. It is anticipated that future surficial mapping and sampling programs will also avail of LiDAR data as the Nova Scotia LiDAR Acquisition Project aims to have all of Nova Scotia mapped with LiDAR by 2020.

P-1838

## Põlluotsa (NW Estonia), revisited.

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### Abstract

In 1995, during the large scale (1:50 000) geological mapping in NW Estonia, peat was found in the Põlluotsa gravel pit buried under the coastal deposits of Ancylus Lake. A short description of the site was given next year during the field meeting of the Peribaltic Group in Lithuania.

Since then the site and its surroundings were visited occasionally, and some new data (OSL, <sup>14</sup>C, pollen, *etc.*) were gathered. Põlluotsa area, an archipelago of islets during the Ancylus time, where buried pre-Ancylus organic matter spreads sporadically over several square kilometres, seems to be a very complex area in geological sense:

- The transgressive nature of the profile deposits indicates that the peat here does not mark the lowest point of the Yoldia Sea regression but formed as a response to the ascending groundwater level caused by the transgression of the Ancylus Lake.
- Local pollen zones from short sections influenced by local conditions mimic effectively the beginning of the (climatic) Boreal period with typical high *Pinus* pollen content. Sometimes this causes the 500–700-year underestimation of the age of only pollen-dated deposits. Of the abovementioned local conditions, the most important is probably the flooding by the waters of Ancylus transgression the relatively low-growing *Betula* brush and so leading to overrepresentation of *Pinus* pollen.
- Exceptionally old, and inverse, IR-OSL-dates of ca 44–25 ka (MIS-3) from the sands of Ancylus Lake suggest a fast redeposition from the sediments older than the Last Scandinavian Ice Sheet, which are very uncommon in northern Estonia, but nevertheless cannot be excluded in the area.
- For the first time in Estonia subfossil Yoldia Sea mollusc fauna was found here. Its freshwater origin, indistinguishable from the one of Ancylus Lake hints that Yoldia fauna may have simply not recognized earlier.
- Between the deposits of Yoldia Sea and sometimes deformed and eroded late-glacial varved [\[WU1\]](#) clays, turbidite-like purely-sorted sands and sandy gravels were found, representing the Billingen drainage event which ended the existence of Baltic Ice Lake.
- Geomorphological, mineralogical and OSL-data hint to the existence around of an ice-marginal zone, younger than youngest generally accepted one in Estonia (Palivere zone).
- A search for the older source sediments in the area led to discovery of even more ancient deposits formed, according to OSL-data, in the Late or even Middle Pleistocene, so far unknown in NW Estonia. It is also not excluded that they were redeposited (reworked) from original sands without access to daylight (*i.e.* they have kept initial age information) by tsunami or storm surge, or they were transported and deposited later, unchanged, by one of the ice sheets.

**P-1839**

## **The development of badlands in a Mediterranean setting: first results of geological mapping and OSL dating**

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### **Abstract**

Badlands are typically characterised by dry and unproductive terrains, which lack soil and are unsuitable for agricultural practices, vegetation or forestry. The growing number of badlands is a substantial problem in the world, particularly in temperate Mediterranean settings, and constitutes a major threat for local land management, economy and urban life. Sediments in a typical badland area are usually made of fine grained sediments such as clay, silt and sand (i.e. from a variety of rock sources). The development of temperate Mediterranean badlands is usually associated with intensive slope erosion caused possibly by change in climate (e.g. lengthy extreme wet periods) or human activity (e.g. bad land use). The influence of other external agents such as active faulting or depositional environments, that serve as conditioning or triggering factors, are hardly emphasised and recognised in the literature. Lithology and the rock structure have not been the centre of focus of most badlands research either.

The Kula Badlands, in the headwaters of a typical Mediterranean small tributary to the Gediz river in western Turkey, is situated in a region known for its Quaternary volcanism in an extensional tectonic regime, exhibit a notable example of intensive erosion. Base level control and lava flow damming of this small Mediterranean system has been mentioned in previous research. However, little is known about the stratigraphy, sedimentation history and the influence of the tectonic regime on these small tributaries and the development of Kula Badlands. This research is an attempt to identify the geological complexity of a badland terrain with field geological mapping and facies analysis to establish a benchmark in badlands research. We also collected samples for single grain optically stimulated luminescence (OSL) dating to build a robust geochronological framework with age control. The reconstruction of surface dynamic in relation to sedimentation and erosion history using age control will provide further insights in our investigation of badland development rates as a Mediterranean analogue.

**P-1840**

## **Mobile streamlined bedforms beneath an Antarctic ice stream**

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### **Abstract**

Mega-scale glacial lineations made up of unlithified sediments beneath the Rutford ice stream in west Antarctica have been known about for some years [e.g. Smith et al. 2007; Smith and Murray, 2009]. New seismic investigations along closely spaced seismic lines in areas of earlier surveys have revealed details of internal structures from which the evolution of the streamlined bedforms can be deduced. Amplitude vs Offset (AVO) experiments and radar surveys also permit some of the physical characteristics of the sediments, including porosities, to be established. Major internal discontinuities separate earlier lineation sets from later sets that have overridden them, reflecting the evolution of the sediment masses in space and time as part of an evolving mosaic. Internal structures also demonstrate that the up-flow (stoss) terminations of the later set have been eroding, whilst the down stream (lee) terminations have been extending and prograding. The prograding masses also show a down-flow front, beyond which earlier lineations are preserved, suggesting that the former are part of an advancing sediment carpet. There are no acoustic emissions from the area of the prograding surface, whereas there are strong emissions from beyond the sediment front, suggesting an un-resistant bed in the former area, which is also an area of high sediment porosity, and a resistant sediment bed downstream of the front. The paper discusses the possible physical conditions that have produced these contrasts, and insights into the evolution of mobile streamlined bedforms.

*Smith, A.M., Murray, T., Nicholls, K., Makinson, K., Adalgeirsdottir, G., Behar, A., and Vaughan, D. 2007. Rapid erosion, drumlin formation, and changing hydrology beneath an Antarctic ice stream. Geology, 35(2), pp. 127–130.*

*Smith, A.M. and Murray, T. 2009. Bedform topography and basal conditions beneath a fast-flowing West Antarctic ice stream. Quaternary Science Reviews, 28, pp. 584–596.*

**P-1841**

## **Drumlin Mapping Using Deep Learning Object Detection Systems**

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### **Abstract**

Recent research has suggested that drumlins and MSGLs belong to a continuum of genetically-related bedforms which are significant geomorphological evidence of ice sheet dynamics. Understanding their origin and formation is therefore crucial to modelling past and future ice sheet behaviour. Current formation hypotheses are inadequately detailed and unable to mathematically model the genesis of all bedform morphologies. This is due in large part to the logistical difficulties associated with mapping entire bedform populations which has resulted in the use of limited datasets with small sample sizes that do not account for the full morphological variability. The recent proliferation of high-resolution digital imagery presents an opportunity to address this data gap, but efficiently mapping bedforms from such data has proven difficult. This presentation explores the viability of using machine learning-based object detection to accurately and efficiently map drumlins and MSGLs. Deep learning object detection systems including Fast R-CNN (region convolution neural network), YOLO (You Only Look Once) and SIMRDWN (Satellite Imagery Multiscale Rapid Detection with Windowed Networks) are adapted and trained to identify and map subglacial bedforms from high-resolution digital elevation models. The results of these methods are compared and their potential for use in drumlin modelling research is evaluated.

**P-1842**

## **The new landslides and rock glaciers inventory map of Canton Ticino (Southern Switzerland)**

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### **Abstract**

The landslide and rock glacier inventory map of Canton Ticino was recently upgraded joining many studies performed since 2005 following a multi-method approach combining 2D and 3D digital photo-interpretation: (1) 2D photo-interpretation using SWISSIMAGE orthophotos and swissALTI3D hillshade, @swisstopo; (2) landslide mapping by 3D digital stereoscopic photogrammetry on analogical and numerical aerial photographs (1950-2015); (3) landslide mapping by digital monophotogrammetry thanks to the WSL-Monoplotting-Tool on ancient oblique non-metric photographs; (4) geological structures and shallow landslide mapping based on field verification of photointerpreted maps; (5) analysis of InSAR (Satellite Synthetic Aperture Radar Interferometry) and GBR (ground base radar) data for the state of activity of landslides and rock glaciers; (3) geodetic monitoring for landslide and rock glacier activity: GPS, theodolite, laserscan and UAV surveys.

This mapping allowed the inventory of 6599 hillslope landforms, from which 2035 were classed as landslides (covering a surface of 184.4 km<sup>2</sup>), 4376 as shallow landslides (covering a surface of 133.7 km<sup>2</sup>) and 188 as Deep Seated Gravitational Slope Deformations (DSGSD). Landslides are composed by 1494 slides, 86 flows, 390 falls (comprised between 100 and 1'000'000 m<sup>3</sup>) and 65 rock avalanche deposits (> 1'000'000 m<sup>3</sup>). 334 landslides were considered as active (238 slides, 17 flows and 79 falls). Shallow landslides includes: 1532 erosion areas; 2000 talus slopes, scree slopes, coarse-scrree slopes and rockfall deposits (< 100 m<sup>3</sup>); 27 debris flow deposits (from which 16 are considered as active); 817 mixed cones composed both by rockfall and debris flow deposits (from which 97 are considered as active).

Based on this mapping, the regional rock glacier inventory was also updated. Actually, 281 rock glaciers and related periglacial landforms were recognised in the Ticino Alps, comprising 48 ice-cemented active rock glaciers, 17 ice-cored active rock glaciers, 51 ice-cemented inactive rock glaciers, 3 ice-cored inactive rock glaciers, 157 relict rock glaciers, 3 push-moraines and 2 large gelifluction lobes. The 124 (44%) active/inactive rock glaciers, push-moraines and large gelifluction lobes are indicators of current permafrost conditions, whereas the 157 (56%) relict rock glaciers are indicators of former permafrost conditions during the Lateglacial and the Early Holocene.

P-1843

## Eskers associated with mid-latitude glaciers on Mars and their palaeoenvironmental implications.

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### Abstract

We have discovered two eskers associated with ~110–150 Myr old glaciers, in the Phlegra Montes [1] and NW Tempe Terra [2] regions of Mars' northern mid-latitudes. Eskers are sinuous sedimentary ridges deposited by meltwater flowing in glacial drainage conduits. Mars' present climate is extremely cold and arid and, until recently, it was widely thought that mid-latitude debris-covered glaciers on Mars had been pervasively cold-based since their formation 10s–100s Myr ago. However, eskers associated with existing glaciers indicate that localised wet-based glaciation has occurred during Mars' most recent geological period.

The mid-latitude glacier-linked eskers are both located within glaciated tectonic rift valleys or grabens. This suggests that, under cold recent climate conditions, locally-elevated geothermal heat flux (above the modelled global average of 23–27 mWm<sup>-2</sup>) may have been a prerequisite for glacial melting. We used a 1D model of heat flow through glacial ice to explore the environmental requirements for basal melting, incorporating the effects of strain heating for the first time [2]. We calculated the temperature at the glacier bed by comparing rates of geothermal and viscous strain heating of the basal ice with the rate of heat loss to the surface under different ice thicknesses.

We found that, under scenarios where geothermal heat is the only source of heat to the bed, basal melting requires conditions that seem unlikely for Mars' recent geologic history (surface temperatures >215 K, ice thicknesses >1100 m, and geothermal heat flux >80 mWm<sup>-2</sup>). However, when we incorporated strain heating, we found that it provided up to 14.5 K of additional warming to the basal ice and reduced significantly the geothermal heat flux, surface temperature, and ice thickness required for basal melting. This arises from a highly non-linear response of strain heating to ice temperature and driving stress. Ice convergence and large deviations in driving stresses (associated with localised variations in ice surface slope and/or ice thickness) may have encouraged strain heating of basal ice within the steep-sided tectonic rifts/graben that host the glacier-linked eskers. Thus, both geothermal and strain heating likely played vital roles in encouraging geologically-recent esker-forming glacial melt events in Mars' mid-latitudes.

We have also used high-resolution (0.25–2 m/pixel) remotely-sensed data to: analyse the 3D morphometries of the Martian eskers; compare them to terrestrial analogues; and explore the spatio-temporal nature, and sediment-discharge dynamics of esker-forming glacial melt events on Mars [3].

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[1] Gallagher, C., and Balme, M.R., (2015), Earth. Planet. Sci. Lett. 431, 96-109, [2] Butcher, F.E.G., et al. (2017), J. Geophys. Res. Planets. 122(12), 2445-2468, [3] Butcher, F.E.G., et al. (2019), This Conference.

**P-1844**

## **Geomorphological and sedimentary signatures of transient subglacial hydraulics during the November 1996 jökulhlaup, Skeiðarárjökull, Iceland**

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### **Abstract**

The landform and sedimentary record of former glacial meltwater systems provides valuable information about the dynamics of former ice-sheets. Although it is well known that ice-sheet plumbing systems can respond rapidly to transient processes such as the drainage of stored meltwater and glacier surging, the identification of such process within the Quaternary record is difficult due to the paucity of accessible modern process analogues. This study presents evidence of the sedimentary and landform signature of extreme hydraulic transience during a well-studied glacier outburst flood (jökulhlaup).

A volcanic eruption beneath Vatnajökull ice cap generated 3.8 km<sup>3</sup> of meltwater which travelled into Grímsvötn subglacial lake until it reached a critical level for drainage. The resulting jökulhlaup reached a peak discharge of 45-53 x 10<sup>3</sup> m<sup>3</sup>s<sup>-1</sup> within 14 hours. After its release from Grímsvötn, the jökulhlaup propagated as a high pressure subglacial flood wave taking 10.5 hours to reach the glacier snout. Negative effective pressure during passage of the subglacial flood wave induced hydraulic jacking of the glacier by 2–5 m. As the jökulhlaup progressed, discharge from the glacier became progressively focussed on major conduit outlets. To exit the glacier, floodwaters had to ascend ~300 m to the sandur surface bursting from multiple englacial vents and fractures, spreading progressively, along the entire 23 km wide ice margin over a 6-hour period.

Recession of the margin of Skeiðarárjökull, by ~ 2 km since 1996, reveals corridors of subglacial meltwater activity which are inset with the drumlinised landscape occupying areas of low elevation and on the ice-distal sides of drumlins. Parallel depressions, subglacial cavity fills, hydrofracture-fills and eskers within these corridors can be linked directly to known November 1996 jökulhlaup outlets. The internal sedimentary architecture of the hydrofractures and cavities is entirely conformable with the surrounding glacier ice and indicates deposition from jökulhlaup flow ascending from beneath the drumlinised surfaces (glacier bed). Hydrofracture and cavity-fills are interbedded with englacial eskers demonstrating synchronous deposition. Rectilinear ridges composed of glacial sediment coalesce into single-crested esker ridges feeding directly to November 1996 jökulhlaup conduit portals. Rectilinear gravel ridges comprise clastic dykes which reflect the upward injection of fluidised sand and gravel from an over pressured aquifer towards the former ice-bed interface. Substrate disruption/evacuation and ridge formation occurred simultaneously during the passage of the high pressure subglacial wave during the early stages of the 1996 jökulhlaup.

This study demonstrates the ability of highly pressurised jökulhlaup flow to produce distinctive assemblages of subglacial landforms and deposits. Such assemblages are associated with large englacial eskers, giant supraglacial ice-walled channels and distinctive pitted ice-contact proglacial jökulhlaup outwash fans.

P-1845

## Geomorphic, sedimentary and hydraulic reconstruction of a glacial lake outburst flood in northern Alberta, Canada

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### Abstract

Glacial lake outburst floods occurred frequently during the last deglaciation of the Laurentide Ice Sheet. Within the Interior Plains, these floods carved large spillway systems, however due to the lack of abundant sediment, deposits within spillways are rarely preserved. Here, we present geomorphic and sedimentary evidence and hydraulic modelling of the eastern Beaver River Spillway, formed by the catastrophic drainage of the ice-dammed glacial Lake Algar, in northcentral Alberta. During this flood, coarse-grained sediment eroded from local till formed large pendant bars. Within the first ~50km of the spillway (Reach 1), pendant bars contain downstream orientated foresets overlain by horizontally bedded coarser gravels. The remaining pendant bars (Reach 2), present downflow of a moraine barrier, differ, comprising massive, matrix-supported, inversely-graded gravels capped by a boulder layer. We use a HEC-GeoRAS/HEC-RAS system in conjunction with palaeostage indicators, to estimate the steady-state water surface elevation. Modelling results show that peak discharge within Reach 1 of the eastern Beaver River Spillway was approximately 14,000-21,000 m<sup>3</sup> sec<sup>-1</sup>. For Reach 2, 30 km downstream, the peak discharge was estimated at 23,000-40,000 m<sup>3</sup> sec<sup>-1</sup>. The downstream discharge increase, consistent with the sedimentary change in pendant bar deposits, is attributed to sediment bulking of the flood flow. This provides the opportunity to observe a range of flow conditions, and associated sedimentology, from a single flood event.

P-1846

## Cool deltas. Sedimentary environments of Salpausselka I and II moraine ridges near Lahti, Finland

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### Abstract

Two large “moraine” ridges (Salpausselka I and Salpausselka II), extending to over 600 km in length, delineate two major stillstand/readvance positions of the Fennoscandian ice sheet during the last deglaciation, inferred to be chronologically related to the cool climate event known as the Younger Dryas (age) [\[SM1\]](#). During this time the Baltic ice lobe and the Finnish Lake District [\[SM2\]](#) ice lobe, constituting a part of the southern margin of the Fennoscandian ice sheet, were grounded in a large proglacial lake, the Baltic ice lake, a predecessor to the modern-day Baltic Sea. Most of the sediments were delivered to the ice margin by meltwater and deposited in the form of ice-contact deltas, over a very short period (230 and 250 years respectively for Salpausselka I and II). As a result, the “moraine” ridge is mostly composed of glaciofluvial sands, gravels and boulders rather than diamicton which is more typical of moraine sedimentology.

In this study, high resolution LIDAR data (2m horizontal, 0.3m vertical), provided courtesy of the National Land Survey of Finland and processed by the Geological Survey of Finland, ground penetrating radar profiles and outcrops were analyzed and interpreted. These provide a [\[RDBR3\]](#) record of rapid sedimentation from high-magnitude meltwater discharge, through subglacial channels, resulting in rapid buildup of ice contact fans to the water surface and subsequent progradation of deltaic forests. Renewed retreat of the ice margin lead to abandonment of the Salpausselka I and deposition of the Salpausselka II ridge, 25 km to the north. In the Lahti region, where the two ice lobes were confluent, the largest deltaic complex developed. Sediments of Salpausselkas in Finland are a world class example of a [\[RDBR4\]](#) sedimentary environment which records, with great detail, the processes of the formation of ice-contact, Gilbert-type, deltas marking stillstand positions of the southern margin of the Fennoscandian Ice Sheet during the Younger Dryas.

**P-1847**

## **The geomorphology and formation of Late Pleistocene outwash fans in northern Poland**

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### **Abstract**

Outwash fans are common landforms in contemporary and Pleistocene glacial landscapes. Research on the subject has usually concerned the general morphology of sandurs, and the lithofacial characteristics and depositional processes of their formation. So far, there has been no detailed geomorphic analysis of sandurs, and of outwash fans in particular. The research examined the morphometric properties of outwash fans in northern Poland and the processes of their genesis.

In 16 test areas, surface and morphometric characteristics were analyzed using high-resolution (1×1 m) elevation data from Airborne Laser Scanning (ALS). The analysis also includes geological and geomorphological data, mainly from the detailed 1:50,000 geological map of Poland. First, geomorphological maps and surface geological structure of the test areas were collected. Then, a detailed mapping of surface topographical macroform was performed, and morphometric parameters of 18 identified outwash fans were determined in detail.

Based on the research, two main types of outwash fans were distinguished. (1) *The typical outwash fans* formed at the outlets of N- and R-type subglacial channels and also sometimes at the extension of upward-opening crevasses along degraded channels within the ice sheet front. As a whole spatial form, these fans represent a record of the subglacial meltwater outflow in the ice sheet forefield. These processes were accompanied by the supply of supraglacial debris, which nonetheless did not significantly affect their morphological development. (2) *The transitional outwash fans* were formed by subglacial meltwater outflows from N-channels, and debris flows from the ice sheet front and accumulating on the extension of short ice-marginal fans.

The outwash fans were created as a result of the temporally and spatially variable activity of meltwaters of diverse flow energies. In most cases, these landforms formed at the outlets of N-channels, and more rarely of R-channels, as a result of repeated outflows of subglacial meltwaters. The macro-relief of some outwash fans suggests that their formation may have involved catastrophic flows.

**P-1848**

## **Exploration of a morphogenetic signature for eskers**

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### **Abstract**

Eskers are typically defined as sinuous ridges of sand and gravel deposited by glacial meltwater processes. This definition does not express the variability in esker form observed in Quaternary and contemporary landscapes. Eskers may be straight to sinuous, consist of single or multiple anabranching ridges, and contain a range of grain sizes representative of the complex interplay between glacier ice, water, and debris. These differences in form and structure are associated with variations in genesis. Esker pattern, morphometry, sedimentary architecture, and composition record the hydrologic and sediment supply conditions responsible for their formation. The use of eskers as indicators of paleo-ice sheet hydrology is often underlain by the assumption that all eskers are of subglacial origin. Studies of eskers in paleo and modern environments suggest that this assumption is not valid. This project investigates the relationship between esker morphometry and genesis. The results will help to better understand glacial hydrology and to inform ice sheet models containing hydrology.

Little research has been done to quantitatively describe esker morphometry. The increasing availability of high-resolution digital elevation data makes assessing the relationship between esker form and genesis possible. Here we present a database of esker morphometry and genetic interpretations sourced from original field research and mining of relevant esker literature. Morphometric indices such as length, sinuosity, continuity, and cross-sectional shape are computed for each record in the database. These indices are calculated at a range of digital elevation model resolutions in order to assess their scale-dependency. Genetic interpretations and supporting evidence are also summarized. This project primarily focuses on relative position in the glacier (subglacial, supraglacial, englacial, etc.) as a genetic marker, but other genetic interpretations have been recorded. This database confirms the variability in esker morphometry and genesis and provides a basis from which to explore a morphogenetic classification of eskers.

**P-1849**

## **An empirical approach to assessing the influence of hydrology on palaeo-ice sheet flow and retreat over centuries to millennia**

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### **Abstract**

Recent observations have shown that meltwater storage (in lakes on or beneath the ice) and routing on, through and beneath ice sheets can critically affect ice flow (speed up vs slowdown) and tidewater glacier recession, on up to decadal timescales. Despite significant recent advances, theoretical limitations and the computational expense of incorporating physically-based ice sheet hydrology into models currently limits their scope to studying individual catchments and short time periods. It is therefore uncertain whether hydrological controls only influence short-term fluctuations in flow speeds and retreat, which could be thought of as noise around a mean value, or whether they are fundamental drivers of centennial to millennial change and ice sheet mass loss.

We present an empirical approach for determining the influence of hydrology on ice flow and margin position change of palaeo-ice sheets over centuries to millennia, based on recent work that demonstrates the routing, storage and drainage of surface meltwater is controlled by transfer of basal topographic variability to the ice surface (Ignéczi et al. 2018; Ng et al., 2018). Using modelled ice sheet geometries, modelled surface mass balance, high-resolution bed topographies and empirical relationships from contemporary ice sheets, we demonstrate that it is possible to reconstruct a representation of the surface drainage system and likely drainage volumes to the bed. Combined with the application of hydrological routing analyses to produce first order approximations of subglacial drainage catchments and basal water volumes, we aim to assess the extent to which variations in the coverage of the surface drainage system, driven by bed roughness and changes in ice geometry and surface mass balance exert a control on empirically-derived retreat rates. The reconstructed surface drainage patterns will also be compared with the distribution and morphology of mapped subglacial meltwater landforms, such as channels and eskers, to determine the role of supraglacial hydrology on their formation.

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**P-1850**

## **Riverscape response to glacial lake outburst flood mapped using UAV surveys: a case study from Zackenberg Valley, NE Greenland.**

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### **Abstract**

Currently, the primary challenge for research related to Earth-surface dynamics in the Arctic is to recognize and quantify geomorphic response to global warming, including the response to (1) high-frequency climate variability (e.g. freeze-thaw cycle, rainy and dry seasons); (2) low-frequency, but high-magnitude extreme events (glacial-lake outburst flow, catastrophic debris flows); and (3) long-term landscape and climate evolution. Previous studies also indicated that there is a need to collect detailed examples of fluvial change in flood-affected areas as our understanding of the geomorphic response to large floods is still incomplete. In this study, we used high-resolution pre-flood, during-flood and post-flood imagery collected with an unmanned aerial vehicle (UAV), which provided us with an excellent opportunity to observe and measure such a response.

The study was carried out in Zackenberg Valley (at the lower reach of the river) located in central Northeast Greenland (74°30'N; 20°30'W). The Zackenberg Research Station, established in 1995, provides access to field-based observations in this High Arctic region. Zackenberg River drains local ice cap situated approximately 30 km from the seashore, and glacial outburst floods have regularly been reported since 1996, usually in July or August. We aimed to quantify the geomorphic effects of the flood which happened on the 6th of August 2017. We mapped 2 km long section of the river, located near the river mouth and Zackenberg Research Station to quantify short-term riverscape response to the flood. Three survey sessions utilising small quadcopter were performed on: 5th August 2017 (a day before the flood started), 6th August 2017 (during the high-water conditions) and 8th August 2017 (after the river returned to the normal water level). From each survey session, detailed orthomosaic (2 cm cell size) and digital elevation model (DEM, 7 cm cell size) have been produced. Volumetric transformations were calculated using geomorphic change detection approach by subtraction of DEMs from subsequent periods. Planar transformations were investigated using time-series of orthomosaics.

Riverbanks retreated by a mixture of two main processes: strong currents removed material, and thermo-erosion of permafrost in the banks resulted in the development of overhanging sections or collapsing of large blocks of sediments and ground ice. The maximal later erosion recorded as an immediate effect of this single flood event was up to 9 meters. However, the occurrence of overhung sections and tension cracks indicate that further bank failure is likely to happen. Morphology of river channel also changed, and numerous gravel and sand bars migrated as a result of the flood. Collected information present a useful analogue of the geomorphic response of small river channels affected by large floods.

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P-1851

## Late Wisconsin meltwater routing In a large embayment along the southern margin of the Laurentide Ice Sheet in Michigan, USA

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### Abstract

Soon after the LGM, a large embayment developed along the southern margin of the Laurentide Ice Sheet bounded to the west, north and east by the Lake Michigan (LML), Saginaw (SL), and Huron-Erie (HEL) lobes, respectively. The movement of these lobes was asynchronous, and therefore meltwater was released from them over a long interval of time. There is little radiocarbon control on ice margin fluctuations, and although we have a growing luminescence database from samples of glacial outwash, the uncertainties of this method may limit resolution of closely spaced meltwater events. Working out the source of meltwater flows from this area is important because the Kankakee Torrent, a major glacial lake outburst in Illinois that flowed down the Mississippi Valley to the Gulf of Mexico, was probably triggered by meltwater flow from the study area.

Based mainly on cross-cutting relationships, the earliest meltwater flow from the embayment originated from a network of tunnel valleys ending at the Kalamazoo moraine of the SL and probably also from the HEL. This meltwater flowed westward until diverted to the south by the presence of the LML, through an interlobate lowland. The LML lobe itself then began to contribute meltwater to the embayment. When the LML retreated to the Valparaiso position, glacial Lake Dowagiac formed in a long linear lowland between the edge of the LML and the Kalamazoo moraine to the east. The rapid drainage of this lake is the most likely source of meltwater that flowed into glacial Lakes Wauponsee, Watseka, and Pontiac south of the LML, causing the lakes to overflow and cutting spillways leading to the Illinois and Mississippi Valleys at about 19 ka. BP. Evidence for a large-scale release of meltwater from the lake includes streamlined erosional hills in the basin.

After the LML retreated westward of the Kalamazoo and Valparaiso moraines, an outburst from an as yet unknown source cut a large spillway through both moraines, which diverted meltwater west of the embayment. The most recent meltwater flow through the embayment came from the HEL and flowed southward along the edge of the Kalamazoo/Valparaiso morainic system.

P-1852

## Patterns of ice-marginally related glacifluvial sedimentation in Eastern Lithuania

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### Abstract

The situations of the ice meltwater running from supraglacial outlets and glacial conduits seem to be common during the Late Pleistocene glaciations in Eastern Lithuania. Depending on the conditions the glacifluvial sedimentation took place in front of the glacial margin in form of glacifluvial ice-marginal ridges or further on terraces of proglacial valleys. During the detailed sedimentological study, the main attention was paid to the ice-marginal ridges (end moraines) composed of the glacifluvial sediments to understand the role of subaerial terminoglacial fans in their formation. Sediments forming some of such ridges are completely glacetectonically dislocated. In the other cases, only the sediments of ice-contact zones in glacifluvial ridges are slightly deformed. The glacifluvial sediment sequences at the other sights show the features created only by sedimentation from ice meltwater flows. The architecture of such landforms usually displays extensive bodies of horizontal to low-angle stratified fine- and coarse-grained sediments with some outsized clasts inside the beds. Subhorizontally laminated, sometimes cross-bedded pebbles and granules usually matrix supported, coarse- and various-grained sand beds make some rhythmite. These mostly coarse-grained rhythmite sheet-shaped beds have a slight inclination away from the former glacial ice margin. In some sites, the inclination of beds is quite high in all the deposit sequence. The sand cross-laminae if present has the same preferred dip direction as the inclination of sediment beds. Such deposit architecture likely represents sheet-flow sedimentation in front of the glacial ice margin forming the sediment ridges in the initial form of glacifluvial fans or their coalescences.

P-1853

## Tunnel channel development and their impact on flow dynamics of the Green Bay Lobe, Wisconsin, USA.

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### Abstract

Subglacial water drainage plays a significant role in glacier flow dynamics. Various forms of subglacial drainage have been observed beneath modern ice sheets, and the same forms of drainage likely occurred beneath paleo-ice sheets, such as the Laurentide Ice Sheet (LIS). Records of paleo drainage are well preserved in Wisconsin's geomorphic record and can serve as a widespread and easily accessible means to investigate aspects of subglacial drainage that are difficult to directly study on modern-day glaciers. Tunnel channels were common subglacial drainage features of the LIS in Wisconsin during Marine Isotope Stage Two (MIS 2). Their locations are marked by a linear series of collapse depressions that extend up to ~15 km perpendicular to the margin. Geologic evidence indicates tunnel channels resulted from sudden subglacial lake drainage eroding into subglacial material, and that only a few drainage events occurred for any particular channel.

This poster presents the results of recent geologic mapping, geophysical surveys, drilling and subglacial hydraulic modeling of tunnel channels along a portion of the Green Bay Lobe (GBL) in central Wisconsin. One km seismic profiles were collected across tunnel channels with 2.5 m common midpoint spacing at nominally 12 folds. Hammer blow and assisted weight drop sources were used and impacts were stacked ca. 5-fold to improve the signal to noise ratio. Core samples were collected with rotasonic and direct push drilling methods to depths of 125 m, including the center of a tunnel channel. We find that the channel incised ca. 65 m into the surrounding unlithified material, which is 6 times greater than the modern surface expression, and has a width of 450 m, which is nearly equal to the width of the surface expression.

Using modeled estimates of the subglacial hydropotential gradient along the western margin of the GBL we identified potential locations for subglacial water pooling. Linear surface depressions appear to correlate well with areas where subglacial water likely pooled. Our modelling of the subglacial hydraulic potential near the margin of the GBL suggests permafrost was not necessary if an adverse bed slope was approximately 11 times greater than the surface slope. This condition occurs at several locations along the western GBL, and in all instances coincident with the presence of tunnel channels. However, there is strong evidence that permafrost was present as ice advanced to the MIS 2 margin, and permafrost must have been present for buried ice to survive through multiple ice advances in the area.

P-1854

## The glacial geomorphology of the last glacial termination of the Godley Glacier, Tekapo Valley, New Zealand

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### Abstract

A 2 m digital elevation model (DEM) generated from airborne LiDAR data, supplemented with aerial imagery and field evidence, are used to map the glacial geomorphology of the Tekapo Valley, Canterbury, New Zealand. The map presents the distribution of glacial landforms and sediments associated with the last recession of the Late Otiran Godley Glacier. It represents the most-detailed and finest-resolution geomorphological map of any glacial valley in New Zealand, which contain important and hitherto understudied palaeo-glaciological archives of landforms and sediments. The DEM reveals previously unrecognised, low-amplitude, ice-marginal landform assemblages including eskers, drumlins, and crevasse-squeezed ridges, overprinted by inset sequences of latero-frontal recessional push moraines. These landforms indicate a final ice stagnation phase. Their presence has significant implications for the nature of subglacial drainage and for the final stages of glaciation. The landforms record spatiotemporal land-system change that is fundamentally diagnostic of an active temperate piedmont lobe of a debris-charged glacier. The mapping is combined with 80 km<sup>2</sup> high-resolution (1 m grid) multi-beam swath bathymetry of Lake Tekapo which reveals widespread and spectacular sub-aqueous slumps. Sub-aqueous slumps are a dominant feature of the lower slope lake walls, covering 20 % of the marginal lake basin floor.

We highlight the nature of deglaciation, which is characterised by exceptional sedimentation and the widespread presence of water associated with proglacial settings. These conditions prevailed to produce a glacial land-system characterised by extensive outwash fans and relatively small terminal moraines. The new geomorphological dataset presented here facilitates land-system analysis at the ice-lobe scale. We produce detailed reconstructions of (i) ice-margin recession (ii) evolving ice-dynamics and (iii) evolving palaeo-lake systems. The glacial landsystem of the Tekapo Valley constitutes important palaeo-glaciological reconstructions for modern dynamics of the Godley Glacier and its proglacial lake. The mapping serves as a foundation into more detailed research into the timings of change and will underpin future chronological investigations. A reliable geochronology is crucial for elucidating the temporal glacial evolution of the Tekapo Glacier throughout the Last Glacial Maximum.

**P-1855**

## **A response of the Middle Pleistocene fluvial systems on climate changes - a case study from Gdansk Pomerania region, northern Poland**

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### **Abstract**

Fluvial systems are characterized by cyclic variability of sedimentary processes and styles. This variability is controlled by both autogenic factors, resulting from the nature of this environment, as well as allogenic factors. Tectonic activity, climate and base-level changes are the main allogenic factors. During the Pleistocene the main role have played climatic changes in glacial-interglacial cycles and sea-level changes connected with them.

Transformation of fluvial system from braided to meandering river type is presumably interpreted as a result of changes from cold to warm climate conditions (Zieliński and Goździk, 2001). However, studies of the deposits of modern and ancient rivers operating in cold climate areas show that at the same time various types of fluvial systems were developing.

The area of Poland underwent repeated transgressions of the Scandinavian Ice Sheet (SIS). Northern part of Poland, which was within the reach of all SIS transgressions, experienced several rebuilt of fluvial systems. Fluvial sediments in several key sites in the region of Gdańsk Pomerania were subject to research. As part of the research, sedimentological analysis was carried out, dating of sediment age with luminescence methods and palynological analysis. The aim of the studies is to establish the impact of climate on sedimentary processes, stratigraphical scheme for fluvial series and to reconstruct palaeogeographical evolution of study area.

Fluvial systems have evolved according to a specific scheme in which four phases can be distinguished. After regressions of SIS, firstly developed outflow of melted water along ice-sheet margin, mainly towards W-NW. In this phase ice-marginal valleys and outwash plains have formed with high ratio of sediment aggradation. The second phase began with a deep incision during amelioration of climate and deposition of interglacial/interstadial series of braided rivers, which are relatively thin and rare. The third phase during deterioration of climatic conditions to cool and humid resulted in a change of sedimentation style to meandering with well-preserved point-bars (Sokołowski et al., 2017). The further cooling and drying of the climate caused widespread aggradation of permafrost and increasing of aeolian processes.

Three periods of SIS advances were detected, during MIS 10, MIS 8 and MIS 6a, respectively. Between these advances fluvial systems developed (MIS 9, 7 and 6), with repeated scheme of evolution from warm, braided systems to cool and cold climate meandering systems with outflow towards S, NW and SSW.

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P-1856

## A glacial-geologic record of post-LGM ice sheet behaviour in NW Scotland constrained with $^{10}\text{Be}$ and the Rannoch Moor production rate

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### Abstract

Despite the generally erosive nature of temperate ice, the geomorphic expression of glaciation in the British Isles and Ireland represents a palimpsest of successive Quaternary ice ages. To reconstruct more fully the history of glacial advance and retreat – and the palaeoenvironmental and climatic conditions these fluctuations represent – it is necessary therefore to establish accurate, precise, and reproducible chronologies for the glacial-geologic record. As a relative newcomer to the geochronology toolkit, cosmogenic nuclide (CN) surface-exposure dating is being applied increasingly to glaciated landscapes at all latitudes, and holds particularly exciting potential for divulging the timing of glacial and paraglacial events in Britain and Ireland. We present a new record of post-LGM cryospheric change in NW Scotland based on cosmogenic beryllium-10 dating of moraines and perched erratics, extending from the point at which the British-Irish ice sheet retreated onto the modern coastline to the disappearance of the last corrie glaciers. In addition to documenting discrete phases of cryospheric retreat and readvance, which we attribute to atmospheric warming and cooling events, respectively, this emerging chronology highlights the necessity of employing a robustly calibrated CN production rate, without which cosmogenic chronologies are effectively floating. We applied a new  $^{10}\text{Be}$  production rate calibrated against independently dated moraines on Rannoch Moor, central Scottish Highlands, that is appropriate for use throughout the former domain of the last British–Irish ice sheet.

P-1858

## Frontal and Equilibrium Line Altitude Fluctuations since the Little Ice Age in the Miyar Basin, Lahaul Himalaya

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### Abstract

We compare the present day terminus position and Equilibrium Line Altitude (ELA) with that of the last glacial expansion (Little Ice Age) that occurred in the Miyar basin Lahaul, India. The positions of the contemporary glaciers were mapped using high-resolution satellite images provided in 3D Google Earth and ESRI online images further supported by fieldworks using handheld GPS. The positions of the last glacial expansion were marked based on the field based mapping of the moraines between 2008 and 2016 supported by the Google Earth and ESRI Earth maps. The last glacial expansion moraines are well deposited in the form of the lateral moraines in all the major glacier valleys. The moraines are morpho-stratigraphically distinct from the earlier Holocene moraines with fresh sediments and landforms assemblage within 2 kilometres from the present glacier terminus supported by available historical maps of 1840-70s. The former terminus of a few glaciers, including Tharang, were incorporated and shown in the historical map of captain Harcourt (1871) and in the Great Trigonometrical Survey map (1840-70). Based on the available archaeological and palaeo-climatic history of the region of the last millennium, we suggest that by the late 18<sup>th</sup> and early 19<sup>th</sup> century the glaciers recorded expansion in the basin.

During this advance (late 18<sup>th</sup> to early 19<sup>th</sup> Century) Tharang glacier expanded down-valley by ~1.8 km, terminating at 3936m asl from its present position of 4486m asl, with an ELA depression of ~275 m relative to the contemporary ELA at 5130 m. Well preserved pair of lateral moraines in the upper Tharang valley marks the limit of this advance. The moraines are similarly marked on the GTS map. Comparatively, during the same advance, Pimu glacier experienced more expansion (~2.35 km), with terminus extending down to ~4276 m a.s.l. compared to the present position at ~4579 m asl (fig.4.7). Similar size of advance is recorded in Karpāt (~2.33 km) and Khanjar (2.31 km) glaciers. Relatively moderate advances (1-2 km) are observed at Darjeyang, Menthosa, Dali, Miyar, Tharang, Gumba and Hulāt glacier, whereas lesser (<1km) expansion is recorded in Takdung, Chhudong, Uldhampū, Palbo and Gangpo glaciers.

The contemporary ELAs in the basin range from 5062 to 5324 meter a.s.l. with a mean ELA of 5145m a.s.l. for the basin. However, during the Little Ice Age period, the ELAs varied between 4833 to 5193m. All the valley glaciers experienced noticeable depression in equilibrium line altitude. There are glaciers (*Karpāt, Darjeyang, Tharang, Menthosa and Dali*) which notice >250m change in ELA, whereas there are glaciers that experienced 250-150m ELA change (*Hulāt, Pimu and Palbo*). However, Khanjar, Gumba, Takdung, Chhudong, Miyar, Gangpo and Uldhampū noticed the lowest ELA change with 95, 70, 51, 46, 41, 35 and 18m ELA depression, respectively.

P-1859

## Depositional phases and sediment provenance in the Okavango Basin

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### Abstract

The Makgadikgadi–Okavango–Zambezi Basin (MOZB) lies within a fault-bounded trough that many believe propagated westward from the East African Rift System into NW Botswana. This depression forms a depo-center within the intracratonic Kalahari Basin of southern Africa. Through dedicated studies, the surficial sediments that were deposited in the ephemeral lakes of the Makgadikgadi Pans, the Okavango River alluvial fan (i.e., Okavango Delta), and the surrounding aeolian dunes, are relatively well characterized and understood. Moreover, structural and seismic studies have defined the tectonic settings of the MOZB. Conversely, little is known about the sub-surface litho- and chrono- stratigraphies, and their relations with depositional environments and regional tectonics. The provenance of sediments in combination with cosmogenic nuclides dating from three boreholes located west of the present Okavango Delta were studied to reconstruct the spatial and temporal evolution of the sedimentation. Independent approaches for interpreting the in situ-produced <sup>10</sup>Be and <sup>26</sup>Al concentrations (i.e., simple burial dating model, isochrone dating model, aeolian accumulation model) reveal three discrete depositional phases during the Plio-Pleistocene (>3, 2.2-1.8, <1.5 Ma), intermitted by hiatuses. The youngest phase seems to be the most widespread and extends to the southern Kalahari Basin. Stratigraphic variations in sedimentological and geochemical properties indicate changes in depositional environments through time and space, from low-energy deposition in still water to deposition in high-energy fluvial systems, all finally covered with aeolian sand. Duricrusts formation within all these units suggests later cementation by migrating solutions. Shifts in isotopic ratios of Sr, Nd, and Pb reveal changes in the sediment sources. These changes suggest adjustments of the drainage systems linked to tectonic events of the suggested southwestern-most extension of the East African Rift System.

P-1860

## Using cosmogenic $^3\text{He}$ for paleotemperature reconstruction in formerly glaciated areas of the central European Alps

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### Abstract

Recent studies demonstrate the potential of using cosmogenic noble gas systems as Earth surface paleothermometers. In particular, diffusive properties of cosmogenic  $^3\text{He}$  accumulated in quartz at subzero temperatures should enable *in situ* paleotemperature reconstructions in mountainous areas where other direct and continuous temperature proxies (e.g. lake sediments, speleothems) are generally scarce. Glacially-scoured surfaces revealed following glacier retreat since the Last Glacial Maximum (LGM, ~26-20 ka) constitute promising sample targets for obtaining a temporal sequence of *in situ* paleotemperature reconstructions. If attainable, such information would be crucial to improve our understanding of glacier dynamics and past changes in atmospheric circulation patterns during deglaciation. However, converting bedrock  $^3\text{He}$  concentrations directly into paleotemperature estimates requires (1) a robust reconstruction of the bedrock exposure history, (2) an accurate quantification of the  $^3\text{He}$  diffusion kinetics and domain size, and (3) an understanding of rock-air temperature interactions over multi-frequency temperature oscillations.

In this study, we present  $^3\text{He}$  data measured from bedrock surfaces sampled along well-constrained deglaciation profiles (based on cosmogenic nuclide surface exposure dating) in three different sites in the central Alps: Gotthard Pass ( $^{10}\text{Be}$  and  $^{14}\text{C}$ ), Gelmersee ( $^{10}\text{Be}$ ), and Mer de Glace ( $^{10}\text{Be}$ ). We investigate lithological effects on  $^3\text{He}$  diffusion kinetics at both the macro (rock type) and micro scales (grain size and shape), as well as the potential influence of snow or soil covering since glacier retreat on bedrock temperatures. Effects of topographic factors such as elevation and aspect are also examined, as well as temperature fluctuations at the daily, seasonal and millennial time scales. The  $^3\text{He}$ -derived paleotemperatures we present will be compared to paleotemperatures inferred from other paleoclimate proxies available for the European Alps, allowing us to explore the spatial variability of past climate conditions and/or paleo-lapse rates across the Alps since the LGM.

**P-1861**

## **Cosmogenic isotopes transect on the northeastern Laurentide ice sheet cold-based plateaus**

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### **Abstract**

Cosmogenic  $^{26}\text{Al}/^{10}\text{Be}$  analyzed in quartz from bedrock (tor), regolith and till across transects on cold-based plateaus once glaciated by the Laurentide Ice Sheet (LIS), provide insights into the spatial relationship between basal thermal regime and glacial erosion among different mapped morphometrically-based subglacial erosion zones. Isotope transects extend from the “internal zone” of the northeastern LIS LGM ice dome region (Boothia and Melville peninsulas) to the “external zone”, toward the LGM ice margin (represented by Hall Peninsula on southern Baffin Island).  $^{10}\text{Be}$  concentrations (normalized to SLHL) indicate relatively homogeneous inheritance within the plateau zones. Total erosion rates and burial duration (by ice or sediment) during the Quaternary can be estimated from numerical models. Assuming homogenous erosion rates among the cold-based plateaus, the hypothetical link between the variations of the  $^{26}\text{Al}/^{10}\text{Be}$  ratios and the relative ice cover durations can be tested against other causes for the variations of the ratios such as burial by sediment cover or analytical uncertainty, because the studied plateaus have different ice cover durations during over the Pleistocene, as suggested by modelled ice cover (for example ICE 6) and deglaciation ages ranging between 11 and 6 ka Cal (considered a proxy for ice burial duration). This new work will complement the glaciodynamical studies on contrasting ice flow regimes in this region, from cold-based regions to ice streams.

**P-1862**

## **Cosmogenic isotope dating of glacial forms in Miętusia and Mała Łąka valleys, Tatra Mountains (Western Carpathians)**

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### **Abstract**

Miętusia and Mała Łąka valleys were glaciated at the turn of Holocene and Pleistocene, with the maximum extent during Last Glacial Maximum. That was one of the assumption of this project that we wanted to proof by dating glacial forms. Both valleys are located in Western Tatra Mountains (Western Carpathians). We used cosmogenic isotope of <sup>36</sup>Cl because of geological structure of the studied area. It is mainly composed of Triassic dolomites and limestones.

Tatra Mountains are at the border of oceanic and continental climate, which gives this region high temperature amplitude and maximum precipitation during summer months. High amount of precipitation cause high level of chemical denudation and high level of changes in glacial forms (especially in lower parts of the mountains).

In the study we show 29 in situ-produced <sup>36</sup>Cl-based cosmic ray exposure dating from maximum and recessional moraine boulders and bedrock. Dates from moraine boulders ranges from  $16,8 \pm 0,8$  ka to  $8,8 \pm 0,4$  ka, with high standard deviation for one moraine. From those results it is very hard to determine reliable moment of glacier stabilization and age of the forms. Unfortunately it makes those glaciers very hard to use as a paleoclimatic information source, because we can not place these climatic conditions in specific range of time.

Results of the investigation based also on the results from previous research shows that rate of denudation of glacial forms made of mix fraction in both valleys is high.

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**P-1863**

## **Glacial stratigraphy and till micromorphology at Pine Point, southern Northwest Territories, Canada**

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### **Abstract**

The Pine Point Mississippi Valley-type (MVT) Pb-Zn mining district extends 50 km along an east-west trend south of Great Slave Lake, Northwest Territories, in northern Canada. The district contains 50 open pits that expose glacial sediments, in some cases more than 20 m thick, providing a unique opportunity for glacial stratigraphic analyses. A detailed stratigraphic study is being undertaken on a thick (>20 m) basal till sequence at open pit M-52 in the north-central part of the district. The goal of the research is to augment the existing knowledge of the regional Quaternary stratigraphy and to investigate the mechanics of till deposition/emplacement throughout the continuous till sequence to better understand the glacial dynamics for the western margin of the Laurentide Ice Sheet. Additionally, the glacial stratigraphy at pit M-52 will be correlated with the previous research conducted within the mining district, regionally with Quaternary sections exposed along the Mackenzie River to the west, and extensionally with seismic shothole and diamond drill hole stratigraphic databases. Till samples were collected for macro- and micro-sedimentological studies.

Macrosedimentology studies incorporate glacial stratigraphy, sedimentology, clast fabrics, geomorphology, and laboratory analyses for matrix geochemistry and indicator minerals. The walls of pit M-52 expose two visibly distinct tills, a grey till exposed at the base of the section and an upper brown till. When a complete vertical section was cleared and examined, the contact between the two tills was indiscernible and suspected to be gradational over several metres. The upper brown till could reflect surface oxidation of the lower grey till. However, based on previous research conducted in the region, it is unlikely that there is only a single till exposed in the pit walls. The suspected gradational contact is likely a product of extensive glacial inheritance and mixing as glacial dynamics shifted during till accretion. Clast fabrics were measured in the section and revealed that the grey till close to the bedrock surface reflects SW ice flow, the middle of the section in the gradational zone reflects NW flow, and the brown till near the top displays evidence of NW ice flow.

Detailed glacial microsedimentological data analyses for 38 samples, collected from the two till units, will be used to determine the stress conditions and rheological environments during till emplacement/ deposition. The use of micromorphology in this study is as a primary tool for the analysis of these subglacial sediments, providing far greater detail on the depositional and deformation histories recorded by these sediments than previously obtained from macroscale studies.

**P-1864**

## **Differentiating iceberg scoured sediments from subglacial tills and mass-wasting deposits at the microscale**

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### **Abstract**

Visual comparison of 'sets' (or 'suites') of microstructures permit differentiation or co-association of sediments from the same or different sedimentary environments. This non-statistical, subjective method is successful when clear and marked differences between microstructure 'sets/suites' are clearly discernible - especially when coupled with other data such as the geomorphic context, clast provenance or the presence of features diagnostic of specific environments. This research compares sets of microstructures identified in iceberg scoured sediments (clay, pebbly sandy mud, sand and diamicton), subglacial tills and mass-wasting deposits. The set of microstructures associated with iceberg scour are distinctly different from the sets of microstructures found in subglacial tills and mass-wasting deposits. In iceberg scoured sediments rotation/ductile deformation is dominated by folds and realigned bedding; planar/brittle deformation is dominated by faults and discrete shears; sediment mixing is dominated by intraclasts type III and multiple domains; porewater is dominated by water escape and flow; and plasmic fabric is dominated by unistrial plasmic fabric. In general, iceberg scour sediment deformation is dominated by planar/brittle deformation, sediment mixing and porewater processes - regardless of grain size (clay, pebbly sandy mud, sand and diamicton). This contrasts with subglacial tills and mass-wasting deposits that are instead dominated by (a wider variety of) rotational/ductile and planar/brittle structures, including a range of plasmic fabrics. Finally, dropstones are notably abundant in iceberg scoured sediments, but remain rare in subglacial tills and mass-wasting deposits. Using sets of microstructures to differentiate or co-associate sediments in this way is crucial for palaeoenvironmental reconstruction. In particular, the set of microstructures that have been identified in iceberg scoured diamicton may even lead to the re-interpretation of sediments that previously have been assigned a subglacial origin, providing new insights into ice-sheet and glacier reconstructions.

**P-1865**

## **Microfabric of soils of the Russian Plain formed in basal tills of Saalian glaciation.**

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### **Abstract**

Base tills of Moscow (Late Saalian / Warthe / MIS 6) glaciation form an important component of landscapes in northern Europe, including the center of the Russian Plain. They are often covered only with a thin veneer of sands, sandy and silty loams - the cover layer, so that basal till and cover layer forms bipartite sediment.

Such bipartite sediments are among the oldest soil parent materials subjected to pedogenesis starting from the time of their deposition (MIS 6) till now. This was confirmed by our numerous OSL datings of the cover layer and spatial field studies. Thus, an assemblage of bipartite sediments features was formed within several climatic cycles. We have subdivided them to a) pre-depositional, b) syn-depositional and c) post-depositional (cryogenic and pedogenic).

Morphologically, the impact of a pedogenesis during the last interglacial (MIS5e) has resulted in the formation of pedogenic structural architecture (cracks, subangular blocky peds) with a superimposed well-developed set of cutans. These lead to the formation of a sequence of Bt horizons. Holocene pedogenesis being mostly of eluvial-illuvial character, probably strengthens initial lithological discontinuity of bipartite parent material: soil horizonation is clearly seen within the cover layer unit (a sequence of A and E or Bw horizons), while the boundary between the basal till, and the cover layer, especially in the frost fissures remains abrupt.

Transformation degree of pre-depositional and syn-depositional features under the influence of pedogenesis have been studied in various regions of the Russian Plain (Moscow, Yaroslav, Tver and Archangelsk) using a set of morphological (X-ray high resolution microtomography on Skyscan 1172 (Bruker, Belgium) for visualization and morphometric analysis of the internal microstructure in non-disturbed natural samples of peds; micromorphology on polarizing microscope and photo scanner; submicromorphology on SEM) and analytical methods.

Many depositional features show high stability under pedogenetic impact. They look similar for the lower soil horizons (BC and C) formed in the basal till at a depth approx. 2m and for those subjected to intensive pedogenesis (Bt1 and Bt2 horizons at a depth approx. 60 cm). These key features include: high weathering through the whole strata; bright reddish-brown color (up to 5YR 6/6 by Munsell soil color chart) inherited from sediments mobilized by the glacier; overconsolidated matrix supported fabric with low porosity as a result of big pressure under the glacier; till architecture including sand lenses, shearing features, folding, thrusting and rotational structures, tension fractures and other evidences of emplacement of matrix within the mobile sediment.

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P-1866

## The role of pressurised water in large-scale glaciotectonic thrusting: Evidence from thrust-block moraines in Melasveit, W-Iceland

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### Abstract

Pressurised meltwater has major effect on deformation and sedimentary processes in proglacial and ice-marginal settings. In particular it is thought to enhance the ability of glacier to detach and transport large blocks of sediment /bedrock by minimising friction occurring along structural surfaces. However, a detailed understanding of the processes occurring during the detachment, transport and emplacement of such blocks has yet to be established. Furthermore it has been argued that unconsolidated sediments must be frozen in order to keep such sediment blocks intact during transportation.

A detailed microscale study was carried out on the structures developed within décollements in two submarine moraines of Late-Weichselian age in Melasveit, western Iceland. The aim of this study is to investigate how detachments form in glaciotectonised sequences and how large blocks/rafts of unconsolidated and unfrozen sediment can be dislocated and transported by glaciers. The moraines are primarily composed of thrust-stacked blocks of glaciomarine sediments and are part of a series of ice-marginal features formed during the active retreat of a marine-terminating glacier. Due to isostatic rebound since the deglaciation, these moraines are now revealed above sea-level and their internal architecture is well-exposed in extensive coastal cliffs. A detailed glaciotectonic model is proposed which argues that the introduction of pressurised water into weak beds (silt/sand) played a key role in the detachment and movement of the thrust-blocks. This resulted in fluidisation of these weaker sediments resulting in decoupling between the allochthonous thrust-blocks and the underlying sediments/bedrock. The deformation associated with the transport of the thrust blocks was focused within relatively thin, water-lubricated zones allowing the blocks to move without undergoing extensive internal disruption. Temporal and spatial changes in the style of deformation have been recognised during the transport and subsequent accretion of the thrust-blocks reflecting fluctuating water pressures within the detachments. Repeated events of hydrofracturing and water-escape caused the thrust-stack to drain, resulting in the progressive locking up of the detachments and eventual accretion of the thrust blocks. The model may be applicable to other similar thrust-block complexes as well as for processes occurring during glaciotectonic sediment rafting.

P-1867

## Using micromorphology to access the impacts of periglacial and mass flow processes on tills exposed at retreating glacier margins

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### Abstract

Micromorphology is increasingly being used to investigate the textural properties and microstructures developed in Pleistocene and older glacial deposits in order to provide a greater understanding of the processes involved during their formation. However, in contrast, comparable studies of contemporary glacial deposits are relatively limited. Consequently, the impacts of periglacial and mass flow processes on tills exposed at the margins of retreating glaciers are poorly understood. This lack is being addressed by an ongoing detailed micromorphological study of recently exposed tills in the marginal zone of the Hansbreen glacier in southwestern Spitsbergen. In thin section these contemporary glacial sediments comprise a coarse-grained, weakly compacted, open-packed, clast-rich diamicton with a silt-rich matrix. The lack of clay minerals within the matrix is reflected in the lack of a well-developed plasmic fabric; apart from a locally developed skelsepic fabric enclosing some of the larger clasts (skeleton). Turbate structures are common and defined by arcuate to circular arrangements of coarse silt- to fine sand-grade clasts locally enclosing coarser sand to pebble sized clasts. "Necked" structures are also present formed by the squeezing of the relatively softer matrix in between the larger, more rigid clastic grains. Penecontemporaneous diagenesis of the till matrix has resulted in the localised formation of a carbonate and Fe-oxide cements. Detailed analysis of the clast microfabrics developed in the till has revealed that the earliest fabric (S1) is a subhorizontal foliation this is cross-cut by two later fabrics (S2, S3) which form a conjugate pattern. The spacing of the fabric domains of these S2 and S3 fabrics is governed by the presence of large granule to pebble sized clasts leading to partitioning of deformation within the matrix of the diamicton. These fabric are also observed to wrap around the larger clasts indicating that they acted as rigid, possibly relatively immobile bodies with the deforming matrix. One sample (8A) represents mass flow sediment that was sampled over a dozen years after deposition, in contrary to other deposits sampled here. The clast microfabric analysis has revealed more prominent vertical fabric in this sample, particularly regarding larger clasts. Observed differences in the texture and style of deformation recorded by this sample are due to the combination of mass flow and subsequent frost heave. Nevertheless, the style of deformation identified within the Hansbreen tills is comparable to that observed with Pleistocene subglacial deposits. Consequently initial results suggest that structures formed in response to subglacial shearing may be preserved within exposed tills unless they undergo significant remobilisation and mass flow.

P-1868

## Middle Holocene palaeoenvironments and paleoclimates in the Middle Atlas: the multidisciplinary study of a Moroccan tufa (Aït Said ou Idder)

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### Abstract

Calcareous tufas are continental open-air carbonates that routinely host evidence of past environmental conditions via well-preserved faunal and floral assemblages. Additionally, as they mostly comprise of calcite precipitated at ambient temperature, tufas are also suitable targets for palaeoclimatic reconstructions, especially from oxygen and carbon isotopes, which allow combining palaeoenvironmental to truly synergic but independent climatic reconstructions.

Tufas are common in areas with carbonaceous bedrock such as the Moroccan Middle Atlas. However, under these latitudes, they are usually indurated. These “travertineous” facies are not suitable for palaeoenvironmental researches as molluscan shells, the usually best-preserved bioproxy in tufas, cannot be extracted by sieving. At Ait Said ou Idder, a deposit dominated by crumbly friable facies rich in terrestrial molluscs was recently discovered. A ca. 8m-high profile was investigated in September 2017 and sampled continuously for malacology and, parallel, for geochemistry allowing the first multiproxy study of Middle Atlas tufa deposit.

Stratigraphy and micromorphology identify two deposition phases. The earliest deposits comprise oncolithic facies, indurate phytoherms and stratified sandy tufa, characterising fluvio-palustrine tufas. After a marked erosive episode, the second phase comprises detrital tufa (encrusted phytoclasts, oncoliths, etc.), locally including decimetric bushes of vegetation encrusted *in situ* and alternating with greyish layers. This pattern of facies is typical of tufa depositing on a low slope. The bottom of this second phase is especially rich in charcoals, ashes and burned elements (including a flint), suggesting a fire event. This darkish layer was dated around 6500 cal. BP (3 radiocarbon dates on charcoals). The following grey levels provide ages between ca. 6200 and 4900 cal. BP (on shells), which assigns the sequence to the Middle Holocene.

Isotopic data range between -9.74 and -7.56 ±0.08 for  $\delta^{13}\text{C}$  and between -7.8 and -7.3 ±0.1 for  $\delta^{18}\text{O}$  which correspond to Mediterranean temperate to semi-arid conditions. Only little variations are observed in the  $\delta^{18}\text{O}$ , indicating constant to slightly increasing temperatures from ca. 6.0 ka cal. BP. The  $\delta^{13}\text{C}$  shows strong changes in the uppermost unit of the fluvio-palustrine phase where relatively drier conditions are recorded. The most humid period is then observed between ca. 6.5 and 6ka cal. BP. From ca. 6ka cal. BP, the  $\delta^{13}\text{C}$  slightly decreases, parallel to the  $\delta^{18}\text{O}$ , which may indicate conditions becoming more semi-arid.

Comparison with mollusc data will allow further developing these interpretations of geochemical data and discussing, for the relationship between climate and environment at a time (the Middle Holocene) which is usually not recorded in other regional continental records (mostly lacustrine and fluvial deposits). As part of the PaléoMex-INEE “Transect Maghreb” program involving various investigations in Morocco and Tunisia, this work will finally contribute to understanding the adaption of societies to climatic changes.

P-1869

## High-resolution quantification and stable isotopes of earthworm calcite granules from European loess reflects stadial-interstadial climatic variability during the Last Glacial

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### Abstract

Although loess deposits are widely recognised as providing some of the best terrestrial records of past climates, quantitative palaeoclimatic data are rare. Here we propose to reconstruct past temperature and precipitation in European loess sequences using an innovative new approach developed in the Nussloch sequence. Indeed, this reference sequence provides one of the most complete palaeoclimate records for the last glacial in western Europe. Its upper part of the section spans 35-22 ka and is characterised by alternating primary loess and tundra gley horizons whereas its middle part spans 50-35 ka and is characterized by arctic and boreal brown soils.

High concentrations of fossil calcite (sparite) granules produced by earthworms (ECG) occur in most of the stratigraphic units at Nussloch but especially within tundra gley layers and boreal to arctic brown soil horizons allocated to short interstadial periods (millennial). Present-day observations demonstrate that earthworms release their granules at the soil surface, indicating that fossil ECGs are coeval with the soil development. In case of upbuilding soils developed in (paleo)environments where aeolian processes (loess sedimentation) is still active, ECGs are preserved within the upper part (5-15 cm) of these soil horizons. It is especially well illustrated in the loess-palaeosol sequence of Nussloch (Germany) where they are particularly abundant in interstadial brown soils and tundra gley horizons, the latter reflecting short-term pulses of permafrost aggradation then degradation during rapid warming events (interstadials). Stable isotope analyses performed on ECGs provide quantitative estimates of past summer temperature and annual soil moisture, which can be calibrated to generate mean annual precipitation values. The synthesis of ECG concentration variations and palaeoclimate data provides a new proxy for Last Glacial terrestrial environments, which will facilitate more meaningful correlations with ice core and marine datasets on millennial timescales.

**P-1870**

## **Classification of stable carbon and oxygen isotope composition of earthworm biospheroids from loesses by combined cluster and discriminant analysis**

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### **Abstract**

Earthworm biospheroids (EBS) are frequent constituents of loess-paleosol sequences, where they show wide temporal and spatial abundance. EBS are composed of biogenic CaCO<sub>3</sub> excreted by the calciferous glands of earthworms. These features are considered to be in isotopic equilibrium with soil CO<sub>2</sub> being dissolved in (soil) solutions; whereas their oxygen isotope composition is related to the meteoric waters and thus to the alterations of temperature.

EBS were collected from loess-paleosol sequences of different thickness along a North – South transect in the Carpathian Basin: as from Verőce (~18 m), Süttő (~17 m), Paks (~10 m), Hévízgyörk (~8 m) and Villánykövesd (~8 m). Bulk samples were taken in 10 cm vertical resolution in a weight of 100 g. After the wet sieving process of bulk samples on a 500 µm sieve, 1-10 pieces of EBS were collected. 450 µg material/EBS was proceeded for measurements with IRMS in order to reveal stable carbon and oxygen isotope compositions.

The mentioned five sequences were divided into different sedimentary units containing EBS, and thus provided high amount of stable isotope data (471 pair of data). Data were processed by applying a novel method called combined cluster and discriminant analysis (CCDA), which defines a statistically optimal group number and determines the largest homogeneous groups. The method can be applied for cases, when data from more than one source are available for the same parameter range, in a way that more observations are available from each source.

The parameter range contained two different parameters, as the stable carbon ( $\delta^{13}\text{C}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotope compositions. The sources of the observations were the following sedimentary units during the CCDA: 1) typical and/or sandy loess; 2) “other” loess (e.g. stratified, redeposited, strongly reworked); 3) paleosols with their upper and lower transition horizons and the CaCO<sub>3</sub> accumulation zone; 4) CaCO<sub>3</sub> accumulation zone.

The main aim of the study was to group the data from the different sedimentary units optimally, thus to determine homogeneous groups – and when it was not possible, to detect the reasons of inhomogeneity. Homogeneous groups were composed of EBS from various sedimentary units, but indicated similar formation circumstances. Difference was made on regional basis, where the mentioned units of Paks, Süttő and Hévízgyörk profiles belonged to the same group, but those from Verőce and Villánykövesd were completely separated. The Verőce section has a special position in a mountain foreland area, developed on an alluvial fan system, whereas the Villánykövesd sequence represents sub-mediterranean effects. Inhomogeneity was connected to the “other” loess group from the Verőce section and the paleosol group from the Paks profile, which seems to represent the complex interaction of different formation factors.

Study was supported by the NRDIO postdoctoral research project PD128908 and the NRDIO K119366 research project.

**P-1871**

## **Uranium/Thorium dating of catastrophic rock slope failures**

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### **Abstract**

Deposits of catastrophic rockslides and rock avalanches composed of lithologies rich in carbonate minerals may undergo precipitation of calcite cements, crusts and small stalactites that can be used to proxy-date the slope failure event and/or subsequent geomorphic changes of the mass movement accumulations. Lithification of rock slope failure deposits to breccias may be localized to meteoric 'runoff-shadows' below larger boulders, or may comprise a layer of breccia or may affect a rockslide/ rock avalanche mass down its base. In addition, precipitation of cements and small stalactites may take place in megapores on boulder undersides. Initial cement formation probably is driven by meteoric dissolution–re-precipitation of (mini-) micritic abrasive rock powder generated by dynamic disintegration during the failure event. <sup>234</sup>U/<sup>230</sup>Th ages of the cements support a concept that cementation starts immediately or early after a rock slope failure event.

We describe minimum age dating of a row of catastrophic rock slope failures by the U–Th isochron method, applied to meteoric calcite and aragonite cements that precipitated shortly after the failure event. For several rockslides and rock avalanches a comparison of these U–Th ages with radiocarbon ages and surface exposure ages indicates that the cementation age represents a precise and accurate proxy of the catastrophic event age. We present a concept of cement precipitation in small-scale meteoric diagenetic systems that integrates the local setting of accumulated boulders and their size and exposition.

Additionally, a very recent study showed that comminution age-dating of a large scale rockslide within prasinite lithology gained reliable results.

P-1872

## The potential of Holocene fluvial tufas as palaeobotanical archives: new insights from the Iberian Range (Spain)

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### Abstract

In the Iberian Peninsula, vegetation reconstructions focused on pollen analysis applied to terrestrial carbonate deposits have scarcely been reported although some of them provided very successful results spanning palaeobotanically poorly-known time intervals. Concerning the current interglacial, palynological studies in Mid Holocene fluvial travertine successions from the Iberian Range (NE Iberia) have also been reported, completing the fragmentary vegetation picture of Iberian continental environments.

The main goal of this research is to characterize the Holocene vegetation landscape in a NW-SE transect from the Iberian Range applying palynological analyses to several tufa build-ups located in the Queiles, Val and Las Parras del Martín river valleys. Pollen data reveal a conifer-dominated landscape during the Early Holocene (ca. 9500-8000 cal BP) in where montane pinewoods (*Pinus nigra/sylvestris* type) and junipers were the main landscape components, well adapted to continental climate features. The riparian woodland widespread during the Mid Holocene (8000-4000 cal BP) being *Corylus*, *Salix*, *Populus*, *Acer*, *Quercus faginea/pyrenaica* type, *Ulmus*, *Juglans* and *Castanea* the most abundant broadleaved elements in the pollen profiles. At regional scale, both *Quercus faginea/pyrenaica* type and *Q. ilex/coccifera* type expanded, accompanied by many warm-loving shrubs like *Olea* and *Pistacia*. This palaeobotanical assemblage highlights the establishment of warm and humid climate features in continental Iberia across the Mid Holocene in correspondence with regional paleohydrological sequences. The onset of the Late Holocene (ca. 4500 cal BP) was defined by the noticeable increase in grazing indicators (Sordariales, Poaceae) nitrophilous taxa (Compositae, *Plantago*) and open-degraded areas (*Genista*), pointing to the onset of agrarian economic activities, culturally corresponding to the Bronze Age.

**P-1873**

## **Towards a mechanistic understanding of carbonates on Chinese Loess Plateau by using stable isotopes**

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### **Abstract**

The stable isotope compositions of calcium carbonates are the most important archives of paleoclimate change because it thought to have form in isotopic equilibrium with soil CO<sub>2</sub> and soil water. But isotope composition of soil CO<sub>2</sub> and soil water reflect the environmental conditions and usually characteristic of seasonally changes. It is not well known what portion of the signal is recorded by the isotopic composition of pedogenic carbonate when it forms.

On the Chinese Loess Plateau (CLP), located in arid-semiarid area, calcium carbonates are widely used in paleoclimate research, but limited works focus on the formation mechanism. Here we present our monitoring work on the CLP modern soils to constrain the seasonal changes of the stable isotope composition of soil water and soil CO<sub>2</sub>, the concentration of soil CO<sub>2</sub>, and soil temperature at different depth. Those continue monthly dates are important for understanding the formation mechanism of carbonate on the CLP.

P-1874

## The Eemian tufa of Caours (France): a multidisciplinary approach of a remarkable MIS-5e sequence and associated Palaeolithic site

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### Abstract

New investigation leads on the Quaternary interglacial deposits of the River Somme terraces have allowed the discovery of an exceptional Eemian tufa sequence at Caours comprising several *in situ* Palaeolithic levels (Antoine et al., 2006). The Caours tufa formation (»3.5 m thick), located on the lowest fluvial terrace of the Scardon River (tributary of the Somme), is composed by irregular layers of incrustated vegetal remains and concretions (stromatoliths) passing through typical fluvial tufa faces with oncolithic sands and large scale cross beddings towards the present day valley. The lower part of this sequence (»0.5 m) includes organic tufa horizons (micro marshy soils) that have provided thousands of large mammal remains (generally modified by human activities) and Palaeolithic flint artefacts. The tufa sequence and the upper 10 cm of the underlying fluvial silts and marshy soil contain an abundant malacological fauna that evidence the initial phases of the Eemian interglacial followed by the climatic optimum. This conclusion is supported both by isotopic geochemical data ( $\delta^{18}\text{O}$  of  $\text{CaCO}_3$ ) as well as geochronological data. Indeed, U-series (TIMS) dates from stromatolith calcite crystals and TL dates from heated flints confirm the allocation of the archaeological layers to the Eemian optimum (MIS 5e:  $123\pm 3$  ka /11 dates). Palaeoenvironmental, dating and archaeological approaches at Caours allow a very detailed reconstruction of the evolution of palaeoenvironments from the end of the Saalian to the last interglacial climatic optimum. Caours appears now as one of the most complete and well preserved Palaeolithic site in Europe for the Eemian optimum and allows to demonstrate that Neanderthal was fully adapted to forested habitat and a temperate climate. In addition a 300m long transect from the terrace to the present day valley has been produced showing for the first time a continuous record of the last two glacial interglacial cycles in the Somme terraces system. This provides robust data for the discussion focusing on the location of incision processes regarding to Interglacial-Glacial climatic cycles.

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**P-1875**

## **Carbonates as indicator of buried paleosoils in aeolian deposits of Lithuania**

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### **Abstract**

New preliminary data was obtained carrying out project entitled „Ichnological and sedimentological evidence of late glacial and Holocene environmental changes in the eastern part of the European Sand Belt”. It is known that aeolian deposits cover about 2.6 % of the territory of Lithuania. The continental dunes prevail over the coastal ones. The coastal dunes are widespread in the Curonian Spit while the area of continental ones is largest in the east southern Lithuania. Examining the internal structure of continental and coastal dunes we could judge about a renewal of aeolian processes. The paleosoils buried in sand reflect periods of dunes stabilization while overlying sand beds indicate a renewal of aeolian processes. All these processes are reflected in the complex internal structure of dunes. The carbonate content (calcite and dolomite minerals) was determined for aeolian sediments. The results obtained show that carbonate content in buried paleosoils is higher than in aeolian ones. The carbonate content could be used as a criterion for very thin or poorly preserved buried paleosoils. Moreover the criterion could be used not only for outcrops samples but also for the ones taken from drill-cores. Once paleosoils will be identified, the traces of fossil and bioturbations textures will be studied. The studies will be followed by sedimentological and stratigraphical analysis which will be based on optically stimulated luminescence (OSL), radioactive carbon dating technique, geophysical and statistical methods. As a result it will enable us to establish spatial dynamics of aeolian sediments and integrate it with the results of ichnological analysis.

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P-1876

## Quaternary calcium transfer in semi-arid African landscapes: pedogenic nodules and the geochemical cascade.

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### Abstract

Calcium (Ca) is a key element of the Earth's system and closely related to the carbon cycle. However, pedogenic Ca-carbonate constitutes a Ca-trapping pathway on continents that has not received the attention it deserves. Significant accumulations of pedogenic carbonate nodules associated with paleo-Vertisols, inherited from the Late Quaternary, are widespread in the Far North Region of Cameroon, although formed in a carbonate-free watershed. A previous study using Sr isotopes showed that Ca sources of carbonate nodules are local granite and Saharan dust. This suggests that Ca is kept in the soil system after weathering. However, the Ca sedimentary and biogeochemical pathways by which Ca is transferred from sources to the trapping compartment, i.e. the carbonate nodules, remained unclear. This present study used major, trace, and rare earth element distributions of carbonate nodules, as well as of the various other Ca compartments of the landscape, in order to document these pathways. Three main processes transferred Ca from its source, in granite and dust, to a trapping compartment, i.e. pedogenic carbonate nodules (Fig. 1). The first process involved the weathering of a granitic bedrock. The residual products were then mixed with Saharan dust to form the host sediment of the nodules. The second process is related to clay minerals, products of weathering, which accumulated Ca and other alkaline cations during Vertisol development. Weathering products, i.e. clays and oxides, as well as vegetation and soil organic matter, have to be considered as transient compartments of Ca. At the end of the African Humid Period, drier climate conditions prevailed, enhancing the precipitation and preservation of pedogenic carbonate nodules. Ca was then incorporated and sequestered into the nodules, until the present-day. Consequently, during the last twenty thousand years, an important part of the Ca was transferred from upstream granite to downstream nodules of pedogenic carbonate developed in Vertisols. Mass balance calculations in soil profiles demonstrated that the Ca accumulation in carbonate nodules exceeded the Ca released by the chemical weathering of the parent material, highlighting the role of Vertisols as Ca-trappers. Therefore, an important part of Ca is still sequestered in the soil system and has not been yet transferred into rivers. Consequently, at the landscape scale, the paleo-Vertisols have acted as Ca-trapping systems (pedogenic carbonate nodules), emphasizing the significant role of Vertisols in terrestrial Ca balances, as they cover large areas on continents. Moreover, such a spatial relationship between sources and transient trapping compartments leads to a new concept of "geochemical cascade" similar, in terms of geochemistry, to the concept of "sediment cascade" developed by continental sedimentologists.

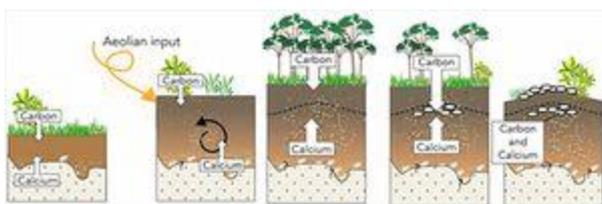


Fig. 1: Ca location through time : Ca is transferred from granite and dust sources to carbonate nodules, highlighting the role of Vertisols as Ca- and C-trappers.

P-1877

## Absolute or relative: Paleovegetational reconstructions using carbon isotopic composition of soil carbonates, soil organic matter, nodule organic matter and biomarkers

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### Abstract

Present study aims to comprehend the factors responsible for the disparity in the abundance of C<sub>3</sub>/C<sub>4</sub> plants estimated from the carbon isotopic composition of soil carbonates ( $\delta^{13}\text{C}_{\text{SC}}$ ), soil organic matter ( $\delta^{13}\text{C}_{\text{SOM}}$ ), organic matter occluded in soil carbonate nodule ( $\delta^{13}\text{C}_{\text{NOM}}$ ) and biomarkers in paleosol organic matter (saturated fatty acids;  $\delta^{13}\text{C}_{\text{FAME}}$ ). In this context, available  $\delta^{13}\text{C}_{\text{SC}}$ ,  $\delta^{13}\text{C}_{\text{SOM}}$ ,  $\delta^{13}\text{C}_{\text{FAME}}$  and newly measured  $\delta^{13}\text{C}_{\text{NOM}}$  values from four sediment cores namely Kalpi, Indian Institute of Technology Kanpur (IITK), Firozpur and Bhognipur from the Ganga plain, India have been used. The abundance of C<sub>4</sub> plants calculated from the  $\delta^{13}\text{C}_{\text{SC}}$  and  $\delta^{13}\text{C}_{\text{FAME}}$  values is consistently higher compared to the estimation from  $\delta^{13}\text{C}_{\text{SOM}}$  and  $\delta^{13}\text{C}_{\text{NOM}}$  values. For instance in the Kalpi core, the  $\delta^{13}\text{C}_{\text{SC}}$  values indicated *ca.* 2 to 75% and *ca.* .27 to 84% higher C<sub>4</sub> plants than the estimation from  $\delta^{13}\text{C}_{\text{SOM}}$  and  $\delta^{13}\text{C}_{\text{NOM}}$  values. Similarly, the abundance of C<sub>4</sub> plants calculated from the  $\delta^{13}\text{C}_{\text{FAME}}$  values were *ca.* 15 to 59% higher compared to the  $\delta^{13}\text{C}_{\text{SOM}}$  and *ca.* 40 to 77% higher than that estimated from the  $\delta^{13}\text{C}_{\text{NOM}}$  values. The difference in the estimation reflects the process through which the proxies form. The organic matter is incorporated into soil throughout the year and reflects average annual biomass, whereas SC precipitates during drier season that favours the growth of C<sub>4</sub> plants (enriched in <sup>13</sup>C). In addition, preferential degradation of <sup>13</sup>C enriched labile compounds and C<sub>4</sub> derived organic matter lowers the  $\delta^{13}\text{C}_{\text{SOM}}$  and  $\delta^{13}\text{C}_{\text{NOM}}$  values resulting in the higher estimation of C<sub>3</sub> plants. The higher abundance of C<sub>4</sub> plants estimated from the  $\delta^{13}\text{C}_{\text{FAME}}$  values is probably due to the isotopic fractionation (<sup>13</sup>C enrichment of ~2 - 10‰) during the incorporation of plant derived long chain fatty acids into the soil. Various factors such as grain size, vegetation density, sub-aerial exposure and pedogenesis that are inherent to the depositional environment also plays a vital role in controlling the carbon isotopic composition of paleosol components. Considering the uncertainties associated with the paleosol based proxies, it would be misleading and erroneous to report the absolute abundance of C<sub>3</sub>/C<sub>4</sub> plants during past vegetational reconstructions. Therefore, the present study recommends presenting the relative change in the abundance of C<sub>3</sub>/C<sub>4</sub> plants while reconstructing paleovegetational composition. In addition, the present study underscores the necessity of similar investigations in different climatic zones namely semi-arid, arid, etc. to have a firm knowledge on the factors affecting the isotopic composition of paleosol components and its implications for paleovegetational reconstructions.

**P-1878**

## **Using novel isotopic analysis and U-series dating of terrestrial carbonates to investigate human evolution and climate change in southern Africa**

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### **Abstract**

Carbonate research is a staple of stable isotope geochemistry; the combination of U-series dated carbonates from southern African archaeological/hominin sites with promising novel isotopes presents a unique opportunity. Furthermore, as most regional palaeoclimate research has focussed on the last glacial-interglacial cycle (the past 100 ka), previous glacial-interglacial cycles (much of the evolutionary record) are largely neglected. The present situation is ripe for a synthesis of carbonate palaeoclimate records over longer timescales (1 Ma) to answer big-picture questions about local changes in hydroclimate and their relation to the global climate system during the Quaternary. While not yet routine, U-Th dating of pedogenic carbonates is showing great promise, with early indications of closed system behaviour on a small (mm) scale. Careful thin section petrography is a necessary precursor to any dating analyses. The U-Pb chronometer opens up the prospect of dating carbonates older than 500 ka, making investigations over longer, 1 Ma, timescales achievable. This technique has reached a level of maturity where it can be applied both routinely and precisely and there is a considerable collection of cave carbonates already U-Pb dated from South Africa. New excavations of arid, inland sites in the Northern Cape, and renewed interest in sites along the west coast of the Western Cape (both in South Africa), are ideal targets for further U-series dating. Here we exploit an underutilised resource - pedogenic calcrete - from South African archaeological sites, and combine high-resolution U-series dating of these materials with novel stable isotope proxies of temperature ( $\Delta 47$ ) and aridity ( $\Delta^{17}\text{O}$ ), as well as conventional stable isotope analyses ( $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) to construct a synthesis of regional hydroclimate change over the past 1 Ma.

P-1879

## Traces of glaciation-induced earthquakes in front of an advancing Pleistocene ice sheet. Case studies from Germany and Lithuania

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### Abstract

Low- and moderate-magnitude earthquakes in Germany and Lithuania (southern Peribalticum) related to the advance of the Scandinavian Ice Sheet (SIS) are interpreted on the basis of sedimentological and regional stratigraphical studies supported by OSL datings. Almost all seismic activity related to glaciation cycles has thus far been attributed to glacio-isostatic rebound during/after deglaciation. However, the possibility of earthquakes related to ice advance was suggested by Brandes et al. (2011), and recently by Pisarska-Jamroży et al. (2018) and Belzyt et al (2018).

Seismites – layers affected by an earthquake while still unconsolidated – are recognized based on several criteria, including a large lateral extent, continuous deformations and vertical repetition. Such seismites have been recognized within a glaciolacustrine succession in a coastal cliff on the eastern Jasmund peninsula (Rügen Island, NE Germany, see Pisarska-Jamroży et al., 2018), and also in fine-grained floodplain deposits of a meandering river at Slinkis, outcropping in the Dubysa river valley (central Lithuania, see Belzyt et al., 2018).

The seismites at both sites are interbedded between undeformed layers and occur in proglacial sediments overlain by diamictons (glacial tills). Their stratigraphic positions in the successions, supported by OSL dating, unambiguously indicate that the liquefaction-prone deposits were deformed, shortly after their deposition, during phases of SIS advance, just in front of the ice masses.

In both sites, seismites were formed during the Last Glacial Maximum, MIS 2. In Dwasieden site – during Brandenburg/Frankfurt phase of Weichselian Glaciation (according to German stratigraphic scheme), whereas at Slinkis site – during the maximal ice advance of Nemunas Glaciation (according to Lithuanian stratigraphic scheme).

The stable, intraplate tectonic setting of both sites is strong evidence that the deformation of the fine-grained sediments was triggered by displacement of the upper crust of the Earth, induced by ice-mass loading in the moat in front of the advancing ice. This process, most possibly, caused re-activation of favourably-orientated pre-Quaternary faults.

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**P-1880**

## **Glacial geomorphology and sediments in Puruogangri icecap, central Tibet**

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### **Abstract**

Sedimentary properties in mountain/valley glacier have been studied in details. However, glacial geomorphology and sediments in plateau glacier in semi-arid area are understood little. It is generally believed that this type of plateau glacier is cold-based glacier and is not active in producing glacial landform. We investigated glacial landforms and glacial sediments in the Puruogangri icefield in central Tibet, where the temperature of glacier ice is 7 degree celsius below 0. The moraine is short and small with flat top surface, but subglacial abrasion is still strong enough to produce striations and polished surface on clasts as well as ground silt. We suggest that subglacial thermal heating melts basal ice and produce water film between ice and rock so that ice or clasts can slide on ice-rock interface to produce glacial sedimentary properties as those in valley glaciers.

**P-1881**

## **A new glacial landscape map of the LIS in central Nunavut, Canada: an integrated approach to understand paleo-ice sheet dynamics**

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### **Abstract**

In the former glaciated areas of central Nunavut in northern Canada, large volumes of ground-based and remote surface geology datasets were acquired by government surveys in key regions that are actively being explored for mineral deposits or assessed for infrastructure expansion under changing climates. These comprehensive georeferenced surface earth materials and geomorphological datasets need to be integrated over broad regions to allow interpretation of glacial landscapes and modelling of past glacial histories and transport patterns. A new digital compilation of glacial features and interpreted glacial landsystems was produced for an area covering ~400,000 km<sup>2</sup> in the Keewatin Sector of the Laurentide Ice Sheet (LIS). The new compilation integrates digitally converted published surficial geology maps, recent framework mapping supported by relative and absolute chronologies, and new mapping interpretations using ArcticDEM (5 m resolution) and LANDSAT8 imagery. It permits the identification and grouping of various glacial features into coherent patterns, including ice streams, ice divides, ice retreat positions, flow sets, palimpsest flows, relict and deglacial cold- and warm-based landscapes, and subglacial meltwater corridors. In addition, the compilation reconciles a number of archived field observations and surface sample compositional databases from years of government mapping. Additional field-based observations as well as samples for age dating and composition were collected in targeted areas in 2017 and 2018 to provide constraints on the glacial history, and help evaluate glacial transport in areas of complex ice-flow dynamics and changing basal ice thermal regimes. The final product will consist of a scalable map with accompanying database of glacial features and landforms (individually identified); a field database including ground and remote stations with field observations, ice-flow measurements and/or glacial sediment samples; an interpretation of glacial landscapes (georeferenced overlays); a bibliography of all published sources; and a nomenclature of the map features.

P-1882

## Characterising the deglaciation and postglacial Tyrell Sea incursion from mapping of deglacial landforms on the western Ungava Peninsula, Nunavik, Canada

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### Abstract

The Labrador Sector was an active component of the Laurentide Ice sheet during the last glacial cycle, with significant migrations its ice divide system and marked changes in its subglacial thermal regime. On the Ungava Peninsula, these changes are highlighted by a mosaic of different glacial landforms and terrains that together outline a succession of landform assemblages arranged symmetrically around the former position of the Payne ice divide. The core area spreads along a north-south axis that is underlain by a thin glacial sediment cover pierced by numerous frost-shattered bedrock outcrops and extensive felsenmeer typical of cold-based ice conditions. This central zone is flanked to the east and west by an unmolded till plain, which gradually changes into a fluted till plain that includes drumlins and crag-and-tails that together indicate a radial ice flow from this ice dispersal center. This latter zone comprises several eskers and associated glaciofluvial deposits. This system terminates at the coastal areas where widespread wave-washed bedrock and/or extensive glaciomarine shorelines and deltas were deposited in the postglacial sea. Deglaciation of the Ungava Peninsula was also complex with asymmetric rates of ice retreat between the eastern (slow) and western (fast) margins and large uncertainties persist on the regional pattern of ice margin retreat as well as on the timing of the deglaciation. Deglaciation of the eastern Hudson Bay coast was marked by the postglacial marine incursion of the Tyrell Sea that led to the formation of a spectacular deglacial landscape characterized by large fields of DeGeer moraines, ice-contact deltas and eskers. Here we use these deglacial features to characterize the nature of ice retreat, geometry of the ice margin configuration and relative chronology of ice withdrawal in the region. We present the first detailed glacial geomorphology map of the northwestern sector of the Ungava Peninsula based on interpretations of high-resolution satellite imagery (RapidEye: 5m; Pléiades: 0.5 m) and extensive fieldwork carried out on the deglacial landscape of the Puvirnituk area on the east coast of Hudson Bay. Our mapping results provide a new high-resolution database of individual deglacial landforms that comprises an exhaustive inventory of DeGeer moraines, which document the nature and style of the regional ice retreat pattern. We also sampled large marine ice-contact deltas for cosmogenic dating at two sites, which are part of an East-West sampling transect aimed at constraining the timing of the deglaciation of the Peninsula. Overall, this work provides a new geomorphological framework that improve our understanding of the ice sheet margin evolution during the final stages of the deglaciation of Nunavik.

**P-1883**

## **Deglaciation of the Kola Peninsula, Arctic Russia, during the Last Glacial-Interglacial Transition**

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### **Abstract**

During the Last Glacial-Interglacial Transition (LGIT; c. 18-10 ka) the Kola Peninsula, Arctic Russia, was glaciated by the Fennoscandian Ice Sheet (FIS). Ice flowed up into the mountains on the peninsula (Khibiny, Lovozero) rather than down-valley as in typical glacial environments. However, low resolution geomorphological mapping, a lack of sedimentary analyses, and limited dating of glacial landforms and deposits mean deglaciation in the Kola Peninsula, including whether there was a periodic ice standstill during the Younger Dryas (c. 12.9-11.7 ka) cold period, is poorly understood.

This project therefore aims to reconstruct the pattern and timing of deglaciation of the Kola Peninsula during the LGIT. The glacial geomorphology of the Kola Peninsula will be mapped using high resolution imagery (ArcticDEM 2m) to determine retreating ice margin positions. To understand subglacial processes occurring during deglaciation, glacial sediments will be described at macro- and micro-scales. Finally, glacial landforms and sediments will be dated (optically stimulated luminescence and radiocarbon dating) to chronologically constrain deglaciation. This research will: (i) allow evaluation of the style, extent and timing, of deglaciation in the Kola Peninsula, determining whether or not there was a periodic standstill in ice sheet retreat during the Younger Dryas, and (ii) provide crucial empirical evidence to validate numerical model simulations of the FIS, which in turn will further our understanding of glacial/deglacial dynamics in other Arctic, Antarctic and alpine regions.

**P-1884**

## **Towards a global glacial landform map**

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### **Abstract**

Glacial landform mapping has led to advances in the understanding of landform genesis, palaeo-ice sheet behaviour and glacial processes. However, the availability and utility of hard-won mapping datasets is currently severely limited. This is due, in part, to the disparate storage of data; currently in maps, journal articles and hard-drives around the world, rather than being accessible from a single location. Glacial geomorphological mapping data also lacks a standardised format, may be unevenly spatially distributed and present conflicting interpretations. Here, our aim is to engage the glacial geomorphological community in the launch of an open-access, global, database of mapped glacial landforms. We present progress on collating datasets and digitising available maps. Our procedure for data-quality control and format standardising is demonstrated. The intention is to enable access to the library of existing mapping, enhancing the scope, visibility and accessibility of published work. With this in mind, we welcome submissions to the database, the aim of which is to create a global glacial landform map.

P-1885

## A study of the evolutionary sequence of paleo-glaciers in the Iberian Central System (Spanish sector). Procedure and results.

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### Abstract

The Iberian Central System (ICS) is a Mediterranean medium mountain range (with summits reaching altitudes 1700 - 2400 m asl), running 650 km WSW-ENE through the centre of the Iberian Peninsula, from near the Atlantic Ocean coast of Portugal to the eastern edge of the Iberian Meseta in Spain. Due to this trajectory and latitude (40°- 41° N), there are significant contrasts between the subtropical-subpolar and continental-Atlantic environments. For this reason, studying the evolutionary sequence of paleo-glaciers in the ICS may contribute valuable data on climate variability, e.g. paleo-NAO and paleo-AMO effects. This paper presents the evolutionary sequence of paleo-glaciers in the Spanish sector of the ICS, corresponding to the Last Glacial Period (in general MIS2, and locally MIS3).

The procedure to establish this evolutionary sequence has six main stages: (1) Geomorphological mapping; (2) identifying morphostratigraphic indicators; (3) defining morphostratigraphic successions, both sectorial and in synthesis; (4) assigning absolute chronologies using cosmogenic nuclide (<sup>10</sup>Be-TCN); (5) defining the evolutionary sequences, both sectorial and in synthesis (regional evolutive model; REM); (6) correlating this REM with similar areas.

The morphostratigraphic indicator of reference, which appears in all the paleo-glaciers, is called here Principal Moraine (PM) and corresponds to the group formed by the two lateral moraines with the greatest dimensions, development and continuity. The indicators in external positions in the valley in relation to the PM, called here Peripheral Deposits (PD), are formed by series of disperse erratic boulders (PD-B) and smaller discontinuous moraines (PD-M). Finally, the indicators in internal positions in the valley in relation to the PM, called here Internal Deposits (ID), are formed by a series of secondary crests on the inner side of the PM, latero-frontal and arcuate moraines, and series of erratic boulders. From an evolutionary viewpoint, these three formations correspond to: (1) PD from the maximum advance stages (PD-B; ~25.0 ka correlated to global LGM, MIS2) and limited retreat (ID-M; after ~24.3 ka and before ~20.6 ka); (2) PM from a re-advance stage and another maximum stabilization stage (later than ~20.6 ka and earlier than ~17.8 ka); and (3) ID from deglaciation stages, showing three stadials in the late glacial sequence dated to minimum ages ~17.5 ka, ~ 13.9 ka and ~11.1 ka (correlating with the Oldest, Older and Younger Dryas stadials). The conclusion which can be drawn from this evolutionary sequence is that glaciation in the ICS is more convergent with glaciation in northern European regions than in the Mediterranean region.

P-1886

## Reconstructing ice sheet decay, sea level changes and glacio-isostatic adjustment using landforms from the Dornoch Firth, Scotland.

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### Abstract

Glacial, fluvio-glacial and marine/coastal landforms and their associated sediments can be used to reconstruct the dynamics of ice sheets as well as sea-level changes and glacio-isostatic adjustments. Such reconstructions have traditionally been based on field mapping combined with land survey and the logging of sedimentary deposits. More recently mapping derived from remote sensing methods (e.g. Lidar) have been used to identify landforms and to reconstruct ice sheet dynamics, however the applicability of such techniques to appropriately identify palaeo-coastal features has not been tested.

The Dornoch Firth, Scotland, contains a wealth of geomorphological features associated with the retreat of the Late Devensian Scottish Ice Sheet. In the outer Firth there are well defined glacial ridges which are truncated by raised marine ridges and terraces which can be used to define the marine limit. In the central Firth there are glacial features with associated outwash surfaces which grade into deltas that can be related to raised marine terraces which are indicative of an ice still-stand or readvance. Whilst the inner Firth contains a succession of outwash fans/deltas with associated glacial and raised marine shoreline fragments that document the continued fall in sea-level. On the higher ground to the south there are a series of deep meltwater channels which can be traced to outwash deltas associated with a former ice-dammed lake.

The sequence of landforms indicate that as the ice sheet retreated 40km westward relative sea level fell from *circa* 30m OD to 12m OD. The retreat was interrupted by a stillstand or readvance during which sea-level fell 10m and this was then followed by a very rapid retreat of the ice front.

The assemblage of landforms can also be used to evaluate the use of mapping methods based on remote sensing techniques to identify raised marine features and in particular shoreline fragments and deltas.

**P-1887**

## **Reconstructing the Last Glacial Maximum in the Southern Alps: the record of the Adige River Glacial Amphitheatre.**

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### **Abstract**

Glacial amphitheatres at the southern fringe of the Alps have been extensively studied in the framework of Quaternary glaciations. Easy accessibility and the presence of well-preserved complex moraine systems allowed retrieving useful middle- to high-resolution geomorphological and stratigraphical records of Pleistocene glaciations. The Adige River Glacier Amphitheatre (ARGA) is one of the smallest end-moraine systems of southern Alps and lies close to the much larger Garda Lake Glacial Amphitheatre. During most of Pleistocene glacial advances, the two adjoining glaciers merged, thus preventing the Adige Glacier to form proper end-moraine systems for most of its duration. This did not happen during the Last Glacial Maximum (LGM), when the extant glacial amphitheatre was built. From field surveys and dating we produced a detailed mapping of the morphostratigraphic units composing the ARGA. This map represents the first step towards the reconstruction of the evolution of the ARGA system and related landforms. We could recognise five morphostratigraphic phases each responsible for the deposition of a moraine arc. Two major moraine arcs (the outermost ones) aggraded during two positive pulses of the glacier. The innermost three moraine arcs are smaller and less preserved; likely, they correspond to subsequent recessional steps of the Adige Glacier. Flat areas, filled by gravel sediments from meltwater outwash streams, separate moraine arcs. Between the glacier terminus and the innermost moraine arcs several flat terraces consisting of sandy to clayey sediments are recognised as kame terraces, deposited by a proglacial lake formed in the last phase of retreat. At the final collapse of the Pleistocene Adige Glacier, the proglacial lake disappeared, and fluvial erosion started sectioning Pleistocene deposits.

In fact, the ARGA, while being a small LGM glacial system, is well preserved and includes evidence for multistep aggradation of moraines during the advances and regressions of the Adige Glacier during and after the LGM. This interpretation substantially confirms previously reported evidence for a two-fold LGM glacial advance along Southern Alps.

**P-1888**

## **Genesis of dead-ice moraines in eastern Poland**

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### **Abstract**

The well-known result of Pleistocene/recent ice sheets (and glaciers) are the landforms called dead-ice moraines, hummocky dead-ice moraines or, most often – hummocky moraines (HM). As a rule, typical hummocky moraines are oval or slightly elongated hills scattered on till plains. In the planform they represent chaotic or faintly oriented pattern, both longitudinal or transverse to ice movement direction. Till is the main deposit of hummocky moraines.

Differentiated genesis of till results in two contrary models of HM development. In 'supraglacial' model the flow till is regarded as mass flows redeposited to the depressions on the ice-sheet surface. Contrary, in 'subglacial' model the basal till is squeezed upwards to ice crevasses.

Dead-ice moraines (DM) are abundant landforms on Polish territory, however they are still poorly understood. We studied DMs in eastern Poland, which are located in glaciomarginal zone of Warthian (younger Saalian) age. This research sheds a new light on the issue of DM origin. Dead-ice moraines are the hills with evident orientation; some of them are elongated perpendicularly ('transverse' DM), whereas other parallel ('longitudinal' DM) to the movement of the ice. All moraines are characterized by the same lithology. Relatively thick glaciofluvial sands are overlain with gravelly-sandy-clayey diamictons of massflow origin (flow till). An important feature is the presence of basal till diapirs in the cores of 'longitudinal' DMs. Substantial difference between both mentioned DM types is that the glaciofluvial deposits and flow tills within 'transverse' moraines are cut by normal and reverse faults, whereas the beds of 'longitudinal' moraines are folded concordantly with underlying diapirs of subglacial till.

Regular pattern of DM planform and their lithology prove that disintegration of stagnant ice sheet was controlled both by the depressions between ice-cored ridges (origin of 'transverse' DM) and ice crevasses (origin of 'longitudinal' DM). At first glaciofluvial sands and flow tills were deposited. Then the deposits subsided due to melting ice walls and ice floors or were uplifted by till diapirs intruding to ice crevasses. These two phases of DM development point to climatic change during the deglaciation. We claim that the second (deformational) phase took place during climate amelioration, when the permafrost declined and the thawed substratum was deformed more easily.

P-1889

## Paleo-ice cap modeling with Parallel Ice Sheet Model (PISM); a case study from Mount Dedegöl, SW Turkey

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### Abstract

We used the Parallel Ice Sheet Model (PISM), to simulate a relatively small size ( $\sim 300 \text{ km}^2$ ,  $17 \times 17 \text{ km}$ ) paleo-ice cap on Mount Dedegöl in southwestern Turkey. Modelling small paleo-ice bodies in mountainous terrain is challenging due to the need for detailed ice flow computations in relatively narrow and steep valleys, high-resolution climate estimations, knowledge of pre-ice topography, and proxy-based paleoclimate forcing. PISM, a numerical ice-flow model that approximates glacier sliding and deformation to simulate large ice sheets such as Greenland, was recently adapted also to Alpine environments. The model was forced by modified temperature and precipitation conditions. The best fit results indicate that if temperatures during LGM were  $8\text{-}11^\circ\text{C}$  lower than the modern-day temperatures, as suggested by the local proxy data, the precipitation should have ranged between the modern levels up to  $\sim 44\%$  wetter conditions. Therefore, we conclude that the local LGM climate was not only colder but also wetter than the present, which is coherent with the other proxy results for the region. Our results also showed that PISM is suitable in high-resolution ( $\sim 27 \text{ m}$ ) ice modeling of mountain glaciers and ice caps on temperate and mid-latitude glaciers. We tested the model sensitivity to multiple climatic and non-climatic conditions and explored paleo-glacier dynamics. Using the current topography may lead to some deterioration in the results, due to the moraines blocking the glacier flow, and thus recommend further studies on this aspect. This work was supported by Tübitak #114Y548.

P-1890

## Using glacial geomorphology to constrain the final deglaciation of the central sector of the Cordilleran Ice Sheet, northern British Columbia

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### Abstract

The Cordilleran Ice Sheet (CIS) repeatedly covered western Canada during the Pleistocene and attained a volume and area similar to that of the present-day Greenland Ice Sheet. The ice sheet had a western marine-terminating margin in the Pacific Ocean, and at maximum extent, an eastern margin that locally coalesced with the Laurentide Ice Sheet. Deglaciation of the CIS following the Last Glacial Maximum (LGM) directly affected atmosphere and ocean circulation, eustatic sea level, and human migration from Asia to North America. However, the subglacial mountainous terrain makes it challenging to reconstruct local glacial dynamics, impeding the reconstruction of ice sheet-wide glacial advance and retreat patterns. Therefore, the central sector of the CIS that covered the mountain systems of northern British Columbia and southern Yukon Territory is one of the least understood areas of any ephemeral Pleistocene ice sheet.

This study uses geomorphological mapping and <sup>10</sup>Be exposure dating to determine the pattern of ice retreat in the Tuya Range of the Cassiar Mountains, northern British Columbia. The Cassiar Mountains are located at the centre of the CIS and previous mapping of glacial lineations indicates that an ice dome existed over these mountains during the LGM. Here we present the first detailed geomorphological map of glacial landforms, including moraines, drumlins, eskers, and meltwater channels, within the Tuya Range. These landforms were mapped using high resolution remotely sensed data and their spatial distribution defines the evolving ice sheet configuration during deglaciation. The meltwater landforms record a regionally uniform westward retreat of the eastern CIS margin towards the Coast Mountains, whilst the morphology of a large valley moraine around Tuya Lake indicates a readvance of ice flow from the Cassiar Mountains in the north. <sup>10</sup>Be exposure dating of stable boulders from this moraine gives ages corresponding to a late glacial re-advance, likely during the Younger Dryas. This provides evidence of an icefield regrowth within the Tuya Range during a climate reversal and shows that the rapid climate oscillations of the Bølling-Allerød (14.6 to 12.9 ka) and Younger Dryas (12.9 to 11.7 ka) had an effect on alpine glaciers and icefields within the Canadian Cordillera.

**P-1891**

## **The northwest Laurentide Ice Sheet: interaction with the Cordilleran Ice Sheet and montane glaciers across the Mackenzie Mountains**

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### **Abstract**

The northwestern sector of the Laurentide Ice Sheet coalesced with the Cordilleran Ice Sheet over the southern Mackenzie Mountains, and with local montane glaciers along the eastern slopes of the Mackenzie Mountains. According to the published numerical modelling, a rapid ice thinning across this area contributed significantly to Meltwater Pulse 1A. However, little empirical data are available for this region and the NW sector of the Laurentide Ice Sheet is perhaps the one least understood. A detailed reconstruction of the NW Laurentide Ice Sheet has not previously been completed, with the last available studies dating back to the 1990s. The lack of empirical evidence constraining the maximum extent of the NW Laurentide Ice Sheet and its interaction with the Cordilleran Ice Sheet and montane glaciers prevents a better understanding of the contribution of this sector to global deglacial sea level change. Reconstruction of former glacier dynamics and extent has implications also for modern infrastructure projects in the region. Ice-rich mass movements, 'retrogressive thaw slumps', occur primarily in previously glaciated landscapes and are commonly associated with ice-cored moraines. This phenomenon has recently been observed in the Mackenzie Valley further south than previously documented, and a better understanding of the former ice sheet dynamics will allow for the identification of areas susceptible to thaw slumping.

We present the results of glacial geomorphological mapping for an area >400,000 km<sup>2</sup> in the Northwest Territories, Canada. A combination of the high-resolution ArcticDEM topographic data and PlanetLabs satellite imagery are used for the mapping of glacial landforms along the eastern slopes of the Canyon Ranges and the southern portion of the Backbone Ranges. The maximum ice extents across the region are delineated and the interaction and relative chronology of retreat of the Cordilleran and Laurentide ice sheets and the local montane glaciers from their maxima are reconstructed. This mapping will provide a basis for further work on the deglaciation of the NW Laurentide Ice Sheet, which in turn will inform on the sources of the Meltwater Pulse 1A and on the regional landscape susceptibility to the warming climate.

P-1892

## Interaction between a Lateglacial ice-cap and the Scandinavian Ice-sheet at the mouth of Hardangerfjorden, southwest Norway

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### Abstract

Here we present new results constraining the ice-sheet thinning during deglaciation and the formation of a local ice-cap during the Younger Dryas at the mouth of Hardangerfjorden, southwest Norway. We base our interpretations on a combination of geomorphological mapping, using high resolution (LiDAR) terrain models, together with <sup>10</sup>Be-dating of glacial erratics and lake coring. We have <sup>10</sup>Be-dated erratics in transects from the highest summits (1200-1400 m a.s.l.) and down towards the fjord. Our results suggest that the highest mountain peaks in the area melted out as nunataks some 20 000 years ago due to thinning of the ice-sheet following deglaciation from its Last Glacial Maximum extent. During the Allerød warm period, the ice-sheet retreated into the inner parts of Hardangerfjord before a major re-advance occurred during the Younger Dryas cold period. In our study we revise the extent of the Younger Dryas re-advance by mapping of moraine ridges using LiDAR-data and the use of <sup>10</sup>Be-dating. In addition, we present sediment cores obtained from both inside and outside of the moraines. Based on our results we provide a detailed reconstruction the Younger Dryas ice-sheet geometry in the area, including the identification of a local ice-cap situated on the Ulvanosa/Englafjell massif. We demonstrate that some of the previously assumed early Holocene moraines in the area actually are of Younger Dryas age. Consequently, we reconstruct a less steep Younger Dryas ice-surface profile in the Matrefjord and identify ice-free areas between the larger ice-sheet in the fjords and outlet glaciers from the local ice-cap.

P-1893

## Kinetostratigraphy of the Płock Basin, central Poland

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### Abstract

Kinetostratigraphy allows a more systematic approach to the analysis of complex, multi-phase deformed glacial sequences, and enables identification of kinetostratigraphic units associated with the deformation stages caused by subsequent ice-sheet advances from different directions. Three kinetostratigraphic units relating to separate generations of glaciotectonic disturbances have been distinguished in the Płock Basin area, the oldest (I), associated with the Elsterian glaciations, older (II), corresponding to the Saalian and younger (III), representing the Weichselian. Each unit varies in scale, spatial extent and style of structures, and in particular the direction of glaciotectonic compression. Unit I concerns a complex of large-scale concealed thrust structures with a significant amplitude (up to 100-150m) and with a southern vergence. Glaciotectonic deformations involve Neogene deposits and they are not expressed as landforms, however, in the sub-Quaternary surface they form vast elevation-depression pairs. The driving mechanism is interpreted to be gravity spreading in front of the thick ice sheets advancing from the N/NE.

Unit II pertains folds and thrusts with a depth range from a dozen to a few dozen meters in which involved are Pleistocene (Saalian and older) sediments. Their formation was associated with glaciotectonic thrusting from NW towards SE during the Late Saalian ice-sheet advance. Unit II structures constitute the king-pin of the highest moraine ridges, and what is significant, the axes of the structures run obliquely to the orientation of moraine ramparts. The structures of unit II are a survived element, relict of thrust end-moraines, transformed during the Weichselian glacial event and incorporated to younger glacial landforms.

Unit III, best recognized, concerns Weichselian sediments deformed to a varying degree. Structural-kinematic analysis showed significant differences in the development of deformations, allowing to separate two subunits: proglacial (IIIp) and subglacial (III<sub>s</sub>). The IIIp subunit concerns compression structures (thrust folds, imbricate thrust fault fans) formed at the forehead of the advancing ice-sheet. Glaciomarginal sediments, previously deposited by the causative glacier, have been strongly shortened. The vertical extent of the disturbances does not exceed several meters, while the spatial extent of the structures is strictly limited to the pre-maximum overridden push-moraines and end-moraines of the Weichselian ice sheet maximum. Subunit III<sub>s</sub> represents small-scale deformations, indicative for shearing at the foot of a moving glacier. III<sub>s</sub> deformations involve sediments in the till-substratum contact zone and reach shallow, up to 1.5 m below the till floor. Their continuum is a subglacial traction till. Glaciotectonic transport vectors as derived from IIIp compression mesostructures and small-scale III<sub>s</sub> shears are concordant and confirmed in till fabric, striations and lee ends orientation of clasts in boulder pavement underlying the till. Glaciotectonites with their inherent till prove a single ice-sheet advance in the Weichselian.

P-1894

## Glacial geomorphology of Trygghamna, western Svalbard - comparing terrestrial and submarine records for better understanding past glacier dynamics

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### Abstract

The sediment-landform assemblages at the recently deglaciated forefields in front of Svalbard's glaciers have been of interest for numerous studies of past glacier dynamics and paleoclimate reconstructions. However, few studies have concentrated on comparing the terrestrial and submarine forefields to gain a holistic approach of the environment. Detailed geomorphological mapping of the terrestrial and submarine forefields of Protektor-, Harriet- and Kjerulfbreen in Trygghamna, western Svalbard, reveal clear contrast between the terrestrial and submarine environments. Crevasse-squeeze ridges (CSRs) are only observed on land in the forefield of Harriet- and Kjerulfbreen, and recessional moraines are only observed at the sea floor. This suggests differences in dynamic behavior between the polythermal land-based part of the glacier compared to the warm-based marine portion of the same glacier. Furthermore, different factors affect the preservation potential between the two environments; fluvial erosion, burial by supraglacial material and permafrost degradation in the terrestrial environment versus burial by glaciomarine sediments and reworking of material by an active glacier margin in the submarine environment. These could be the reason for the absence of CSRs in the submarine environment and the forefield of Protektorbreen.

The landform assemblage in Trygghamna does not show a good correspondence to the existing surge-type glacier landsystem models. Conceptual landsystem models for surge-type glaciers with combined terrestrial and marine margin, based on geomorphological archive from Trygghamna, are presented. The contrast between them demonstrate how the glaciers behaved differently in the environments during the retreat as a result of differences in the thermal regime. The study emphasizes the importance of incorporating data from both archives to understand and reconstruct past glacier behavior and that the glacier environment and dynamics are highly controlling for the preservation potential of landforms, which needs to be taken into account when discussing the dynamics of the glaciers.

P-1895

## Tasmanian glaciokarst: glaciers restrained karstification on lowlands and enhanced it on uplands

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### Abstract

During the Quaternary Tasmania was the only region of Australia to have substantial valley glaciers that in some locations reached close to present-day sea level. The influence of glacial processes on karst development has been underestimated in previous karst studies. As a significant area of Tasmania's mountains in northwest and southern Tasmania are underlain by limestone and dolomite, glaciokarst has developed. Prominent examples are cirque glaciers formed in sinkholes at Mt Anne and the Cracroft River headwaters and glacial deposits (moraines and erratic boulders) in karstified terrain in the Picton valley and Mole Creek area. More than 25 karst areas containing major dolines and caves have been directly impacted by mid- to late Quaternary glaciations. While the glaciokarst at Mt Anne containing the 380 m deep Anne-a-Kandanda cave and the 700 m deep Lake Timk basin (Kiernan 1990) are well known and documented, many other glaciokarst areas have not been recognised or research on them remains unpublished.

This presentation summarises the extent of knowledge on glaciokarst in Tasmania, and presents new information regarding the evolution of active valley floor glaciokarst in the Mersey River catchment in lowland northern Tasmania and a newly-discovered sub-alpine glaciokarst in the King River catchment in western Tasmania. The Mersey River site demonstrates a complex sedimentary, hydrological and geomorphic history in which karst development has essentially been dormant for several hundred thousand years as a result of burial by deposits associated with lobes of the Mersey Glacier during middle Quaternary glaciations and by more recent MIS7 lacustrine deposits and cold-climate fan alluvium dating from MIS5c to MIS2. In contrast the sub-alpine King River site as with other upland karst landscapes in Tasmania has been impacted by several Quaternary glaciations including cirque and small valley glaciers during the last glacial cycle. Here glacial erosion has enhanced karst development by exhumation of limestone bedrock, enabling sediment-laden subglacial meltwater streams to sink into underlying karst conduits.

Kiernan, K., 1990. Bathymetry and origin of Lake Timk, south-west Tasmania. *Helictite* 28(1):18-21

P-1896

## Late Quaternary Glacial History of Zemu Valley, Sikkim Himalaya, India

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### Abstract

Glaciers provide a huge repository of landforms that can be used as proxy data source to assess magnitude and frequency of processes over time and space. Zemu glacier (27°45'58.62"N, 88°22'45.95"E), one of the largest (26km) in Eastern Himalaya, descends from the eastern slopes of Kanchenjunga in Sikkim Himalaya, India. Climate is dominated by SW monsoon, followed by winter rain from the South China Sea as well as the Mediterranean Westerly which influence the behavior of glaciers in the region. In such geo-climatic settings, smaller changes in climate will be reflected in the behavior of the glaciers in the region. The present study investigates glacial fluctuations in the Zemu Basin on the basis of deposited glacial landforms. The sequence of moraines provides a fair opportunity to reconstruct the glacial history since the Last Glacial Maximum in the region. Several field studies with GPS and remote sensed data with 3D view of Google Earth have been helpful to understand the geomorphology of the area. Accumulation-area Ratio, Maximum Elevation of Lateral Moraines, Toe to Headwall Altitude Ratio and Area-Weighted Mean methods have been used to estimate the Equilibrium Line Altitudes (ELAs) changes to understand the paleo-environmental conditions. Relative timings of the glacial advances have been estimated on the basis of ELA Change, distance of moraines from the present snout, and their comparison with the established chronology of glacial landforms in the neighboring areas of Bhutan and South-eastern Tibet.

Based on moraines, at least four glacial advances have been recognized in the study area. The maximum extent of Zemu glacier reached Zema, a place 16.2km downstream from the present snout position of Zemu glacier. This glacial extent, covered by climax vegetation and stable slopes along with ELA change of 412m suggests that it must be >20Ka old. A small lateral moraine which terminates at Poke, runs up to Zemu glacier in a broken line. Its 4.38km distance from the present snout position and an ELA change of 320m probably represents a Younger Dryer cooling event (>9Ka). A small advance which seems to be Late Holocene in age formed Yabuk ridge, which is 1875m downstream from the present snout position. An ELA change of 100m is estimated for this stage. Zemu seems to have been in a state of retreat ever since, except for a stand-still position that is 1240m far from the present snout. With an ELA change of 57m, this stand-still position probably indicates an extent during the LIA.

The glacial advances appear to be synchronous with the glacial histories of the neighboring regions. However, to understand the exact timing of glaciation, accurate dates should be acquired through various absolute dating methods.

*Keywords: Quaternary, Glaciation, Sikkim Himalaya.*

P-1897

## The glaciation history of the overdeepened Lower Aare Valley (northern Switzerland): insights from scientific drilling and outcrop data

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### Abstract

During the Pleistocene, extensive and repeated glaciations covered the foreland of the European Alps and carved up to several hundred meters deep trough structures, termed overdeepened valleys. These sediment traps were later – sometimes over the course of multiple subsequent glaciations – infilled with sub-, pro-, or non-glacial deposits. Therefore, overdeepened valleys can serve as excellent archives of pre-LGM glaciations, whose relics were otherwise largely obliterated by the following ice advances. However, timing and processes of formation of pre-LGM overdeepenings in the Alpine foreland are discussed controversially.

To gain insights into the pre-LGM glacial and fluvial history of northern Switzerland and to constrain the process of subglacial erosion, we currently investigate the overdeepened section of the Lower Aare Valley as well as a nearby glaciofluvial paleochannel. The project comprises four scientific drillings and is complemented by field work. Our study area is situated just beyond the local LGM, at the confluence of the rivers Aare, Reuss, and Limmat. There, the valley is deeply incised (>100 m below surface) into the substratum composed of Jurassic limestones.

In 2018, we recovered more than 350 m of drill cores. Here, we present first results of our sedimentological, geotechnical, and geochronological analyses.

**P-1898**

## **From ice-marginal to distal, sediments from filling a fjord-like glacial lake in the Aare Valley (CH) about 220'000 years ago**

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### **Abstract**

Repeated glacier advances affected the Swiss Plateau during the Quaternary. Deeply carved valleys, where the bedrock surface is located far below the current drainage level, are a prominent feature on the Swiss Plateau. How and when the glaciers lead to the formation of so-called overdeepenings is still a matter of debate. Different studies show that overdeepenings in the Bern area contain thick and widespread lacustrine deposits of pre-Eemian age (Preusser & Schlüchter, 2004; Preusser et al., 2005). A coherent geological model of this complex setting is missing. Likely, glaciers carved into pre-existing overdeepening fills and repeatedly dug large troughs.

Furthermore, access to the sedimentary record is limited. Outcrops containing sediments of the last glaciation are scarce and isolated. Access to older sediments is almost entirely limited to excavations and drillings.

Nevertheless, the overdeepenings served as local sedimentary traps while and after they were covered by ice during different glaciations. Hence, these troughs are prone to preserve a coherent sediment succession of a glaciation cycle in an ideal case, and they are therefore worth studying.

In this study, we attempt to resolve the local stratigraphic framework of pre-Eemian lacustrine deposits in the Bern area. In February 2019, we will conduct a ca. 200 m deep scientific drilling in order to link it to existing investigations aided by publicly available drill log data. We will study the lithofacies and use relative and absolute dating methods (palynology, luminescence dating, U-Th dating) to determine the development of a lake throughout a pre-Eemian glacial cycle. Preliminary OSL results of the lacustrine sediments yield a minimum age of 220 ka. This study will provide new insights into the timing, extent and impact of this glaciation as well as its climatic conditions.

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P-1899

## Crevasse forms – bridging the gap in glacial geomorphology between East and West

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### Abstract

Crevasse forms are a group of often-occurring glacial landforms, the origin of which are still variously interpreted by the east and west glacial geomorphologists, regardless their presence in contemporary glaciated areas of the high latitudes or formerly glaciated lowlands of Europe and North America. In the history of their research, they have been related so far to two extreme dynamic states of ice sheet:

1. Stagnant ice (among others Flint 1928; Bartkowski 1967; Johnson 1975; Eyles et al. 1999; Friello & Hanson, unpublished; Godlewska & Terpiłowski 2012; Gruszka et al. 2012);
2. Surging ice (among others Sharp 1985, 1988; Evans & Rea 1999, 2005; Evans et al. 1999, 2007; Christoffersen et al. 2005; Waller et al. 2008; Evans et al. 2016; Sobota et al. 2016).

Scale of deposition of Pleistocene and contemporary glacial landforms may result in misinterpretations of forms developing in ice crevasses. In some cases, despite morphological or geological differences, they are concerned or even named as the same landforms. In this context, the following tasks were executed: 1) review of the published examples of forms interpreted as developed in ice crevasses, 2) comparison of their characteristics and an attempt to explain their origin, and 3) assignment of the analysed forms to specific dynamic states of modern glaciers and/or Pleistocene ice sheets. Based on these studies, the following conclusions were drawn:

- 1) Forms filling ice crevasses are generally ridges, parallel or perpendicular to the direction of ice advance, which are composed of glaciofluvial, glaciolacustrine and glacial (mainly flow till) sediments from supraglacial deposition. These are forms typical of disintegration of stagnant/dead ice, named so far e.g. *kames*, *dead-ice moraines*. A place of their deposition, i.e. the crevasse, develops by ice cracking in the active ice but supraglacial deposition in these crevasses occurs mainly after ice activeness, i.e. when ice becomes inactive.
- 2) Crevasse forms *sensu stricto* are low, narrow sharp-edge glacial ridges subglacially deposited in crevasses during their formation. Such conditions of their development are possible only in surging glaciers. Deposition of such forms occurs from bottom to top of crevasses by squeezing of basal till – hence e.g. *crevasse squeeze* ridges develop.

It is high time glacial landforms developing in ice crevasses of Pleistocene ice-sheets and contemporary glaciers were regulated. This approach can offer an opportunity to limit misinterpretations of crevasse forms *sensu stricto* mainly in the research of Pleistocene glacial landforms, carried in the East.

**P-1900**

## **Morphological analysis of large-scale glacial and glaciofluvial bedrock-incised landforms**

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### **Abstract**

Understanding the controls on focused glacial erosion is important given the potential impact on ice sheet development and dynamics. Previous work undertaken in this area has assumed that large glacial erosional landforms such as troughs and overdeepenings are morphologically distinct from glaciofluvial landforms such as tunnel valleys. However, there are many examples of glacial bedrock incision that are difficult to categorise as either glacial or subglacial-fluvial, and process-based morphological criteria for distinguishing between the two are lacking. We present morphological analyses of overdeepened bedrock-incised landforms present on the Northern Swiss Foreland (NSF), focusing on their cross-profile morphology and comparability to that of similar features in other settings. This work aims to develop criteria that can be used to assess the relative contribution of glacial versus subglacial-fluvial erosion to the formation of such features, and therefore inform understanding and numerical modelling of subglacial conditions and processes.

**P-1901**

## **Ice-cored ridges: topography and melting dynamics based on sedimentary and structural evolution of collapse structures within kame deposits (eastern Poland)**

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### **Abstract**

The topography and melting dynamics of ice-cored ridges within marginal zones of the Pleistocene ice sheets have been reconstructed based only on simple conceptual and qualitative models supported by geomorphological, sedimentological, and palaeogeographical studies. A novel approach based on detailed sedimentary and structural analysis of two collapse structures affecting the Pleistocene kame deposits in eastern Poland is presented. The high regularity in the geometry of synclines and the patterns of subsidence of the folded strata are interpreted as evidence of topography and melting dynamics of ice-cored ridges. The topography is determined in terms of elongation, orientation and cross-sectional shape of ice-cored ridges. Dynamics of their melting is assessed based on a semi-quantitative model of different relative rates between backwasting and downwasting. The topography of ice-cored ridges, derived independently from the morphology of the related supraglacial landform, is interpreted as an effect of ablation controlled by debris bands within parent ice. The formation of the ice-cored ridges was initiated in subaerial conditions and then continued subaqueously during deglaciation. The reconstructed ice-cored ridges probably represent second order topographic features which were progressively emerged within wide ice-cored depression. The sedimentary evolution of collapse structures in terms of hinge/depocentre migration within them, provides new insight into dynamics of ice melting, to show the predominance of backwasting over downwasting. It concerns the final stage of de-icing which was probably preceded by stage of lowering of the ice-cored topography and progressive emergence of the ice-cored ridges. This approach offers the opportunity to overcome some limitations associated with using the present-day glacier margins as a modern analogue despite the differences in the scale between ice-cored topographic features and Pleistocene supraglacial landforms.

**P-1902**

## **Last Glacial Maximum glaciers reconstruction in the Karkonosze Mountains (Sudetes, SW Poland)**

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### **Abstract**

Karkonosze Mountains represent the highest mountain range within the Sudetes Mts. (Bohemian Massif) and contain one of the best preserved glacial relief among all mid-mountains (Mittelgebirge) ranges of Europe. Geomorphological signatures of intensive recurrent local glaciations (i.a. cirques, niches, moraines), are nowadays the only remnants of past glacial activity, and therefore can be used as natural tracers of glaciers formed during the Last Glacial Maximum (LGM). At the time of the LGM, glaciers have been emplaced in cirques located both on northern (6) and southern (10) slopes of the Karkonosze Mts. By a combination of a high-resolution (ca. 1x1 m) LiDAR DEM, geological data and field observations, integrated within an ArcGIS GlARE python tool, a new numerical model of paleo-glaciers has been proposed. In the beginning, reconstruction of the flowline, ice and moraine boundaries, have been used as proxies for the glaciers' past position. Ice thickness has been calculated based on airborne LiDAR DEM data and reconstructed glaciers' flowline. The total length of all reconstructed glaciers oscillates between 3 to 5 km, and the main type is cirque glacier. The area of glaciated terrain was not large or densely scattered, nevertheless, the quality of erosion, residuum and landforms is uncommon and worth investigating.

The main aim of this project is to reconstruct paleo-glaciers evolved both on northern and southern slopes of the Karkonosze mountain range, at the same time trying to decipher their contribution to the Quaternary relief remodelling, sediment flux and glacial erosion. The result in a form of the detailed Last Glacial Maximum paleoglaciological map of the Karkonosze Mountains should allow to better understand the importance of glaciation as triggering factor of mid-mountain ranges destruction and give an overview on past spatial ice extent.

P-1903

## Sedimentary and seismic stratigraphy of buried glacial landforms at Dogger Bank, North Sea: implications for ice-sheet retreat

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### Abstract

Dogger Bank, in the southern North Sea, is a large shallow bank surrounded by deeper waters, which makes it an ideal site for offshore wind turbine development. Site investigations as part of the Forewind windfarm project have provided an integrated dataset comprising a dense grid of high-resolution 2D shallow seismic survey, geotechnical tests and vibrocores. Calibration between observed sedimentary facies to the seismic stratigraphy allows for robust geomorphological interpretation. This provides vital inputs into ground models for placement of offshore wind turbines.

At the Last Glacial Maximum, Dogger Bank was covered by the British-Irish Ice Sheet. During ice-sheet advance, streamlined subglacial bedforms formed and were subsequently preserved. This implies both fast ice streaming during ice advance, and limited reworking of the bedforms during retreat. During ice sheet retreat, a large terminal thrust moraine ridge formed. The NE-SW trending moraine ridge dammed a large (approximately 750 km<sup>2</sup>) proglacial lake. Subsequent sedimentation infilled the lake with up to 30 m of glacial outwash sediments. The lake-fill seismic stratigraphy comprises discrete units of low amplitude, chaotic, or moderate to high amplitude, rhythmic seismic facies. A unit of chaotic facies with a lobate geometry thinning towards the southeast is interpreted to be an ice-contact subaqueous fan. This has minor thrust faulting and folding at the toe of the wedge, which suggest gravity-driven mass movement, or deformation due to minor ice margin oscillation. Iceberg scours and a layer of ice-rafted debris at the base of the lake suggest that the ice margin was calving icebergs into the lake. Onlapping the subaqueous fan, rhythmic seismic facies represent lake sediments calibrated to vibrocores as alternating clay and silt laminae, which are interpreted to be varves reflecting annual variation of sediment input. The varves also indicate quiet water sedimentation, which suggests ice sheet retreat and ice-distal sedimentation with a strong density stratification of the water column and a range of overflow and underflows that dispersed sediment in the lake.

This dataset suggests a record of punctuated ice-sheet retreat. After the initial formation of the terminal moraine, an ice-contact lake formed. The ice front then retreated to allow distal lake sedimentation, before sediment supply switched off as the ice retreated further northwards. This stepped retreat occurred after the LGM at around 27 ka and before a ribbon lake formed to the north of Dogger Bank, approximately 60 metres lower in elevation, dated previously to 23 ka. An initial phase of rapid, passive retreat was followed by a slow phase of retreat that allowed approximately 2000 years of lake varves to form. Subsequently, retreat was rapid towards the 23 ka ribbon lake. A negative subglacial slope as the ice sheet retreated northwards may have influenced this rapid phase of retreat.

P-1904

## Luminescence chronology of fluvial and marine records from subsurface cores in Kaveri delta: Implications to deltaic geomorphic evolution

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### Abstract

Long-term evolution of river deltas is a result of various contributions of external forcings (tectonics, climate, sea level, water and sediment inputs) and internal controls (avulsion, compaction etc). Thus, the deltaic fluvial deposits could be potential proxies to reconstruct past climate as well as to understand the response of river to changes in the sea level that are generally in sync with the changing climate. Presence of the past shoreline signatures in the form of palaeo beach ridges in Kaveri delta suggest a wave dominated delta and thus past sea level variations directly affecting the sedimentary dynamics of the Kaveri river forcing river to either aggrade or prograde. We present the results of luminescence dating of sediments from four sediment cores (VKI, TNR, SY and KKI) of 25 m depth each from the Kaveri delta in south east India. The coring sites are located ~2.5 km, ~11 km, ~17 km and ~20 km away from the present coastline respectively. The sediment cores were analyzed for OSL dating, <sup>14</sup>C dating, lithology and microfossils. OSL dating technique was used to provide robust chronological framework to the cores. This study extends OSL dating to a geographic region not covered in previous OSL dating literature, providing robust chronology for the Kaveri river delta. OSL dating provides an estimate of last daylight exposure of sediments, thus giving last burial ages. The cores represent various stages of fluvial and marine activity in the region over the last 150 ka. The chronology of the core closet to the coast (VKI) reflects eight major phases of increased sea level (142-140 ka, 104-100 ka, ~121 ka, 87-81 ka, 60-57 ka, 9-6 ka, ~5 ka and ~3 ka) partly coinciding with the global climate cycles MIS 6, MIS 5, MIS 3, MIS 1 respectively during the late Quaternary period. During ~121 ka and 9-6 ka, marine transgression reached the core location to leave marine signatures in the forms of foraminifera. VKI core replicates the quaternary sea level curve, showing strong control of the sea in coastal deposition. The bottom most age of this core is much older (~140 ka) than the rest of the four cores (~120 ka) situated further inland. This indicates the coastal land has uplifted in the recent years (somewhere post~50 ka), creating a basin fill situation for sediments to accumulate, as observed from the sedimentation pattern and robust luminescence chronology of the rest of the inland cores. The chronology of the topmost ages of the cores indicates delta has prograded gradually towards the sea during ~27 ka, ~19 ka and ~14 ka. Thus, the present work examines the geomorphic evolution of Kaveri delta, an archive of fluvial and shoreline activities.

P-1905

## The Holocene coastal dunes of the eastern Hengchun Peninsula, Taiwan – A synthesis of their development and palaeo-environmental implications

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### Abstract

Coastal dunes of the Feng-Chuei-Sha coastal area, Gang-Ko River mouth area and the Giopong-Gangtzie coastal area in the eastern Hengchun peninsula of southern Taiwan provide important opportunities to understand the interactions between the land and sea during the middle to the late Holocene. Our study applied UAV to carry out the landform survey, and developed digital surface model (DSM) for Integrating with the ground penetrating radar (GPR) data to show the relationship between landforms and internal structures of the dunes. Detailed descriptions of the dune outcrops and samples taken from the outcrops for grain-size analysis, radiocarbon dating and feldspar OSL dating allow us reconstruct the landscape evolution of the coastal dunes. Results show that (1) in the context of gradual eustatic sea-level dropping since the middle Holocene around Taiwan, rates of tectonic uplift, ranging from 0.4 mm/yr to ~2 mm/yr, primarily control the timing of coastal dune development in the study areas. The faster is the earlier. (2) The sand accumulation periods of the coastal dunes at ~4 ka to ~2.3 ka, ~1.8 ka to ~1.1 ka, and ~0.7 ka to ~0.4 ka are mainly consistent with the cold/cool climatic periods during the late Holocene. This finding indicates that stronger Asian Monsoon winter winds during the cold/cool periods blow abundant sand from the continuously extending beach toward land, even onto the uplifted marine terrace surface with 70 m in height. (3) Because of the topographic effect, the cliff-top dunes preserved more fine eolian deposit than the other coastal dunes did, and the grain-size changing trends in the cliff-top dune deposit may indicate the changes of the palaeo-wind transportation capacity. (4) Recently, layers of eolianites were observed in the profiles of the coastal dunes. The appearance of the eolianite layers and their implications about palaeo-environmental conditions should be further addressed in the future study.

P-1906

## Deciphering Quaternary palimpsest landscapes to constrain 3D (4D) geological models: an example from the Po Plain-Apennines border (N-Italy)

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### Abstract

Palimpsest landscapes represent important archives of the geological evolution of a basin. Deciphering the nature, timing and hierarchy of successive episodes of landscape-changing events in dynamic settings helps to constrain reliable evolutionary models and/or simulations, which incorporate the 4<sup>th</sup> dimension into 3D geological reconstructions.

The landscape of the Quaternary Po Plain, in the foreland between the Alps and the Apennines, is the surface expression of active thrusting of the Apennines (South) and Alpine glacial cycles (North). Reliable models of this complex, geomorphological and tectono-stratigraphic setting, are of interest for both the Quaternary reconstructions of the basin and the relevant issues in land and resources management.

Aiming to describe the Late Pleistocene-Holocene incremental landscape evolution of the basin, and to develop 3-4D models, we focus on a region close to the Po Plain-Apennines border, where three isolated low-relief hills emerge above the plain as a consequence of N-wards blind thrust-related uplift and wrenching/collapse. The hills expose stratigraphic boundaries and (paleo-) morphological surfaces otherwise buried in the adjacent plain sectors and show the involvement of the Quaternary, mostly alpine-sourced littoral, alluvial and glacio-fluvial succession in Apennine folding and faulting.

The adopted multidisciplinary approach combines different scales of geomorphological, geopedological, stratigraphic and structural field observations corroborated by OSL and <sup>14</sup>C age determinations to feed GIS-assisted, quantitative morphotectonic and stratigraphic analyses. The 3D forward models were processed by interfacing the GIS management with the 3DGeoModeller software.

The results highlight how, where and when climate and tectonic-driven processes fingerprinted the evolution of the hills and surrounding plain landscape. The proto-hills, i.e. paleo-highs uplifted during active Apennine thrusting in the early Late Pleistocene, were the sites for polycyclic loess-soil aggradation. This suite of non-erosional surfaces, characterized by *in situ* paleosols, relates to sites of morphological stability. Valley incision, fluvial terracing, soil truncation and redeposition occurred along the faulted boundaries of the uplifting reliefs and in the intervening structural lows. Late Pleistocene transtensional faulting induced abrupt changes of the drainage network by shifting the base-levels and enhanced reworking of paleosols. These were redeposited in colluvial wedges on the fault-block hangingwalls, the latter highlighted by peculiar alignments of morphotectonic indicators. A latest uplift stage during the latest Pleistocene-Holocene is recorded by the regional entrenchment of the major drainage network of the southern Po Plain, which is affected by several fault-related diversions, river captures and terrace-slope intersections. These cross-cut relationships and the tectonic increments have been converted into modelling rules, which have been incorporated as new routines into the GeoModeller suite.



The work shows that palimpsest landscapes represent the topographic and geomorphological constraints for modelling, where the modelled volumes, assembled by their hierarchy and formative increments, incorporate the evolutionary steps and drivers deciphered from field observations.

**P-1907**

**Preparing climate input data series for the FACSIMILE Rio Bergantes landscape evolution model-data comparison project.**

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**Abstract**

While numerical models can usefully be explored using synthetic climate input data, for the more challenging task of real world simulation, where model outputs are to be directly compared with observed field data, these inputs data series should attempt to more closely reflect actual climate history. The challenge set for the FACSIMILE project was therefore to establish likely timeseries for temperature and precipitation for the Rio Bergantes catchment spanning the modelled 140ka time interval, thus encompassing a full interglacial-glacial cycle.

Not surprisingly proxy climate data spanning this interval at annual resolution is not available. In order to reconstruct these series required the use of multiple proxy records spliced together and resampled using interpolation techniques. As temperature and precipitation are independent variables, that often show only weak correlation, we tried to reconstruct them using different data sources. For temperature a pollen data transfer function was used and for precipitation biomarker records were used as a proxy. Where overlapping data was not available generalised patterns were used to interpolate the missing data. Time series resampling was performed using the Rioja package in R. Modifications to these series will continue as the project moves forward.

The annual data series are used directly in the reduced complexity models e.g. LAPSUS, PARALLEM where appropriate spatially distributed temperature and rainfall are modelled using generalised lapse rates for temperature and modern precipitation gradients across the catchment.

P-1908

## Reconstruction of long-term soil erosion and deposition in a mesoscale catchment of the Central German Uplands: A field-based modelling study

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### Abstract

Soil erosion and related sediment deposition caused by climatic variations and human activity are important geomorphic processes in Central Europe during the Holocene. Since the Neolithic Period (c. 5.500 BCE) humans turned natural into cultural landscapes and thus further altered sediment dynamics. In the last decades, many studies have shown the importance of quantifying the contributing parts to the sediment cascade within a catchment to better understand the underlying driving forces on Holocene sediment dynamics. Due to the specific landscape history and often complex responses of geomorphic systems to change (e.g. feedback processes, resilience times, self-organization), the analysis of these underlying forces remains challenging.

Therefore, numeric models are used to provide valuable information on past geomorphic processes, test different scenarios of landscape evolution and complement field-based studies, as long as careful considerations of choosing a model and its limitations (e.g. data availability, calibration, validation and uncertainty) are made (Van de Wiel et al., 2011). When simulating actual landscapes, reference areas with well-established chronostratigraphies and spatially distributed data on long-term erosion and deposition patterns are of great importance.

This approach tries to reconstruct and quantify the sedimentation history of colluvial and alluvial archives in the Weismain river catchment (125 km<sup>2</sup>), located in the Northern Franconian Jura of the German Central Upland region, by using a combination of field-based methods, laboratory work and modelling setup. The OSL and AMS radiocarbon based chronology shows an increase in sediment deposition since the Early Bronze Age (2100-1550 BCE) for colluvial sites and around 590 CE for floodplain deposits. However, there is a variation in the onset of sedimentation between the individual sites, indicating the need for multiple regional site studies to reconstruct sediment dynamics on a catchment scale.

Van de Wiel, M. J., Coulthard, T. J., Macklin, M. G., Lewin, J., 2011. Modelling the response of river systems to environmental change: Progress, problems and prospects for palaeoenvironmental reconstructions. *Earth-Science Reviews*, 104, 167-185.

P-1909

## Widespread lake deposits on interfluves of Middle Pleistocene glaciated plains: problems of age and origin interpretation (Central European Russia)

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### Abstract

At the Russian Plain, a set of uplands in the marginal zone of Mid-Pleistocene glaciations are traditionally thought to have dominant glacial origin of landscape structure. The entire postglacial sedimentary sequence of interfluve areas is interpreted as mantle loams – relatively thin (2-3 m) cover sometimes correlated with loesses of the southerly regions. While still debatable most agree on its subaerial origin under periglacial conditions involving combination of eolian, cryogenic and shallow pool deposition. However, recent individual investigations show widespread much thicker (up to 8 m) silts to sandy and clayey loams even at the highest interfluves of several uplands. Those infilling depressions of initial glacial and glaciofluvial topography usually have brownish-bluish grey color and contain organic-rich lenses, which frequency increases downwards. Those covering hilltops have lower thickness (<3 m) but are found almost throughout the entire area.

Complicated by various cryo- and pedofeatures and partially destroyed, these sequences are not always recognized in cores and cross-sections. To obtain their reliable stratigraphy, we applied a hierarchical multiscale approach including detailed macromorphological description of sediments followed by comprehensive analyses of grain size, chemical, organic, and spore-pollen contents, microstructures and paleopedofeatures using scanning electron microscopy and energy dispersive spectrometry, and numerical dating of organic-rich lenses.

Revealed microlamination highlighted by color and granulometric variability, general lithological homogeneity and specific structural features allow considering both addressed sedimentary units of lacustrine origin. Stratigraphic (incl. overlying paleopedofeatures of texturally differentiated soils) and geomorphological positions suggest that on hilltops short-lived residual lakes formed during the final stages of Moscow ice cover degradation (MIS6). The accumulation in depressions started later - during the Mikulino (MIS5e) or Early Valdai (MIS5d-MIS4) and, in places, continued till the Late Valdai (MIS2) when was largely substituted by the intensified mass-wasting. Several asynchronous local water table drops and erosion episodes in the Valdai caused substantial reworking of deposits in periglacial environments and local stratigraphic hiatuses.

Thus, for the peripheral areas of uplands in the Mid-Pleistocene glaciation marginal zone, we propose a long-term discontinual postglacial transformation mostly by lacustrine type of exogenesis, which led to a significant flattening of its initially higher-amplitude glacial topography at least during the last glacial-interglacial macrocycle. Nonetheless, resuming the extents of lake basins either causes of their origination is still problematic. High regional base level rises in large proglacial lake systems are occasionally proposed in light of a potential Late Pleistocene ice-damming of the Upper Volga and glacioisostatic effects. However, the existence of such extensive waterbodies is supported neither by the required water sources nor by the regional topography. As for the local agents of widespread distribution of multiple small lake basins, high activity of zoogenic (during interglacials) and slope (during periglacial and transition periods) processes can be suggested.

**P-1910**

## **Comparing differently derived soil depth and bedrock strength inputs for landscape evolution modelling of the Bergantes catchment (Spain).**

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### **Abstract**

In the field of landscape evolution modelling, initial conditions strongly steer model behaviour and, when modelling actual catchment evolution, influence the validity of model results. One of the important inputs for landscape evolution models is information on soil depth and bedrock strength. These not only control the available initial erodible material, but also control, in combination with climatic and topographical data, long-term weathering rates and depths. Within the scope of the Facsimile-working group (Field And Computer SIMulation In Landscape Evolution), the Bergantes Catchment (Alcañiz province, Spain) is chosen as a test case to compare different Landscape Evolution Models (LEMs) because of its relatively well-known fluvial archive. One of the key questions of the working group is to compare results of different LEM's over a 150ka timespan modelling the same catchment with the same input parameters. These input parameters need to be constrained. This paper investigates the available data of initial soil-sediment depths and bedrock strengths to be used as an initial condition. It will show comparisons of relatively simple, more conceptually constructed input maps, such as a slope related sediment depth map and compare these with more data driven maps, using maps from readily available online soil and geological data. These data can then be used for model sensitivity studies and model to model comparison studies to eventually lead to meaningful landscape evolution modelling of the Bergantes catchment.

**P-1911**

## **Relic cryogenic features on cultivated interfluves and their impact on modern soil redistribution and gully erosion processes (Western European Russia)**

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### **Abstract**

Widespread relic cryogenic features (RCF) in topography and soil structure beyond the present permafrost southern limits are observed in many areas of Europe (Pewe, 1966; Kolstrup, 1986; Jetchik and Allard, 1990; Bertran et al., 2014). It is generally accepted that most of those were formed under the most severe conditions of the last stage of the Late Pleistocene glaciation (Vandenberghé et al., 2014; Andrieux et al., 2016). Recent progress in studies of the RCF has been largely achieved due to latest development of the remote sensing (RS) techniques and especially increasing availability of high-resolution satellite imagery. By present time, morphological classification of RCF has been proposed (Velichko, 2015; Andrieux et al., 2016) and specifics of their zonal distribution more or less established for the Eastern European Plain (Velichko, 1982, 2015). Significant progress has also been achieved in investigations of role of RCF in structure of modern soils (Duchaufour, 1951; Makeev, 2009; Alifanov, 2010, Sycheva, 2012). Several problems still lacking detailed scientific considerations, namely relationships between different types of RCF and modern hillslope processes, soil degradation, sediment export from cultivated slopes into fluvial network.

The research reported here is concentrated on evaluating relationships between different types of the RCF and morphological and geochemical differentiation of soils, intensity and spatial distribution of soil erosion and deposition processes on cultivated slopes. Approaches employed include analysis of the RS data, application of several independent techniques for quantitative assessment of soil redistribution on cultivated slopes and in small catchments, geodetic DGPS surveys, airborne photo by unmanned aerial vehicles (UAV), morphological and geochemical investigation of soil properties and georadar surveys. Several case study sites with various combinations of relic cryogenic feature types, zonal soil types, morphological and morphometric characteristics of cultivated slopes, density and structure of stream network have been selected basing on examination of the RS data and reconnaissance field surveys. Two case study sites located in the Yaroslavl and Kursk Regions respectively have already been studied in more details. Detailed satellite images interpretation allowed distinguishing several types of RCF spatial patterns (similar to determined by Andrieux et al., 2016) including regular and irregular (by size and shape) polygonal networks with rounded outlines due to thermokarstic degradation of the wedges, striped grounds, transition zones between polygons and stripes and individual thermokarstic depressions. Ground control in combination with DGPS survey and detailed UAV photography allowed additional determination of RCFs prominent in the present-day microtopography or only in topsoil and vegetation color. It has been found that for the case study sites microtopographically-prominent RCF exert important influence on spatial pattern of overland flow, especially runoff concentration, and, therefore, on sediment redistribution within cultivated hillslopes. Present gully network also partly inherits downslope parts of polygonal or striped RCFs.

P-1912

## Late-Cenozoic bedrock denudation rates and tors exhumation in the Sudetes (SW Poland) quantified with $^{10}\text{Be}$ and $^{26}\text{Al}$ cosmogenic radionuclides dating

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### Abstract

To quantify Late-Cenozoic dynamics of relief evolution in the Central European mid-mountain range type as represented by the Sudetes Mts. (SW Poland, Bohemian Massif), we applied cosmogenic radionuclides (CRN) dating technique based on  $^{10}\text{Be}$  and  $^{26}\text{Al}$  measurements. All samples originated from granite and metamorphic tors, located at different topographic positions (ridge, slope, valley side) and altitudes (ca. 400-900 m a.s.l.). Obtained  $^{10}\text{Be}$  minimum exposure ages (assuming null denudation rate) clustered in the range between  $17.08 \pm 0.53$  to  $67.08 \pm 2.00$  ka for tors top surfaces and from  $6.84 \pm 1.14$  to  $35.78 \pm 18.60$  ka for tors bottom surfaces respectively. Estimation of maximum denudation rates (assuming steady-state and infinite time) for outcrops in a valley side position has yielded the value of 24.3 to 37.1 m/Ma, whereas for those occurring in a summit and ridge position shown the value of 9.2 to 15.7 m/Ma. The highest  $^{10}\text{Be}$  concentrations were found at subhorizontal top surfaces of the sampled tors occurring at flat summits (planation surface) and in the upper parts of valley slopes. Cosmogenic nuclides derived denudation rates for the Western Sudetes evidence a Plio-Pleistocene (ca. 2.6-1.0 Ma) maximum tors formation period. However, we do hypothesise that they could evolve most intensively mainly during Elsterian (MIS12) and Early Saalian (MIS6) glaciations. Intensification of erosion and deposition processes during the Middle Pleistocene glacial-interglacial cycles are well evidenced with glacial and glaciofluvial sediments reported for the Sudetes area. Performed cosmogenic radionuclides dating, provides a first geochronological insight into the problem of Sudetic tors origin and evolution, which hold inherited non-steady exhumation history.

**P-1913**

## **Human mobility in the Lop Nur region during Han-Jin Dynasties: A multi-approach study**

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### **Abstract**

The Lop Nur region, as the junction of the Silk Roads, played an important role in human migration and cultural communications between the East and the West, north and south Eurasia during Han-Jin Dynasties. However, the extent and intensity of human mobility in this region during Han-Jin Dynasties remain unclear. Here we present a multi-approach (wood species identification, strontium and oxygen isotopes of tooth enamel and historical documents) to investigate the extent of human mobility in the Lop Nur region. From a Han-Jin Dynasties cemetery in the Lop Nur region, two particular tree species which are not common in the region have been identified among wooden objects, suggesting a human migratory behavior in the Lop Nur region. Strontium isotope and oxygen isotope data show that at least 8 out of 27 individuals are identified as immigrants, and the great isotopic variation indicates that these immigrants have diverse origins. Furthermore, exotic mortuary object, such as lacquerware originated from eastern China, indicates the existence of long-distance exchange. In context with historical documents, we infer that the Lop Nur region was once the political, economic, and cultural meeting place of various societies, and also a communication corridor on the Silk Roads in Han-Jin Dynasties.

P-2001

## Middle Pleistocene rocky shores and rock-boring biota at Kuromatsunai, southwestern Hokkaido, Japan

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### Abstract

Rocky-shore habitats are often well preserved in the geological record, and are well suited for interfacing with reconstructions of paleoecological, paleogeographic and paleoenvironmental changes. Hard bottom environments often bear rock-boring trace fossils produced by boring organisms, such as bivalves, gastropods, brachiopods, barnacles, polychaete annelids, sponges and bryozoans. In general, these trace fossils are used as indicators of ancient rocky shores and are useful for reconstructing paleoenvironmental conditions.

In Hokkaido, the shallow-marine facies that are rich in rock-boring biota were primarily deposited during the Pleistocene. We studied rock-boring bivalves and their clavate borings in the Setana Formation in the Kuromatsunai area, southwestern Hokkaido. The Setana Formation contains well-preserved molluscs that have been dated to approximately 0.95 to 0.83 Ma based upon microbiostratigraphy using planktonic foraminifera and nannofossils. In the Soibetsugawa section of the Kuromatsunai area, the basal part of the Setana Formation unconformably overlies a basement comprised of a conglomerate of Pliocene siltstone deposits. Many wave grooves and tidal pools are apparent on the basement surface. Boring bivalves are dominant in conglomerate clasts and are absent from the basement layer.

The rock-boring bivalve, *Nettastomella japonica*, and the clavate borer, *Gastrochaenolites orbicularis*, are dominant in clastic sediments. Moreover, rocky-substrate molluscs, such as mussels, limpets, and chitons, are also recognized. These molluscs are considered to be semi-autochthonous in origin, and are presumed to wave-cut platforms associated with boulder beaches on ancient rocky shores.

The paleoecological characteristics of the molluscan and ichnofossil assemblages in the studied section reflect changes in the sedimentary environment during a sea-level transgression during the Pleistocene. Wave-cut platforms bearing wave grooves and tide pools were created during the initial period of the transgression. Subsequently, *N. japonica* and *G. orbicularis* assemblages found in the conglomerate during the late transgression reflect the semi-autochthonous occurrence of these taxa on unstable substrates.

Bioerosion of rocky marine surfaces is well suited to revealing geological episodes, such as oscillations of sea level, erosion/sedimentation rates and the intensity of physical disturbance. The Setana Formation is assigned to the interglacial stages of the middle Pleistocene (ca. 0.95 to 0.83 Ma) based on microbiostratigraphy, and is likely correlated with a marine isotope stage of 27 or 25.

P-2002

## Paleoenvironmental dynamics of the passive margin of the Niger Delta during the Late Quaternary: Future implications

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### Abstract

The Niger Delta is ideally located in a region of great sensitivity to climate change and sea level fluctuations and offers the possibility to provide insights on Late Quaternary environmental change in Equatorial West Africa. In comparison with other major tropical deltas, this deltaic system's response to past climate change and sea level fluctuations during the last 20 ka is poorly understood due limited studies in the basin. This presentation documents the detailed analyses of a multi-proxy dataset collected from three gravity cores obtained from the shallow margin of the Niger Delta in an effort to fill this scientific knowledge gap. The dataset included sedimentology, grain size, geochemistry, calcareous nannoplankton, foraminifera, and palynomorphs. The study hypothesised that the dynamics of the Intertropical Convergence Zone (ITCZ) and sea level fluctuation played a major role in shaping the landscape in the Niger Basin and adjacent coastal regions. The palynological sequences defined in the three gravity cores show very similar fluctuations; afro-montane forest (Podocarpaceae), freshwater swamp (Cyperaceae), savannah (Poaceae) and lowland rainforest (Polypodiaceae) dominated the late glacial and deglaciation periods, followed by the development of mangrove vegetation (Rhizophoraceae) during the interglacial in Early to mid-Holocene. In addition, high values of charred grass cuticles and Ti/Zr ratio are observed during the late glacial, whereas high values of Fe/S ratio and planktonic foraminifera correlate with the expansion of mangrove vegetation during the interglacial period. These records suggest dry conditions and lower sea level during the late glacial and deglaciation periods, and warm conditions leading to the rise of the sea level during the interglacial. These extraneous controls on the environment confirm a direct link between the vegetation dynamics (pollen), and sediment supply in the Niger Delta sedimentary paleoenvironment from ~ 20 to 6.5 ka. The sequential record links the evolutionary stages of the littoral margin of the Niger Delta to the deltaic landscape and sequence architecture with two brief time-bound regional stages based on evidence derived from the integrated multi-proxies. Thus, the controlling factors that accommodate the two complete stages of evolution at different periods has resulted in an improved understanding of the paleoenvironmental dynamics of the passive margin of the Niger Delta during the Late Quaternary.

**P-2003**

## **A preliminary study on sedimentary facies from a sediment core of Nakdong river delta, Korea**

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### **Abstract**

A vibro-core (16ND-C02) was obtained from the Nakdong river delta in 2016. Based on the sediment composition and texture, and color, the deposits can be divided into eight sedimentary facies. In ascending order these are: a) weathered rocks, b) basal gravelly sand, c) massive sand, d) thin laminated silty mud, e) bioturbated mud, f) bioturbated sandy mud, g) alternated muddy sand and, h) cross bedded sand. The distribution of the facies is significantly variable in the core. These facies can be then grouped into three units: 1) fluvial deposits, 2) marine deposits, 3) delta deposits. Each unit is separated by sharp and unconformable erosion surfaces. The lowermost Unit 1 is about 25 m thick and comprised massive gravelly sand and gravels. The presence of massive sand suggests that Unit 1 is a fluvial deposit, which evidently formed during the lowstand sea level during the glacial period. OSL dates of the base of Unit 1 is  $76.7 \pm 7.5$  ka. Unit 2 consists of thin silt lamina that vary systematically in thickness, suggesting tidal influences. OSL dates of this unit range from  $10.9 \pm 0.7$  to  $9.0 \pm 0.6$ . The presence of weakly tidal signatures suggest that Unit 2 is estuarine deposit. Unit 3 is composed of bioturbated mud and cross-bedded sands. This unit contains either shells or foraminifers or any other marine indicators. It is mostly oxidized and weathered. The OSL dated age of Unit 3 ranges from  $6.6 \pm 0.4$  to  $1.1 \pm 0.1$  ka, the deposits belonging to the Holocene. The depositional record of the most recent sea-level highstands (Holocene period) is well preserved. During the late Holocene sea-level highstand, the stratigraphic pattern consists of the deltaic sequence, formed as a seaward progradational pattern.

**P-2004**

## **Re-evaluation of a 19 ka BP meltwater pulse in the Northern Hemisphere: new data from offshore northeast Ireland (Kilkeel)**

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### **Abstract**

It has previously been hypothesized that glacial and glacimarine deposits infilling incised river channels exposed in coastal cliff sections at Kilkeel (Northern Ireland), provide evidence in support of a major meltwater pulse at 19 ka BP (MWP-19ka), marking the end of the global Last Glacial Maximum (gLGM). This is the only site that constrains both the timing and magnitude of MWP-19ka in the Northern Hemisphere. We present new offshore multibeam bathymetry and sub-bottom data, sediment cores and radiometric dates that question the MWP-19ka hypothesis at this site. Geophysical data reveal a drumlinized landscape with no evidence of a river channel network incised during an interval of low relative sea level (RSL). Instead glacimarine muds accumulated within inter-drumlin troughs during a single period of higher than present RSL during deglaciation. A subsequent RSL fall, to c. -20 m below present, likely caused by glacio-isostatic rebound, is indicated by evidence of a wave ravinement and planation of now-drowned drumlins. The site provides no evidence for MWP-19ka and should not be used to inform oceanographic, ice sheet and sea-level models for this period.

**P-2005**

## **Reconstructing the coastal response to Last Interglacial sea-level rise in the southern North Sea**

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### **Abstract**

Global temperatures during the Last Interglacial were  $\sim 1^{\circ}\text{C}$  warmer than pre-industrial values and  $3\text{-}5^{\circ}\text{C}$  warmer at polar latitudes, during which time global mean sea level was 6-9 m above present, far above that experienced in human memory. Though the drivers of warming during the Last Interglacial are different to those of today, it is the amplified warming at polar latitudes, the primary locations of the terrestrial ice masses likely to contribute to long term sea-level rise, which makes the Last Interglacial an interesting analogue for improving understanding of future climate and sea-level change and associated landscape response. However our understanding of Last Interglacial sea level change is primarily limited to tropical and sub-tropical latitudes and it is important to understand the response of temperate estuarine settings to rising sea level.

A new project focuses on specifically targeting palaeo shorelines sequences buried within the southern North Sea, preserved beyond the limit of the Last Glacial Maximum ice sheets, to reconstruct the rate and nature of transgression of the basin during the Last Interglacial. There is a broad understanding of the Last Interglacial sedimentary sequences of the southern North Sea, but not the flooding of the former terrestrial landscape. Geophysical data has been used for a long time in 'deep time' offshore Geology, but recent advances in higher resolution data collection makes it possible to identify shallow late-Quaternary stratigraphic units. A wealth of new offshore geophysical and borehole data has become available as a result of significant investment into energy sources in the North Sea region and is providing a driver for Holocene-focused research, establishing a methodological framework that can be applied to older sequences.

The offshore sedimentary archives offer significant advantages over the geomorphologically restricted onshore records, with the ability to trace the transgression in 3-dimensions over a much greater area. Furthermore, the offshore record should capture the earliest flooding of the Last Interglacial North Sea basin, when the far-field data suggests ice sheet melt was at it maximum, during the peak in global warmth during the Last Interglacial. This has the potential to allow us to 'fingerprint' the source of melt (Greenland and/or Antarctica) during the interglacial sea-level highstand.

P-2006

## Rate of sea-level rise as a control on shoreline preservation

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### Abstract

The recorded preservation of submerged shorelines as geomorphological features on continental shelves indicates the implausibility of standard models of coastal response to sea-level rise (e.g. the Bruun Rule and its derivatives). The distribution and preservation of Late- and Postglacial shorelines at specific periods and at specific sea-levels in the United Kingdom, South Africa, Brazil, the Mediterranean and the Gulf of Mexico, for example, points to an important role for the *rate* of sea-level rise rather than simply the *amount* of sea-level rise as a constraint on shoreline evolution. We present a model for shoreline preservation that involves a slowing or halt in sea-level rise (a stillstand or slowstand) during which mature shoreline features develop. These are then preserved if subsequent sea-level rise is rapid enough for the surf zone to translate across the shoreline without totally reworking it. Evidence from several locations suggests that this has occurred several times since the LGM and that sea-level surges associated with meltwater pulses are a key factor. During intermediate rates of sea-level rise, shorelines are reworked and not preserved except under exceptional circumstances associated with local topography, energy levels and sediment volumes. Our findings are important not just for former shoreline preservation but also for predicted future shoreline response to sea-level change.

**P-2007**

## **The evolution of a submerged glacial and deglacial landscape from east Ireland (Dundalk Bay and Carlingford Lough).**

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### **Abstract**

During its final deglaciation, the Irish Ice sheet (IIS) underwent different phases of advance and retreat that have often been linked to global climatic events as opposed to local scale ice-sheet dynamics. Two important readvance phases are known locally as the Clogher Head and Killard Point stadials, with evidence of both in Dundalk Bay and Carlingford Lough (east coast Ireland, C. Lough). Associated with these readvance phases are multi-meter scale relative sea-level oscillations. However, the offshore extent of these advances is unknown and there is large disagreement between the empirical evidence of relative sea level and the modelled sea-level response for this region. This contribution presents the analysis and interpretation of marine geophysical data, eight vibrocores and six radiocarbon dates from offshore C. Lough to investigate the evidence of these readvance phases and the associated sea-level response.

The bathymetric and radiocarbon evidence suggests initial ice-sheet retreat was northwards, with ice-free conditions offshore C. Lough sometime before 18.7 ka cal BP. The core stratigraphy indicates this early retreat was set in a glacial marine environment. A large arcuate moraine ridge in Dundalk Bay and a series of smaller ridges at the mouth of Carlingford Lough are evidence of a readvance of the IIS eastward. The composite nature of these features suggests an oscillating margin and possibly suggest that the IIS was not solely dependent on external forcing factors but also sensitive to local ice-dynamics. The outer most moraines indicate that the maximum extent of ice advance in the region is more restricted than previously thought. We correlate these features with ice margins mapped onshore and are likely correlative to the Clogher Head and/or Killard Point Stadial, a period spanning 18.2 to 16.5 ka BP.

The cores collected in this study currently lie in a dynamic marine setting where evidence of sea-level minima has not been preserved. The lack of primary sea-level index points restricts us from constraining the sea-level models for this region. However, the seismic data display a consistent ravinement surface down to -40 m, suggesting sea level dropped to around -30m when wave base erosion is taken into consideration. A date above the ravinement surface of 13.2 ka cal BP indicates the timing of the sea-level lowstand occurred prior to this date. In Dundalk Bay the moraine crest is 12 m below sea level and would therefore have been sub-aerial during this lowstand. The sea-bed geomorphology behind the moraine suggest this acted as a barrier, possibly damming a lake and/or providing a suitable environment that preserves evidence of an intertidal setting that is not preserved seaward of this feature.

**P-2008**

## **Late Holocene mangrove dynamics and coastal environmental changes in the Sundarbans, Ganges-Brahmaputra delta, India**

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### **Abstract**

Mangroves are halophytes occur on intertidal shorelines in the tropics and subtropics. Mangroves constitute an expressive ecosystem in the east coast of India and one of the best examples of mangrove forest is located on the coastal area of the Ganges-Brahmaputra delta, India. A 4.6 m sediment core from mangrove region of southwestern part of the Sundarbans, Ganges-Brahmaputra delta has been studied through pollen analysis in order to reconstruct mangrove dynamics and coastal environmental changes during Late Holocene. Pollen and stratigraphic data indicate dominance of mangroves between 4000 to 3500 cal yr BP. A contraction of the mangrove area and an expansion of midland and aquatic vegetation occurred between 3500 to 2500 cal yr BP. The reappearance of mangroves at the study site occurred with a return of brackish water estuarine environment between 2500 to 900 cal yr BP. This trend continued until the present. Occurrence of *Casuarina equisetifolia* and *Palmae* pollen in good percentages from a few surface samples from the upper section of the core also indicate anthropogenic activities during the recent past in this area.

**P-2009**

## **Coastal processes of the Eastern Gulf of Finland: recent dynamics and driving forces**

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### **Abstract**

Littoral zone lithodynamics, together with geology, morphology and tectonics control the main features of coastal processes as well as the size, shape and development of erosion/accretion formations. Therefore the study of recent coastal processes provides another valuable proxy for modelling of shoreline displacements.

The eastern Gulf of Finland coastal zone is characterized by intense coastal processes. Upper part of geological sequence consists of easily erodible Quaternary deposits represented by Holocene marine sands and Late Pleistocene sandy and clayey loam. Due to the complicated interplay of eustatic and isostatic processes, there have been several pronounced sea-level variations during the Holocene. Evidence of many phases of these variations is well-preserved in the modern landscape at different elevations both onshore (relict lagoon systems and sand spits at altitude +5 -+20 m) and offshore (submarine terraces at water depth -5 – -20 m). Sand, gravel and pebble material from glacial and glaciofluvial landforms were the main source of sediments for the Holocene coastal accretion bodies. Conservation of big sediment volume in relict coastal landform together with very low (from 0 to +3 mm/year) rates of uplift at a near zero rate of recent sea-level change caused sediment deficit, which is one of the important driving forces of coastal erosion.

Annual coastal monitoring carried out by VSEGEI since 2000, has shown the highest intensity of coastal dynamics are confined to the easternmost part of the Gulf of Finland. The most extreme erosion events occur when long-lasting western or south-western storms, high water level, and the absence of stable sea ice take place simultaneously. Such situations are recently more frequent due to climate change. Along the northern coast (Kurortny District of St. Petersburg), the average rates of coastal retreat is about 0.5 m/year, but within some coastal segments they reaches 2 m/year, and can be up to 5 m per one strong storm.

Southern coast of the Gulf (near Bolshaya Izhora village) is one of the most dynamic coastal area. The coastal zone here is steadily developing along the principle of longshore sand waves, moving eastward along the coastal line with an average speed of 25 m/year. From 2011 to 2018, the movement of the coast projection (waves) is 180 m.

Comparative analyses remote sensing data (started from the WWII Aerial Photos of August 15, 1939) has shown that the same phenomenon of longshore sand waves is observed within coastal zone of Kotlin Island. It is resulted in western coast retreat (rates 1.2–2 m/year) and sand spits forming in the east.

This research undertook in frame of project № 17-77-20041 of Russian Science Foundation.

P-2010

## 2000 years of changes in primary producers communities using *Posidonia oceanica* (*L. Delile*) mat sediments: chronology and driving factors

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### Abstract

*Posidonia oceanica* is a long-living marine phanerogam in which a significant part of the production is stored on seabottoms as an organic bioconstruction (mat). In principle, seagrass mats are reliable archives of long-term environmental change; although palaeoecological approaches using seagrass archives are still rare, particularly those using fossil pigments. Competition for light and/or nutrients between algal organisms and the seagrass have been observed at decadal scales and symbiosis between cyanobacteria and *P. oceanica* has recently been suggested to play a key role in the production of these seagrass meadows. Planktonic and epiphytic communities as well as *P. oceanica* production have also been observed to change with water depth. The aim of this study is to elucidate how primary producer communities interact and change in *P. oceanica* meadows at millennial scales: are cyanobacteria or others organisms linked to seagrass production? Which factor(s) regulate(s) main changes in assemblages? To answer these questions, sediment cores were obtained from two bays of Cabrera island (Balearic Islands, Spain), including a transect of cores from different depths. All cores were sectioned, dated using <sup>14</sup>C and <sup>210</sup>Pb, analysed for biomarker pigment composition using high performance liquid chromatography, analysed for the elemental chemical composition, grain size was also determined using a laser-based particle analyzer and Fourier Transform Infrared Spectroscopy was used to get absorbances of biogenic silica. Diverse pigments derived from cyanobacteria, diatoms, chlorophytes, cryptophytes and dinoflagellates were preserved in sediments. In each core, changes in the relative abundance of carotenoids from cyanobacteria (canthaxanthin, echinenone) and diatoms (diatoxanthin) reflected changes in the seagrass ecosystem production. Higher seagrass production, indicated by seagrass debris and biogenic silica in sediments, was associated with elevated abundance of cyanobacteria. This higher production state seems to depend on external contributions of nutrients, specifically iron, to the aquatic system. Periods of clear cyanobacteria dominance go from 1000 to 500 cal. yr BP and from 300 to 125 cal. yr BP, both coincident with enhanced aeolian dust from Sahara, a known significant source of nutrients to the Mediterranean waters. From 300 to 125 cal. yr BP, agricultural activities in the island could have also enhanced the arrival of terrestrial nutrients to the aquatic ecosystem. Pigment assemblages associated with lower seagrass production states were composed mainly of diatoxanthin from diatoms. A pattern in assemblages along a depth gradient reveal that cryptophytes (alloxanthin) and cyanobacterial pigments (echinenone) were both associated with shallower and more productive waters while at deeper stations, dinoflagellates (diadinoxanthin) were more abundant. Fluctuations in pigment composition in seagrass soils records reveal that primary producer assemblages and seagrass production in the *P. oceanica* ecosystem are mainly associated with water depth and iron inputs (either from atmospheric or terrestrial sources).

**P-2011**

## **Paleoenvironmental Changes Based on Geochemical and Palynofacies Analysis of the sediment cores from Lagoa Salgada, southeast Brazil**

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### **Abstract**

Lagoa Salgada is a seasonally brackish to hypersaline coastal lagoon located in Rio de Janeiro State, southern Brazil. It sets in the context of the coastal plain of the Paraíba do Sul river with its formation associated with sea level fluctuation in Quaternary. This study aims to provide a high resolution of the Lagoa Salgada paleoenvironmental evolution by the study of the organic matter (OM) associated with the sedimentation.

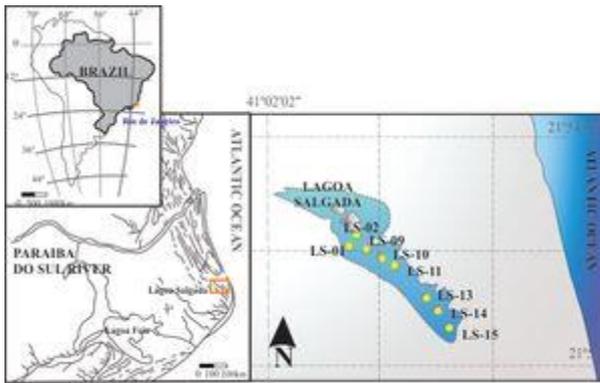
In order to do it, eight sediments cores were described. These sediments were characterized mainly by coarse and fine sand, sandy mud and mud. LS15 is the deepest sediment core of 212 cm and in a previous study it was constructed a chronological model resulting in a period between 6.300- and 1.300-years cal. BP.

The cores LS-01, LS-02, LS-03, LS-09, LS-11, LS-13, LS-14 and LS-15 were sampled at intervals of 10 cm, totalizing 96 intervals. They were submitted to the analysis of Total Organic Carbon (TOC) aiming to quantify the OM in the sediments. Except for LS14, the same sampling intervals were submitted chemical isolation of OM. All these 77 intervals were studied by Palynofacies analyses. Geochemical data indicates high heterogeneous content with TOC values varying from 0.04 to 9.45wt%. Carbonate content ranges from 3 to 90%. Both results show an increase in the top area, reaching the highest values in the upper mud.

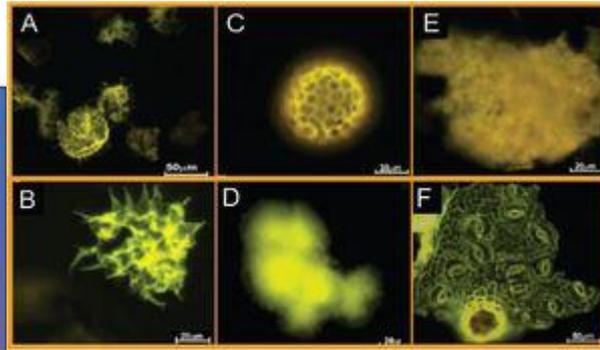
The kerogen assembly is complex for sand and sandy mud sediments with a high allochthonous contribution. For this reason, the results of 34 intervals were submitted to cluster analysis by applying R-Mode and Q-Mode. The rise in the amounts of the Phytoclast Group (0 to 39.68%) is related to an input from the river bringing these compounds derived from terrestrial macrophytes. Dinocysts (0 to 13.09%) from species *Operculodinium centrocarpum* and the genus *Spheniferites* spp are the main marine contribution. The occurrence of peaks was related to transgressions. The occurrence of freshwater microplankton - *Botryococcus* and *Pediastrum* - indicates moments of lower salinity. Sporomorphs has a great occurrence and the appearance of the family *Amaranthaceae* is recurrent. This family is associated to arid environments and altered human settlements due to their high temperature tolerance. Amorphous organic matter (AOM) occurs in all sampling intervals (10.19 to 100%), and even though they are from distinct origins, they are always autochthonous. The AOM dominates the palynological assemblage of the top intervals and its origin is related to the activity of autotrophic and photosynthetic bacteria. Moreover, Phytoclasts and Palynomorphs are extremely rare in these intervals which are related to the closure of this coastal lagoon. Through these results, it is possible to characterize the evolution of the paleoenvironment of Lagoa Salgada over the 6340 years BP.



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Location of the sediment cores from Lagoa Salgada



Polymorphous Group: (A) Dinocysts; (B) Pediasstrum; (C) Pollen grain; (D) Botryococcus;  
Amorphous Group: (E) Amorphous Organic Matter; Phytoclast Group: (F) Cuticle.

P-2012

## Autogenic and allogenic processes involved in the formation of *Posidonia oceanica* environmental record.

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### Abstract

*Posidonia oceanica* is a highly productive marine plant that promotes sedimentation leading to the formation of a well-stratified soil (mat), whose upper part can be equated to a Histosol. Similar to continental peatlands, the value of the mats as late Holocene environmental archive has been explored, most particularly over the last decade. However, knowledge on soil formation and dynamics is scarce and mainly refers to the epipedon. On this study, we determined the chemical composition (by XRF) of a core (470 cm long) sampled in Portlligat bay (NE Spain), which spans the last 4000 yr. We aimed to reconstruct autogenic and allogenic factors involved in *P. oceanica* mat formation and dynamics. Using principal component analysis, we have been able to identify four processes: organic vs inorganic matter accumulation, carbonates production, deposition of fine particles and metal accumulation. Organic matter (OM) is mostly composed by plant remains, which are deposited at the surface as the plant grows avoiding burial. Its decomposition essentially occurs in the epipedon (upper  $\approx$  40 cm, last 300 yr BP), being very slow below it – i.e. the proportion of organic vs inorganic matter remains almost constant with depth except for punctual increases in mineral matter which reflect past inputs of continental material. Carbonate content seems to be controlled by biocalcifier organism's production, but changes at the top of the core are controlled by OM content. Fine grain size particles deposition is promoted by *P. oceanica* canopy and arid periods. Metallic elements showed two different accumulation records, and are split between two components, related to anthropogenic and natural sources. Change point modeling enabled to identify eight main periods: 4000-3600, 3600-3050, 3050-2200, 2200-2000, 2000-800, 800-250, 250-40 and <40 cal BP, involving changes in one or more of the process identified. Several paleoproxies have also been previously studied in the same core, which allows us to discuss the causes of the changes.

P-2201

## Mammalian fossils from Hualong Cave, a recently recovered Middle Pleistocene human site in Anhui, China

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### Abstract

The Hualong Cave of Dongzhi in Anhui Province is located on the southern bank of the Yangtze River, and it was recovered in 2004; several excavations since then have resulted in the discovery of several human remains and numerous mammalian fossils. Currently 43 mammalian species, including indeterminate species, belonging to 24 families and 8 orders have been identified. The fauna is dominated by artiodactyles. The majority of the fossils are bone fragments with very few gnawing marks of rodents, dental specimens are relatively few, and complete bone is scanty. The Hualong Cave fauna is similar to those of Nanjing Man site and Hexian Man site in the following aspects: 1) With human remains; 2) Absence of relict elements of Neogene fauna; 3) Containing the common elements of *Ailuropoda-Stegodon* Fauna of southern China, e.g. *Ailuropoda*, *Stegodon*, *Megatapirus* and *Arctonyx*; 4) Some boreal elements are also presented, but Hualong Cave bears no more than *Cricetulus*, *Lasiopodomys brandti*, *Ursus arctos*, *Sus lydekkeri*, *Cervus (Pseudaxis) grayi* and *Sinomegaceros* sp., and the latter represents the southernmost occurrence of its kind; 5) Containing *Stegodon* instead of *Elephas* as in other Late Pleistocene fauna in southern China; 6) Containing rich postcranial bones, which is different from other cave sites which mainly bear isolated teeth specimens. Based on the faunal composition, the Hualong Cave fauna can be correlated with the fauna of Hexian Man Site, whose geological age should correspond to late Middle Pleistocene.

P-2202

## Silvicolous Neanderthals in the far West: the mid-Pleistocene palaeoecological sequence of Bolomor Cave (Valencia, Spain)

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### Abstract

A palynological study of archaeological layers from the Neanderthal site of Bolomor Cave, eastern Spain, is presented. Vegetation landscapes for the interval MIS 8 to MIS 5 are described. The sequence, regardless its chronology, is dominated by trees, mainly *Quercus* and *Pinus*, accompanied by a diversity of deciduous, Mediterranean, and thermophilous woody species. It is worth stressing the continuous occurrences of *Olea*, *Fraxinus*, *Pistacia*, *Myrtus*, *Phillyrea* and Cistaceae, and the abundance of evergreen *Quercus*, thus suggesting the existence of a Mid-Pleistocene glacial refugium for mesothermophytic vegetation. To our knowledge, no similar record of forest landscape has been described so far in glacial context for Neanderthals, which bears archaeological and anthropological implications. The record of past vegetation in Bolomor parallels the palaeontological findings, especially concerning the mammal fauna, suggestive of forest landscapes.

P-2203

## Late Pleistocene age, size, and paleoenvironment of a caribou antler from Haida Gwaii, British Columbia

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### Abstract

The basal portion of a fossil caribou antler from Graham Island British Columbia, Canada is the only evidence of large terrestrial vertebrates older than the Fraser (late-Wisconsin) glaciation on Haida Gwaii (former Queen Charlotte Islands). This antler has been radiocarbon-dated three times by different laboratories and all ages fall within the mid-Wisconsin Olympia Interglaciation (Marine Isotope Stage 3; MIS 3). We suggest that the latest date, using ultrafiltration of bone collagen is closest to the true age at  $43,200 \pm 650$  BP (48,200-45,200 cal BP). Previous paleoecological analysis using pollen and plant macrofossils from Graham Island reconstructed a vegetation cover during MIS 3 consisting of mixed coniferous forest with non-forested openings, similar to cool subalpine forests of the northeast Pacific region today. These conditions are consistent with environments that support Woodland Caribou today, and likely also the closely related extinct endemic Dawson caribou subspecies of Haida Gwaii. Morphometric comparison of antlers from Woodland and Dawson Caribou suggest that they are more similar than previously interpreted, and raise questions about the inferred differences between the mainland and island subspecies.

P-2204

## Small vertebrates from Fuente-Nueva-3 (Guadix-Baza Basin, SE Spain) and their bearing on the early Pleistocene hominin occupation of Western Europe

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### Abstract

The site of Fuente-Nueva 3 (Guadix-Baza Basin, Southern Iberian Peninsula) records, together with the very close site of Barranco León, the oldest evidence of human presence in western Europe, as is evidenced by one deciduous human tooth and thousands of Mode 1 or Oldowan lithic artifacts. The age of this site has been established by different methods at ca. 1.2-1.5 Ma. The small vertebrate assemblage from this site includes anurans, squamates, insectivores, rodents and lagomorphs. Anurans are represented by four species (*Discoglossus* cf. *jeanneae*, *Pelobates cultripes*, *Bufo bufo* s.l. and *Pelophylax* cf. *perezi*), while squamates include four lizards (*Chalcides* cf. *bedriagai*, *Timon* cf. *lepidus*, indeterminate small lacertids and cf. *Dopasia*) and five snakes (*Coronella girondica*, *Natrix maura*, *Natrix natrix* s.l., *Rhinechis scalaris* and *Malpolon monspessulanus*). The insectivores (Lipotiphla) are represented by shrews (*Crocidura* sp., *Sorex minutus*, *Sorex* sp., *Asoriculus gibberodon*) and aquatic talpids (*Galemys* sp.). Rodents are represented by arvicolids (*Allophaiomys* aff. *lavocati*, *Allophaiomys* sp., *Mimomys savini*), murids (*Castillomys rivas*, *Apodemus mystacinus*) and glirids (*Eliomys* sp.). Lagomorphs are represented by the species *Oryctolagus* cf. *lacosti*. The Mutual Ecogeographic Range method has been applied to the paleoherpetological assemblage in order to quantify paleotemperatures and paleoprecipitation for the Fuente Nueva 3 site. In this way, the Mean Annual Temperature is calculated in 16.4°C while the inferred value of the Mean Annual Precipitation is 738 mm. In comparison with the current climatic data from the vicinity village of Orce, the Mean Annual Temperature is much higher (+2.6°C) than at present and the total amount of rainfall are also higher (+432 mm) than at present in the Guadix-Baza Basin. Those results indicate a warm climate, with a lower atmospheric temperature range. More specifically, summers should be warmer and winters rather milder, and rainfall should be higher than at present but with an irregular distribution, with four dry months during summer and early autumn. The data reported here clearly support the idea that the early hominin occupation of Europe was strongly constrained by climatic and environmental conditions, rather than by physiography or cultural factors. This paper is part of projects SGR2017-859 and CGL2016-80000-P.

P-2205

## Diet and living environment of extinct *Stephanorhinus kirchbergensis* on the basis of palaeobotany research

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### Abstract

In western Poland (near Gorzów Wielkopolski) almost complete remains of a rhino *Stephanorhinus kirchbergensis* were found in lake sediments. From the rhino's teeth, it was possible to extract material that probably corresponds to its last meals. 11 samples of sediments filling of teeth caverns and 6 sediment samples directly adjacent to the jaw were analysed.

Results of pollen, macrofossil and cladoceran analysis of 6 "jaw" samples show dominance of *Carpinus* and *Corylus* communities as the rhinoceros' living environment, which is tantamount on the end of the Middle Eemian Interglacial (MIS 5e). The abundance and variety of remains of aquatic plant species, especially *Trapa* sp., characteristic for sediments of the Eemian Interglacial *Aldrovanda* sp. or *Najas marina* indicate a warm climate and shallowing lake.

Pollen analysis of 11 "teeth cavern" samples indicates that the majority of samples consists of lake sediment that penetrated into the spaces inside the teeth post mortem. Only four samples differ in their pollen composition indicating mainly *Betula* and *Corylus*, as the source of food of the *S. kirchbergensis*. The intriguing discovery was *Taxodium* sp. pollen in amounts up to 4%. This species has not been found yet in the Eemian Interglacial sediments.

The analysis of plant macro-remains allowed to determine only a small fragment of heavily damaged seed scales of *Betula* sp. Fragments of wood were also found. The majority of them represented twigs of 1-2 mm in diameter and were in a bad preservation state due to chewing, permitting only a determination up to the level of angiosperms. However, wood of *Corylus*, *Carpinus* and cf. *Viscum* were identified.

Based on research of woody plant remains found in the teeth of this rhinoceros, and on the basis of the construction of the teeth, it is considered that the rhinoceroses of the *S. kirchbergensis* species nourished themselves with hard branches and twigs of trees and shrubs, deciduous vegetation, woody and shrubby, hence called them a "forest rhinoceros".

P-2206

## Pleistocene environment change and its impact on human activities in the Qinling Mountains, central China

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### Abstract

Research in Africa and Europe shows that vegetation and climate change takes an important role in Pleistocene human migration and adaptation. The scene, however, is obscure in East Asia. Recent decades, hominin fossils and abundant *in-situ* Paleolithic artifacts buried in the loess deposits are discovered in Qinling Mountains (QM), making it an ideal area for this study. Here the vegetation cover and monsoon climate change since ca. 1.2 Ma in QM were reconstructed by pollen analysis. Our results show that the arboreal coverage was relatively higher during interglacial periods than those in glacial periods, consistent with the East Asian summer monsoon change indicated by magnetic susceptibility of loess-paleosol sequences. The site density and artifact abundance suggest that early human preferred warm- humid interglacial climate and open forest/ forest steppe vegetation. Before ca. 0.3 Ma, human, termed *Homo erectus*, might not adapt to the relatively cold temperature in the northern QM during glaciation, and they had to migrate to southern QM, where probably acted as the “source” refuge. Since ca. 0.3 Ma, the broadleaf trees and summer monsoon became retreated, with significantly increasing fluctuation. Along with the worse environment, human evolved into early *Homo sapiens* and changed their adaptation routine in glacial period. The further weakening of Asian summer monsoon and expansion of grassland since ca. 0.07 Ma enhanced their adaptability to grassland and cool climate, and promoted them to migrate to the open plain areas. The migration, adaptation and evolution of Pleistocene human in East Asia were significantly affected by both the glacial-interglacial change and stepwise trend in vegetation and climate.

P-2207

## Climate and vegetation of the last natural Mediterranean ecosystems preceding the dispersal of *Homo*

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### Abstract

La Puebla de Valverde (Teruel, Spain) fossil locality is one of the most relevant mammal-bearing deposits of the European Early Pleistocene. It is interpreted to be located between the Reunion event (2.27-2.14 Ma) and the Olduvai chron (1.95-1.78 Ma), and represents therefore an association that lived just prior the emergence and diffusion of *Homo*. It has also produced one of the greatest concentration of continental mammalian diversity of the epoch, with a fossil record that comprises 19 macromammalian taxa including also cercopithecoid primates. As such, we consider La Puebla de Valverde as an extraordinary example for gaining an updated knowledge and better understanding about the environmental context that prevailed in Western Europe and that favoured the early occupation of *Homo* in this area. Here, we aim at investigating the diet and ecology of large herbivorous mammals through their long- (molar mesowear) and short- (dental microwear texture analysis) term tooth-wear patterns and hypsodonty to reconstruct climate and habitats of this site in a period for which there exists still a dearth of palaeoenvironmental information. Our preliminary palaeoecological data show La Puebla de Valverde as a complex site, probably composed by steppe-like and open woodland landscapes with a strong development of graminoids. Evidence of this is provided by a considerable dietary breadth found among the large herbivorous-faunas here recorded, with perissodactyls (equids and rhinos) being more engaged in grazing, and ruminants (deer and bovids) being more opportunistic groups, some of which had a significant browse component. Our results provide thus firm evidence that environmental heterogeneity and a wide spectrum of available food resources could have been factors favouring the settlement of early species of *Homo* in Western Europe.

P-2208

## Epivillafranchian-Galerian hyenas from Italy

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### Abstract

The Villafranchian/Galerian transition can be considered one of the most controversial issues in the European biochronological framework. At the Jaramillo Subchron a marked faunal turnover occurred. In Europe the term Epivillafranchian was adopted for this transitional faunas and recently it has been formalized (Bellucci et al 2015). The period 1.2 – 0.7 ma was characterised by the shift of the climate from 41 ky obliquity orbital cycles to a highly non-linear system dominated by 100 ky periodicity with asymmetric glacial/interglacial cycles. This period is characterised by significant fluctuations in  $\delta^{18}\text{O}$  values, in contrast to those recorded from the earlier part of the Matuyama magnetochron. A special relevance in defining the biochronology of this faunal turnover is related to the hyenas, and the fossil record coming from Italy is of particular interest. In the Italian fossil record, the large mammal assemblage of Slivia, referred now to the Epivillafranchian, includes the latest occurrence of the giant hyena *Pachycrocuta brevirostris*. The FO of the giant hyaena (*Pachycrocuta brevirostris* event) is the bioevent that marks the Late Villafranchian (Rook and Martínez Navarro 2010) and this carnivore is a common element in the Late Villafranchian and Epivillafranchian assemblages of Europe. The *Crocuta crocuta* bioevent represents a further renewal in European faunas, when most of the Villafranchian large carnivores became extinct. The *Crocuta crocuta* bioevent is documented in the lower unit TD 4/5 at Atapuerca (Spain) (García and Arsuaga, 2001), and the occurrence of the spotted hyaena is documented also at Casal Selce (Rome, around 0,7 Ma) (Sardella and Petrucci 2012).

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P-2209

## The effects of climate change upon peatlands: past and future perspectives from a Welsh raised bog.

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### Abstract

The effects of future climate change are projected to be most severe in the northern hemisphere, where the majority of peatlands (>75-85%) are located. Peatlands represent important long-term terrestrial stores of carbon (C), containing an estimated 600GT C despite only covering 3% of total land area globally. Pristine peatlands act as net sinks of atmospheric CO<sub>2</sub> and sources of CH<sub>4</sub>. How projected future changes in temperature, precipitation and other environmental variables will affect the carbon balance of peatlands is poorly understood and results carry large uncertainties due to the complex nature of the peatland carbon cycle.

Two methods are widely used in order to help understand future the carbon dynamics of peat bogs under climate change. Experimental studies measure greenhouse gas fluxes under manipulated climatic and environmental conditions and palaeoecological studies, examine the effects of past climate change upon carbon accumulation throughout the peat profile. However, results from these two approaches can contradict each-other, with many palaeoecological studies suggesting carbon accumulation increases during warming periods, and many warming experiments observing greater carbon loss with increased temperature.

The aim of this project is to link contemporary experimental and palaeoecological approaches to understand peatland response to climate change. Our study focuses on a raised bog, Cors Fochno in Ceredigion, Wales which is the site of a long-term climate manipulation experiment. The contemporary greenhouse gas budgets for these experimental plots are compared to long-term carbon accumulation and how this has responded to Late Holocene climate variability. To understand how the climate manipulations are represented by palaeoenvironmental proxies surface a time-series of surface samples is being analysed. Finally, a high-resolution multi-proxy palaeoenvironmental reconstruction spanning the past 1000 years will be compared with reconstructions derived from short-cores from each plot covering the duration of the experiment from each treatment, to see how faithfully climate manipulation mirrors real periods of climate change.

Understanding the future role of peatlands in carbon sequestration and storage is of vital importance for modelling future climate change.

P-2210

## Ecological climatology along an elevational transect in the outer belt of the European Alps: comparing modern pollen deposition, vegetation, climate

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### Abstract

In mountain areas, climate parameters vary strongly with elevation, largely determining the vegetation cover. In turn pollen rain reflects both vegetation cover and climate-triggered pollen production at different elevations. Analyses of modern pollen deposition is essential for a better understanding of fossil pollen sequences in a particular region, and thus for pollen-based palaeoenvironment and palaeoclimate reconstructions. This study analyzes the relationships among modern pollen assemblages, vegetation and climate along an elevational gradient in the outer belt of the European Alps. Modern pollen assemblages have been studied in pollen traps and moss samples from different vegetation communities along an elevational transect (stretching from 1240 to 2390 m asl), as well as the vegetation using the Braun-Blanquet system. Moss samples are assumed to record an average of several years of pollen deposition and can be profitably used as analogues for fossil pollen assemblages; while pollen traps can be expressed as Pollen Accumulation Rates (PAR) and used as a modern reference to estimate past plant population densities. Results of Canonical Correspondence Analysis (CCA) demonstrated a general good agreement with previous studies, which identified elevation as the main gradient in the variation of modern pollen and vegetation assemblages in mountain areas. *Alnus viridis*, the main woody species forming the dwarf forests in the timberline ecotone, shows a specific elevational PAR arrangement under modern climate conditions. The highest PAR values are observed in sites from river corridors and waterfalls with mountain alder scrub. Results of pollen analysis show an uphill transport of strong pollen producers (e.g. *Pinus sylvestris/mugo*, *Picea*, *Castanea*, *Corylus* and *Ostrya*) by wind to subalpine and alpine zones leading to wider pollen belts with less defined boundaries than vegetation. Thus, if it is possible to identify the major vegetation types by means of their modern pollen deposition, it becomes more difficult to identify specific thresholds (e.g. treeline). To overcome these limitations, potential indicator pollen taxa of alpine/subalpine belts (*Vaccinium*, *Rhododendron*, *Loiseleuria*) documented in this study could be useful for this purpose.

P-2211

## Continental molluscs as indicators of hydrological changes during the Late Quaternary in plain rivers

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### Abstract

Molluscs have conquered successfully different types of continental environments, both terrestrial and aquatic, have an important record in Quaternary sediments and are usefulness as paleoenvironmental and paleoclimatic indicators. Salado River in Buenos Aires province, Argentina, like all river of plains is a system highly sensitive to environmental changes, both during periodic episodes of intense rains, as it happens today, as dry conditions that causing great economic loss in one of the most important agricultural areas of Argentina.

However, alternation of dry and wet periods is not recent and analysis of the mollusk assemblages allow to know these type of event also during Late Quaternary in the region. Mollusks assemblages have been subjected to an integral analysis, taking into account composition and dominance species changes and their taphonomic characteristics in more than 15 localities throughout of the principal course where sediments have been accumulated during last 13,000 years BP.

Knowing the composition of the communities and habits that species present today, associations show three types of main variations. First, *Heleobia parchappii* plays is the dominant specie in all studied assemblages, analyzing the co-dominant species can be recognized two principal groups: one composed of aquatic gastropods such as *Biomphalaria peregrina*, *Uncancylus concentricus* or *Pomacea canaliculata*, and another with species of hydrophilic or terrestrial habits as *Succinea meridionalis*, *Miradiscops brasiliensis* or *Gastrocopta nodosaria*. These compositional changes, especially the presence of associations of first type from 6000 years BP, allow reconoced an improve in the availability and development of bodies of freshwater.

When analyzing the number of recovered specimens, the density of the individuals recovered it varies from 0 to 10000 individuals, and the alteration of the external surface of the shells has allowed to recognize differents events. Accumulations with high densities of individuals, mainly of *H. parchappii*, and low values of taphonomic alteration (fragmentation scarce, good preservation of color and ornamentation original) would allow to recognize assemblages that have not been transported outside their original habitat and that have been accumulated during an extraordinary flood event.

Conversely, the presence of poorly preserved associations conserved, with evident signs of dissolution and loss of original ornamentation represent shells that have remained exposed more time, probably during drought periods, favoring a greater alteration of the surface in the shells.

Therefore, these changes could be related to the residence time of the remains near the water-sediment interface and the differences in the sedimentation rate of the different exposure cycles suffered by them.



Thereby, integral analysis of the mollusk assemblages from different perspectives (ecological, taphonomic, actalist) has allowed to recognize different events of flood and drought that have occurred in the region in a cyclical way, not only at present but throughout the Late Quaternary.

P-2212

## Fire-driven biodiversity change in Mediterranean ecosystems

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### Abstract

The recent increase in the size and severity of wildfires in the Mediterranean Basin has prompted concern about the future of biodiversity and ecosystem functioning in this plant diversity hotspot. Are fire regime changes unprecedented or have they occurred in the past? What were past fires' effects on ecosystem dynamics, particularly in terms of key biodiversity indicators? Using strict data-quality criteria, we selected palaeoecological records (pollen and charcoal) from the Mediterranean Basin and analysed rates-of-change, richness and turnover in response to fire regime shifts through the last 10,000 years. Event sequence analysis showed that fire regime changes and major fire peaks initiated biodiversity change significantly more often than by chance ( $p < 0.05$ ). Fire regime changes were associated with non-forest turnover, while major fire peaks were associated with richness changes and forest turnover. The timing of fire-led biodiversity changes was non-random and suggests a strong link to the intensification of human activities since the Neolithic. These results reinforce the idea that Mediterranean biodiversity carries a strong legacy of prehistoric fire and land-use change. Palaeoecological records help to pinpoint the likely biodiversity trajectories of future fire, helping to validate ecological theories and paving the way for a more far-sighted approach to land-use policy and management.

P-2213

## Conifer refugia and beech expansion in the North Hungarian Mountains during the Holocene

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### Abstract

We investigated the stand-scale vegetation changes and the Holocene history of a beech dominated forest in the North Hungarian Mountains. Although several studies provide a broad overview about the vegetation changes in the Carpathian Basin during the Holocene, there is a lack of spatially explicit information about how climate change and human presence influenced the forests in the last several thousand years. Stand-scale paleoecological methods give information about local vegetation changes and long-term ecological processes; however, suitable sites are rare in Hungary due to the temperate continental climate and the relatively low altitude.

We examined the sediment of a small forest hollow (Pisztrángos-hollow, 690 m, 0.15 ha). The site is located in the central part of Mátra Mountains, on the north-facing slope of Kékes (1014 m) in close proximity of the Kékes Forest Reserve, one of the last primary deciduous forests in Europe. The full length of the sediment was 240 cm, we analyzed it at 4 cm resolution for pollen and plant macrofossils. The investigated sediment profile was exceptionally rich in plant remains, and showed a unidirectional vegetation trajectory. The site is dated back to 15,425 Cal yr BP, when an open boreal forest and wet tundra-like habitats are indicated by cold tolerant herbs and *Picea*, *Larix decidua* and *Pinus* remains. Closed forest cover developed around 14,600 Cal yr BP, when boreal European larch - Swiss stone pine (*Larix-Pinus cembra*) forest surrounded the site. This vegetation type remained stable during the early Holocene, up to 7700 Cal yr BP. Between 7700 and 2700 Cal yr BP we observed a hiatus followed by a mixed temperate deciduous forest with *Fagus sylvatica* and among others *Quercus* and *Carpinus betulus*, similar to the current forest cover. The human influence is visible through the presence of cereal pollen from 175 Cal yr BP, the modern deforestations and artificial plantations showed up from 110 Cal yr BP.

The most interesting finding of our study is the relatively long lasting presence of the Swiss stone pine in the Holocene at relatively low altitude (690 m), as it is not the member of the present natural vegetation, and has never been found in Holocene sediments in Hungary before. If our study area was a cold conifer refugium during the Holocene, it is possible that it can play the same role for present day beech forests which are threatened by recent climate change in Hungary.

P-2214

## Palaeoecology is ecology: the new Palaeoecology Special Interest Group of the British Ecological Society

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### Abstract

Palaeoecology is outside the toolkit of many ecologists and often not well integrated with modern ecological research, to the detriment of both ecology and palaeoecology. As Quaternary scientists, INQUA attendees are well aware that given the rates of ecosystem processes and varied species lifespans, ecological dynamics play out over a range of spatial and temporal scales, including those well beyond a human lifetime. The current 'planet-wide experiment' of climate change and the accumulation of evidence from long-term monitoring data over the last few decades emphasise that the timescales needed to understand the effects of ecological and environmental change extend over decades, centuries and millennia, but ecologists still often overlook or are unaware of the insights available from sedimentary records, and regard "long term" data as monitoring series of a few decades. On the other hand, ecology is a rapidly developing and diversifying field, yet engagement with organisations like the British Ecological Society is low amongst palaeoecologists.

In August 2018, a new Special Interest Group within the British Ecological Society was launched, which aims to:

- improve the use of the long timeseries derived from palaeoecological data within the wider ecological community
- bring the latest ecological understanding to palaeoecologists' attention.
- serve as a forum for palaeoecology in Britain and beyond, since the research community is currently spread across multiple different organisations

The BES now recognises palaeoecology as a suitable field for grant support and palaeoecological perspectives are increasingly represented in BES journals. It also provides funding and professional administrative support for SIG events including training, conferences and field based meetings.

This poster will introduce attendees to the British Ecological Society and to the SIG, identify upcoming SIG events, and explain how interested attendees can join the SIG or otherwise become involved in its activities.

P-2215

## Climate impacts on egg hatching drive snail community dynamics over the past 1,300,000 years

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### Abstract

The processes by which climate change impacts organisms are crucial for understanding community dynamics and even species extinctions. However, such understanding is mainly based on modern observations and therefore the nature of the processes on long timescales is mostly unknown, owing to the paucity of long, direct and continuous records. Egg sequences spanning numerous interglacial-glacial transitions are particularly valuable since the vast majority of animals are oviparous and hatching is sensitive to climate change and thus closely related to community dynamics. Here we present egg records of one of the representative oviparous invertebrates, land snails, from the Chinese Loess Plateau (CLP), covering the last 1,300,000 years (1,300 kyr) that include all the largest-amplitude interglacial-to-glacial transitions. The results show that 20 stages of high egg abundance occur during 17 interglacial-to-glacial transitions. Within each stage, egg abundance reaches peaks when snail abundance is low or decreasing, and vice versa, revealing a near-inverse relationship between egg and snail abundances. The maximum egg abundance within each stage mainly occurs near glacial inceptions or glacial maxima. The 10 largest-amplitude changes are characterized by an over 95% increase in egg abundance and an equivalent reduction in snail abundance. These results indicate that climate impacts on hatching are consistently responsible for large-amplitude oscillations in snail communities over the past 1,300 kyr. Earth's obliquity minima and Arctic amplification, associated with glacial expansions, would have induced strong cooling at high northern latitudes and therefore strengthened the Siberian High and the occurrence of severe seasonal climatic events over the CLP, causing high hatching failures and thereby reductions in snail abundance. Conversely, weakness of severe climatic events would favor hatching successes and thereby increase snail abundance. Our findings stress the importance of hatching in snail community dynamics on long timescales, which may have implications for other invertebrates with similar biological characteristics to land snails.

P-2216

## Peat loss and renewed accumulation in a rewetted, former drained fen

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### Abstract

The interdisciplinary project WETSCAPES studies turnover processes in drained and rewetted peatlands in Northeastern Germany. The project aims to support climate and water protection and to provide a basis for **sustainable (wet) peatland cultivation**. The main objective of the project is to understand the development and functioning of drained peatlands after rewetting.

For high resolution analyses we sampled peat monoliths from pairs of drained and rewetted sites in a percolation mire, in a coastal wetland, and in two adjacent alder carrs. The monoliths were cut into 0.5 cm contiguous slices which were subsampled for a set of analyses: micro fossils (palynomorphs), macro fossils, microbial DNA (methanogens, [de]nitrifiers) and soil chemistry (elements, carbon species).

Here we present the results from a percolation mire that was deeply drained for agriculture in the late 1960s. Slight human-induced changes in the hydrology of the mire system date back to at least 1744 (Succow 1969), but significant peat losses likely only occurred after deep drainage in 1967. The site was rewetted in 1997 and is now water-logged during the whole year. Vegetation is dominated by sedges (*Carex spec.*). The monolith of 55 cm includes about 10 cm of newly formed material (litter, roots and radicles) underlain by a 25 cm thick layer of compacted and highly decomposed, amorphous peat material (the former cultivated grassland soil). Below this layer lies the well preserved original peat; the top of this original peat has been radiocarbon dated to ~3.700 cal. BP. These different layers as well as the rewetting event show clear differences in the micro and macro fossil record. Recent roots and radicles are found throughout the profile.

Based on the radiocarbon date, the bulk density, and ash and carbon content of the peat samples, we calculate the loss of peat and carbon during the 30 years of intensive agriculture. Gas flux measurements have shown that the site today is again a net C sink. We try to reconcile the measured fluxes with the newly accumulated carbon in the profile. Together, these data help to better understand the C dynamics of rewetted fen peats.

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P-2217

## Temporal scale changes in species distribution in boreal peatlands: Store Mosse, South-central Sweden (preliminary results)

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### Abstract

Boreal peatlands play an important role in the global biogeochemical cycle of carbon with an estimated third of global soil carbon stored in northern peatlands. Peat is made up of decomposed plant material, making it especially suited to macrofossil analyses. *Sphagnum* mosses can tolerate nutrition-poor and highly acidic environments and, as a consequence, they tend to dominate in boreal peatlands. As such, it is important to understand what factors drive changes in the *Sphagnum* species distribution on longer time scales than that traditionally used in ecological studies as this can impact peatland carbon storage (or release) in the changing climate of the future.

This project aims to assess the internal successional processes and biotic interactions and external climate drivers (humidity, solar irradiation, nutrient supply) of *Sphagnum* species over time in the peat paleo-record, by reconstructing temporal changes in species distribution, identifying the main factors controlling species distribution on multi-decadal to millennial scales, and testing whether current spatial distribution of *Sphagnum* species can be explained by models of temporal distribution of *Sphagnum* in peat cores. It involves three bogs in South-central Sweden: Store Mosse, Dala Mosse, and Draftinge Mosse. By comparing and contrasting across these three sites as well as with relevant published paleoclimate studies, we will examine potential drivers of changes in species distribution in peatlands.

Store Mosse, which is the first focus site of the project, has been studied previously for macrofossils (Svensson, 1988) but the age control in this study was poor (only four <sup>14</sup>C dates). Since then, several detailed paleoclimate studies have been made (Kylander et al., 2013, 2016, 2018) which provide information on major environmental changes at the site over the last 9000 years. A set of triplicate sequences were collected using a Russian corer in November 2018 which exceed these previous studies in depth, reaching to nearly 7 m. Here we present a preliminary age model and plant macrofossil analyses from what will be our "high resolution" sequence from Store Mosse.

P-2218

## Future Arctic Ecosystems (FATE): drivers of diversity and future scenarios from ethno-ecology, contemporary ecology and ancient DNA

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### Abstract

The Arctic is currently experiencing dramatic ecosystem changes, with immediate effects on ecosystem services connected to food production, climate regulation, natural resources and cultural integrity. Understanding the relative impacts of climate, herbivory and human management on ecosystems, in particular on vegetation, is of paramount importance for their long-term sustainability and conservation, as well as for its inhabitants. Arctic and Subarctic communities, whose livelihoods are closely linked to their environment and who directly depend on the herding and hunting of large herbivores, will have to adapt to the effects of climate warming and vegetation changes. Building relevant scenarios requires understanding the relative roles of climate, herbivory and increased anthropogenic pressures as large-scale drivers as well as on local scales relevant to the communities. Well-informed ecosystem management and species conservation is however precluded by the scarcity of long-term (millennia) data sets spanning ancient and contemporary climatic and land use events. Palaeorecords offer a unique possibility to fill this gap as they provide data on long-term ecosystem development, historic events of climate change and land use modification. In the BiodivERsA project "Future Arctic Ecosystems (FATE): drivers of diversity and future scenarios from ethno-ecology, contemporary ecology and ancient DNA" we are therefore conducting a comprehensive inter- and transdisciplinary study using sedimentary ancient DNA, current ecological observations and anthropological investigations of indigenous and local knowledge and interpretations. By coupling indigenous and local knowledge with scientific analyses and interpretations, fine-grained and broad spatio-temporal scales, and qualitative and quantitative data sets, we will create scenarios that support decision-making in the face of accelerating socio-ecological transformations throughout the circumpolar North.

To reconstruct past vegetation changes over large spatial (circumarctic) and temporal (Last Glacial Maximum until today) scales, and investigate to what extent changes are driven by herbivory or by climate, we will analyse sediment core DNA for plants, mammals and fungi. This will generate datasets with a high taxonomic resolution for vegetation and herbivores, allowing us to make detailed inferences about questions of palatability and potential toxicity to herbivores, as well as refine reconstructions of past ecological conditions. The data on past diversity changes will be integrated with data from modern ecological experiments to evaluate the stability of biotic interactions through time and space and to parameterize species distribution models, which will be used in ecological forecasting. We here present our approaches for biodiversity reconstruction using sedimentary ancient DNA along with an evaluation of the taxonomic resolution and explanatory power of our molecular methods.

**P-2219**

## **An assessment of some of the constraints of pollen-based vegetation studies in Tropics and an experimental method to understand them**

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### **Abstract**

While entomophily is the major mode of pollination in tropics, the pollen of anemophilous plants are generally over represented and are the major pollen components of the pollen retrieved from the lake sediments (Bush and Rivera, 2001). This can bias the interpretation carried out by a palyno-paleoecologist in inferring the past vegetation.

In a tropical context ecological associations of pollen taxa are important in delineating the actual landcover and an indicator taxon identified to the species level is quite significant. The present study was conducted primarily to investigate the pollen dispersal-deposition mechanism of a key taxon present in south east India i.e., *Hardwickia binata*, the Indian Blackwood, which is endemic to Peninsular India. This tree is an indicator of dry deciduous forests. The pollen of this taxon could be identified up to the species level because it is the only species of the genus *Hardwickia* in India.

The lesser occurrence of *Hardwickia* pollen in the modern pollen samples and its frequent presence in the pollen samples extracted from the lakes and marine sediment cores directed this assessment. The dispersal-deposition function of the *Hardwickia binata* pollen from its tree was studied by collecting and analyzing the surface samples during the flowering seasons and non flowering seasons at a distance from 0m to 75 m. The surface soil samples were collected at equal intervals of every 3 months during one year. The samples were extracted and assessed at a distance of 5 m, 10 m, 20 m, 35 m, 55 m and 75 m by fixing the *Hardwickia* tree as the centre point.

This study provided two major inferences: (i) *Hardwickia binata* pollen are not predominantly dispersed by wind. (ii) Despite the seasonal changes in flowering pattern of different plants in SE India, the pollen composition of the surface samples collected during an interval of 3 months each in a year, remained almost the same.

Fine resolution pollen analysis arises out of attempts to bridge the gap in time scale that has separated paleoecology (few thousand years) from field ecology (few decades). An important point is the sampling resolution: even a single sample (typically 10-20 years worth of lake mud) would average out all the data of field ecological studies (Green & Dolman 1988). From our study, we conclude that pollen grains indicate vegetation patterns, not on a seasonal basis, but on a longer time basis. This can be perceived as a constraint if we are looking at seasonal or annual patterns.

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P-2220

## Holocene hydroclimate variability in the glacial highlands of Costa Rica: Evidence for abrupt climate change at 5.2 ka BP

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### Abstract

The vulnerability of high-elevation regions, such as the Cordillera de Talamanca in Costa Rica, to global climate change is extremely high, due in part to vertical amplification of warming. Developing a long-term perspective of climate variability for Central America broadly, and Costa Rica more specifically, through paleoclimate and paleoenvironmental studies, will improve our understanding of the mechanisms driving hydroclimate variability and climate change in the Neotropics.

We make use of an existing chironomid-based calibration set from Costa Rica together with subfossil chironomid remains, sediment geochemistry and charcoal extracted from a 5.75 m sediment core recovered from Lago Ditkebi, in Chirripó National Park, Costa Rica, to reconstruct Holocene hydroclimate variability and paleoenvironmental change in southern Central America. Chronological control for the Lago Ditkebi sediment core is based on eight AMS <sup>14</sup>C dates obtained on charcoal and aquatic moss. Geochemical analyses of the lake sediment recovered from Lago Ditkebi included total organic carbon (C%), total organic nitrogen (N%) and stable carbon isotopes ( $\delta^{13}\text{C}$ ). Variations in the signature of  $\delta^{13}\text{C}$ , together with the chironomid-based estimates of thermal conditions and the charcoal-inferred reconstruction of the local fire regime, enable the development of an integrated multi-proxy record of regional hydroclimate and environmental change spanning the past ~8100 years.

A holistic consideration of the multi-proxy record developed for Lago Ditkebi, indicates that the glacial highlands of Costa Rica were characterized by: 1) relatively cold, dry conditions and limited fire activity between ~8100 and 5270 cal yr BP; 2) persistent elevated temperature, relatively wet conditions and frequent, high-severity fires between ~5270 and 2820 cal yr BP; and 3) cool, dry conditions, and frequent low-severity fires between ~2820 cal yr BP and the present. Macroscopic charcoal analysis, which indicates that wildfires periodically burned throughout the Holocene, document the occurrence of a sudden and severe fire event at ~5270 cal yr BP and elevated fire frequency between ~3300 and 1600 cal yr BP. Concurrent maxima in C/N, charcoal accumulation rates and the abundance of *Polypedilum* N type, a thermophilous chironomid taxon, provides evidence of the occurrence of an abrupt climate change event at ~5200 cal yr BP characterized by elevated temperature and increased lake levels. A 1.5 cm-thick layer of large macroscopic charcoal and the presence of multiple large woody charcoal fragments (~0.25 cm<sup>2</sup>) also support the inference that this fire event was the most intense and severe of the entire record. The evidence of an abrupt climate event at ~5200 cal yr BP at Lago Ditkebi, Costa Rica corresponds well with existing records from elsewhere in the low latitudes and provides additional support for the existence of a global-scale event at ~5200 cal yr BP.

P-2221

## Middle-Late Holocene palaeoenvironmental change and anthropogenic impact in tropical Southeast Asia: a multi-proxy lacustrine record from Tasik Chini, Malaysia

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### Abstract

Tropical areas are currently experiencing rapid environmental change due to the combined effects of climate change and human impact on the landscape. Climate variations in Southeast Asia play a key role in the global hydrological cycle, but past changes in the Asian monsoon system and its effects on local ecosystems are poorly constrained due to a shortage of well-dated palaeoenvironmental records that can provide a longer-term perspective on environmental change. This study investigates sediment cores from Tasik (Lake) Chini situated on the Malaysian Peninsular and provides the first lacustrine record of palaeoenvironmental change from the area. The flood pulse wetland is one of the few lake basins in the lowlands of this region and is of great ecological importance, contributing to the site's UNESCO designation. Tasik Chini comprises twelve interconnected basins with a hydrology dependent on monsoonal rainfall, therefore the lake is highly sensitive to variations in hydroclimate. Here, we provide new information on past environmental changes at Tasik Chini using the carbon isotope composition ( $\delta^{13}\text{C}_{\text{org}}$ ) and Rock-Eval pyrolysis of sedimentary organic matter, diatom assemblage, elemental analysis, and chlorophyll and carotenoid pigments. An established chronology based on  $^{14}\text{C}$  and  $^{210}\text{Pb}$  dating shows that the cores span the last ca. 4.8 ka, covering the lakes inception as a permanent water body as well as a transition to higher sedimentation rates since the late 19<sup>th</sup> century. The multi-proxy record indicates large changes in organic matter production and preservation, hydrology, and water quality over the lake's history with the most pronounced variations occurring during the past 150 years, especially since the 1950s. Together, these proxies demonstrate major shifts in the Tasik Chini ecosystem that were most likely driven by a dynamic monsoonal system during the Middle to Late Holocene, and more recently initiated by anthropogenic catchment land use changes. This rare wetland record offers the potential to better understand past hydroclimate development in Southeast Asia and provide context for the human impact-related changes that have occurred, and are likely to continue, in this rapidly developing region.

P-2222

## Pollen-based vegetation and climate reconstruction over the mountains of Equatorial Africa over the last 90,000 years

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### Abstract

The inverse modeling through iterative forward modeling (IMIFM) approach was adopted to reconstruct the last 90,000-year climates (mean annual temperature, total annual precipitation, and a plant-available moisture index) at western Equatorial Africa using a pollen sequence from the Lake Bambili on the Cameroon highlands. The pollen sequence provides the first and exceptional high-resolution record of vegetation change in the tropical mountains of Africa over the last 90,000 years (Lézine et al, in press). Pollen data and reconstructed biomes have shown the extreme instability of the Afromontane environments with phases of expansion of different kind of mountain forests alternating with phases of the expansion of savanna and grasslands (Lézine et al., 2013; Izumi et al., 2016; Lézine et al., in press) in response to the glacial-interglacial climate and atmospheric CO<sub>2</sub> concentration changes.

The IMIFM approach, which originated as an inverse-modeling approach, has been developed to consider vegetation responses to changes in atmospheric CO<sub>2</sub> concentration as well as to climate changes. It is based on an equilibrium vegetation model (BIOME4 or/and BIOME5-beta) and overcomes some debated issues of conventional statistical approaches for reconstruction (e.g., modern analog, regression and response-surface techniques). After the Last Glacial Maximum, warming and wet conditions and higher CO<sub>2</sub> concentration promptly established the Afromontane forest and keep it over the Holocene, whereas cold and dry conditions and lower CO<sub>2</sub> concentration promoted the expansion of savanna and grasslands. Compared to climate reconstructions using other data, our climate reconstructions show smaller amplitude. In this study, we also compare our results for Bambili to climate reconstructions over the Equatorial Africa during the last deglaciation (22,000-9,000 years ago) using pollen records from the eastern Congo basin (e.g. Burundi Highlands, Rukiga Highlands and Rwenzori Mountains) in order to discuss the large-scale vegetation and climate changes over the Equatorial Africa.

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P-2223

## A continuous tropical record of glacial-interglacial cycles spanning more than 600 ka from Lake Junin, Peruvian Andes

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### Abstract

Lake Junin (11.0°S, 76.2°W) is a shallow (12 m), high-elevation intermontane lake (4080 m asl) located in the inner-tropics of the Southern Hemisphere. It is dammed by coalescing alluvial fans that are >250 ka formed by glacial debris from low gradient watersheds with headwalls under 4700 m. The lake was drilled by the Lake Junin working group funded by NSF and ICDP in 2015 and over 100 m of section was recovered, spanning over 600 ka based on an age model produced with radiocarbon, U/Th, and paleomagnetic measurements. Sedimentary and moraine evidence indicates that during cold phases glaciers advanced down valleys and approached the edge of the lake, but did not overrun it, whereas during warm phases ice disappeared from the watershed. This limits clastic sediment inputs during interglacial periods, allowing for the precipitation of lacustrine carbonates and the formation of peat deposits during arid phases when lake level is lower. The sedimentary record from Lake Junin provides a detailed record of glacial-interglacial cycles that is characterized by three distinct facies: 1) a clastic-rich, fine-grained facies representing periods of glaciation, 2) an authigenic lacustrine calcite facies that is precipitated from lake water during interglacial periods, and 3) an organic-rich peat facies that forms during times of low P/E, representing periods of low lake level.

Stable isotope measurements of oxygen and carbon on Holocene lacustrine carbonates document changes in the strength of the South American Summer Monsoon (SASM), indicating dry conditions during the early Holocene with precipitation increasing toward the present as Southern Hemisphere summer insolation increased, thereby enhancing monsoon circulation. Oxygen and carbon isotope values are highly correlated throughout the Holocene, supporting sedimentary evidence that Lake Junin is sensitive to changes in hydrologic balance. Although lacustrine carbonates are not precipitated continuously throughout the sedimentary record, where they are present, precessional-scale variability in oxygen isotope values is clear and the amplitude of the signal suggests major changes in the SASM over time. Interestingly, the range of oxygen isotope values during previous interglacial periods is considerably greater than during the Holocene, indicating more variable SASM strength and suggesting that tropical circulation/convection was significantly enhanced in the past.

**P-2224**

## **9000-year multi-proxy record of climate and vegetation change from north-central Cuba**

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### **Abstract**

Relatively little is known about the climate and environmental history of the Caribbean region. Here we provide a continuous 9000-year long sedimentary record obtained from a karst sinkhole, known as Cenote Jennifer, located on the island of Cayo Coco offshore north-central Cuba, which represents one of the longest and most detailed Holocene paleoenvironmental records for the Caribbean region to date. The sinkhole is 14 m deep and consists of an anoxic bottom which has resulted in the excellent preservation of macrobotanical remains such as leaves, twigs, and bark, and thousands of cm- to sub-mm scale sedimentary laminations. The Cenote Jennifer core was dated by AMS and Pb-210 techniques and analyzed for a range of proxy indicators such as pollen, microcharcoal, grain size, elemental composition by XRF core scanning, O and C isotopes on bulk organic matter, and O and C isotopes on benthic foraminifera. The results of the multi-proxy analysis show that Cenote Jennifer is highly sensitive to both regional- and local-scale environmental and land-use changes. Key findings include: (1) the presence of the 8.2 kyr event; (2) a possible rapid sea level rise event 7600 years ago; (3) a long-term shift from dry to wet to dry conditions during the mid-Holocene; (4) the presence of a severe drought around 1000 cal BP that may correspond to a similar event associated with the Maya Collapse; and, (5) a dry Little Ice Age. In addition, significant deforestation is recorded for the historic period and there is circumstantial evidence for prehistoric maize agriculture beginning as early as 2500 cal BP. The record at Cenote Jennifer provides a continuous and highly detailed window onto the Holocene in the Caribbean and highlights the utility of karst sinkholes as repositories of long sedimentary records.

P-2225

## Geoarchaeology of western Sicily, tracing the footsteps of the Elymi

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### Abstract

This research employed geomorphic and archeometric techniques to investigate human-environmental interrelationships in western Sicily. Sicily contains a wonderfully diverse geoarchaeological record landform sediment-assemblages and Prehistoric to Historic settlement patterns. The Chuddia River Valley (230 m) between Monte Polizzo (700 m) and Montange Grande (750 m). The southern slope of Montange Grande contained coalescing clast-supported alluvial fans: Verme, Ardigna, Armata, and Lentini. The Armata Fan contained a well-developed paleosol, (A-horizon, 7786 to 8033 cal. yrs BP), indicating a locally stabilized landscape prior to Neolithic occupation. The Lentini Fan contained a complex geoarchaeological sequence. A younger organic-rich channel has scoured and deposited angular limestone particles in a series of eight stacked channels. These eight channels contained diagnostic artifacts including equine skeletal fragments and fossil land snail shells. These data suggest landscape destabilization began shortly before, 7113 to 7294 cal. yrs BP.

Twenty-five stratigraphic sections along the banks of the Chuddia River show a well-preserved record of alluvial sedimentation, diagnostic artifacts and pollen. Chronologic data from radiocarbon analysis of charcoal and diagnostic artifacts from within these sediments indicate three primary periods of sedimentation within the valley, 2340 to 2491 cal. yrs. BP, 1298 to 1429 cal. yrs. BP, and 646 to 735 cal. yrs. BP. These sedimentation periods correlate well with major periods of anthropogenic occupation within the Chuddia River Valley suggesting human-induced landscape changes. These data imply a direct correlation between erosion, deposition, and the growth/decline of the Elymian presence at Monte Polizzo. Pollen analyses from Chuddia River, dating back to 3500-4000 BP, reveals *Olea*, cereals, legumes and several indicators of human activity. This supports the archaeological data showing settlement in the area of Monte Polizzo during the Early Bronze Age. *Juglans* were not recorded in the pollen record from Chuddia River sediments, which may indicate that walnut was not growing in the vicinity of the site. High values of *Isoetes* within the valleys basal fluvial stratigraphic units indicates the presence of water at least during parts of the year. Also the alga *Botryococcus* indicates the presence of water.

Recent archeometric results from Monte Polizzo's cultural material provided evidence towards a local Archaic ceramic production center. A comparison between the indigenous and experimental ceramics revealed that the local potters preferred clays from the Terravecchia Formation. The mineralogical, textural and chemical composition of the Terravecchia Formation's clay correlated well with the recovered indigenous ceramic artifacts recovered from Monte Polizzo (92%). The remaining 8% were interpreted to be imported from the Sicani Mountains. These data facilitate human-environmental interpretations that when used carefully may help us learn from the past and may provide guided insight to the present and future.

**P-2226**

## **Polished stone tools from the Caribbean Lowland of Colombia, evidence of an advanced lithic industry and large-scale ecological changes**

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### **Abstract**

Large numbers of highly polished stone tools occur throughout the Caribbean Lowlands of Colombia. Despite their remarkably large quantities and the impressive craftsmanship they display, the stone tools have gone unnoticed by archaeological surveys. In an area where the surface geology is dominated by thick sequences of pelagic turbidites, reef limestone and sandstone rocks, the presence of stone tools made exclusively from high-grade metamorphic and igneous rocks implies that these were likely imported as finished products. This study reports on an assemblage of over 300 tools collected by farmers as surface finds in the area centered on the Gulf of Morrosquillo in the central lowlands. Using a combination of geological and archaeological evidence, these tools are traced to the Sierra Nevada de Santa Marta (SNSM), a 5800 m high coastal massif, located 300 km to the north, that served as the enclave of the Taironas for 1000 years (AD 600 to 1600). An abundance of high-quality raw materials in the SNSM enabled the development of an advanced and highly specialized lithic industry. Production at a large scale and a well-organized distribution system are required to rationalize the large volume of lithic tools. Ecologic implications of such an industry include increased land clearance, the expansion of agricultural land and management of drainage systems, as were recorded in early European chronicles.

**P-2227**

## **Drainage basin and valley systems in the nature management history**

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### **Abstract**

River valleys and drainage basins were purposefully brought under cultivation in various natural environments since the Holocene. In the process of the cultivation the man-induced changes in landscapes triggered a response in erosional-channel systems; the response differed notably in different parts of the system (closely to the head, in the middle and lower reaches, at the river mouth) according to the principle of the relative importance of factors. The human activity impact is traced geographically - from small river drainage basins to large ones and chronologically - from the Neolithic revolution to the present days. Methods and techniques are considered that were developed by various cultures and civilizations in the process of their adaptation to the hydrological regime (in particular, to liquid and solid runoff fluctuations). Particular attention is given to hydrotechnical constructions having been used on our planet in different historical epochs.

P-2228

## Hydrological change and human activity during Yuan–Ming Dynasties in the Loulan area, northwestern China

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### Abstract

Human activity on arid lands has been related to oases evolution. The ancient Loulan, an important transportation hub of the ancient Silk Road, developed on an ancient oasis on the west bank of the lake Lop Nur in Xinjiang, China. Previous studies and historical documents suggest that the region has experienced dramatic natural environmental and human activity–related changes over time, transitioning from a particularly prosperous oasis to a depopulated zone with harsh environment after about 1500 a BP (before present, where present = AD 1950). Based on systematic radiocarbon (<sup>14</sup>C) dating for natural plant remains and archeological sites in the Loulan area, it was revealed that the region re-experienced oasis environment from 1260 to 1450 cal. AD, corresponding to the Yuan–Ming Dynasties, which is the climate transition stage from the ‘Medieval Warm Period’ to the ‘Little Ice Age’, encompassing a series of pulse-like flood events which cannot be identified from lacustrine deposition due to the limits of sampling resolution and dating. It was found that humans re-occupied the Loulan area and built canals to irrigate farmlands during the period. The more habitable hydrological conditions that resulted from these environmental changes present one major reason for the re-emergence of human activities in the Loulan area.

P-2229

## The LGM and Heinrich Event I on the Iberian Peninsula: A regional climate modelling study for understanding human settlement patterns

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### Abstract

The spatial distribution and dating of archaeological sites suggest a poor occupation of southern Iberia by hunter-gatherers after the Last Glacial Maximum (LGM) and during Heinrich event 1 (H1) compared to Northern Iberia. The H1 was a period of cold and arid climate conditions and is suspected to have played an important role in the population dynamics in Europe at the end of the Pleistocene. In this study, the potential influence of climate change on the human settlement patterns in Iberia is analysed based on regional palaeoclimate modelling. Here, the WRF model is used to simulate continuous time slices of 30 years of climate conditions representative for both the LGM and H1 at high spatial resolution. The model results indicate that, apart from a general decrease in temperature, a considerable decrease in precipitation over southern Iberia occurred during the H1, that agrees with the available climate proxy data. The analysis of ombrotypes unveils extremely arid conditions, particularly over southern Iberia and during the growing season (summer), which could have constrained the availability of food and water to the inhabitants. The total area in Iberia that can be characterized as ultrahyperarid in summer enlarged from 2% (13 K km<sup>2</sup>) during the LGM to 22% (148 K km<sup>2</sup>) during the H1. Likewise, the reconstruction of vegetation types shows an increase of non-arboreal (open shrubland, grassland) types at the expense of arboreal types in southern Iberia for H1. Thus, the different climate conditions and changes in palaeovegetation between the LGM and H1 probably played a major role in the decrease of the hunter-gatherer populations in southern Iberia.

**P-2230**

## **Connections and interactions in the Danube Delta: searching for avulsions and waterways changes since the Greek colonization until the present**

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### **Abstract**

This research is focused on Danube delta connectivity aiming at deciphering the ancient fluvial and maritime waterways following their specific dynamics during successive historic periods starting with the Greek period (7 c. BC) – or since the first indices (indirect) of fluvial navigation in the delta - until the end of the Middle Age in the region (17<sup>th</sup> c. AD).

The confrontation of ancient sources (maps and texts), archeological findings, as well as paleogeographical reconstructions of the Late Holocene Danube delta led us to the formulation of a first working hypothesis according to which the first Greek colonies were founded on open coast shoreline (or in its proximity) and declined once with shoreline progradation and their subsequent decoupling from the sea, followed by the concentration of the main navigation along the southern Danube arm called Peuce or Hierostoma in Antiquity (and Sf. Gheorghe in the present) which was also coincident with the Roman limes) during Roman times, until the 7<sup>th</sup> c. AD and transportation pathways relocation on the northern Danube arm, Chilia, during the Genovese supremacy (ca. 12-14 c. AD) within the Black Sea basin and during Ottoman period (ca.13-19 c. AD).

Our new geo-scientific data (e.g. absolute ages, textural, bio-stratigraphic), as well as new archaeological findings, complement this picture with further pieces of evidence attesting natural waterscape configuration during different historical periods and changes of the deltaic dynamics which influenced the navigation network during the last 2500 years. The newly discovered antique ceramics found downdrift of the former mouth of the southern Sulina branch (Împuțita) which was active during 2100-1300 years ago contribute to the reconfiguration of the existing knowledge about the waterways used by our ancestors. Moreover, these new data shed new light on the existing knowledge about certain parts of the Danube delta evolution (e.g. Chilia arm) in that it proves the latest deltaic lobes developed at a slower pace sometimes earlier than previously reported and add information about delta system inhabitation and services (e.g. Sulina branch).

P-2231

## Mapping the paleogeographic evolution of the Central Asia and human migrations during Late Quaternary

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### Abstract

The development of the ancient societies of the Early, Middle and Late Paleolithic in Central Asia was determined by the evolution of the natural environment. The dynamics of landscape components and various natural barriers predetermine the direction of migration from adjacent regions. Currently, two main directions of migration are reconstructed: the southern (India and Pakistan) and the south-western (Iranian plateau and the Middle East). There are numerous natural barriers that form serious barriers: high mountains system for the southern route in the cooling phases of climate. In the south-west of this territory it was the dynamics of the level of the Caspian Sea and aridization of the territory of modern Iran and Turkmenistan.

One of the most important geological phenomena in the region of Central Asia is transgressive-regressive dynamics of the Caspian Sea, which, is due to the complex combination of climatic, geological and other natural phenomena. In all stages of transgressive-regressive dynamics, the greatest influence was exerted on the coastal relief. The coastal plain areas decreased in the transgressive stages, and increased in the regressive stages. The area of the Caspian Sea was rapidly decreasing, and it could decay into two levels in the southern and northern basins since the most significant regressions. An extensive meridional land corridor was created in the entire eastern tip of the Caucasus, which also contributed to the mutual infiltration of flora and fauna.

Hypotheses about the infiltration of the Early Paleolithic industries into the Eastern Caspian and North Caucasus regions under conditions of deep sea regression are associated with this process.

The appearance of the earliest stone industries on the territory of the Afghan-Tajik Depression is associated with paleo-migration of population from the South - from Pakistan, India; or from the south-west - from Iran, Turkmenistan

We have attempted to analyze the main stages of the migration of the ancient man in the Quaternary. For the main periods, a series of Paleolithic monuments are identified, for which paleogeographic conditions are determined. Special attention is paid to the development of objects that created natural barriers not only on the periphery of Central Asia, but also between regions (Pamir on the East and Caspian Sea on the West, development of the Aral Sea basin and evolution of main river systems of Amudarya and Syrdarya). We will present new data on the chronology of the Paleolithic of Central Asia and paleogeographic reconstructions in a form of series of maps.

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P-2232

## The changing role of wild boar in Ireland during the Mesolithic-Neolithic transition

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### Abstract

Much has been made of the social, economic and symbolic importance of red deer in people's lives from the Palaeolithic through to the Neolithic. Their ecology and significance during prehistory has been extensively discussed and studied through faunal, technological and ethnographic analyses, and studies of genetic and isotopic variation. In Ireland however, flora and fauna during the Mesolithic (the period of Ireland's earliest widespread settlement by humans) were characterised by a restricted range of species compared to Britain and Continental Europe. Large terrestrial prey species, including red and roe deer were absent. Instead, wild boar dominate the mammalian faunal assemblages at both Early Mesolithic sites, (such as Mount Sandel and Lough Boora) and Later Mesolithic sites, (such as Ferriter's Cove and Derragh Island). It has been postulated that the first wild boar were brought to Ireland by humans, and thought that boar were eaten and their hides, fat, bones, teeth and tusks used; but relatively little research has been conducted on the precise nature of boar-human relationships in an Irish prehistoric context<sup>1</sup>.

In order to contextualise the arrival of wild boar after the LGM in Ireland, a brief review of the relationship between wild boar and humans in the European Late Upper Palaeolithic, Mesolithic and Neolithic will be presented in this poster. This will be followed by preliminary results from ongoing isotopic analyses of Mesolithic and Early Neolithic wild boar teeth<sup>2</sup>. These analyses should permit the identification of the seasonal locations of boar, allowing insights into the relationship between boar and human landscape-use and human hunting strategies. Understanding wildlife movements during the Holocene can help in understanding the role of human agency in shaping evolutionary processes as well as the changing nature of the historical relationship between humans and animals. Ultimately this research aims to move beyond basic conceptualisations of boar simply as a subsistence or economic resource, to consider boar diets, mobility and their broader ecological niche. This will form a basis for more nuanced considerations of boar-human relationships through time which might include practical aspects such as a) the relationship between settlement proximity and boar access to atypical food sources, and b) the impact of the introduction of domesticated pigs on 'wild' populations; as well as more challenging considerations such as c) how these animals and their remains were viewed by Mesolithic and Neolithic people and d) the degree to which such objects made from them reflected and constructed human-animal relations.

<sup>1</sup> McCormick, F. 2007. Mammal Bone Studies from Prehistoric Irish Sites. In: E. M. Murphy and N. J. Whitehouse (eds). *Environmental Archaeology in Ireland*. Ch. 5, 77-102, Oxbow, Oxford.

<sup>2</sup> Small, J, forthcoming. PhD thesis, Queen's University Belfast.

**P-2233**

## **Neolithic arable farming on the SW Baltic coast: insights based on crops, weeds and stable isotopes from Oldenburg sites**

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### **Abstract**

The Neolithic sites located in the c. 20km-long Oldenburg depression (Oldenburger Graben) in northern Germany yielded significant amounts of crop products and by-products, demonstrating that arable farming was the mainstay of subsistence economy. The Oldenburg depression represents remnants of a fjord that, by 3000 BC, was completely separated from the Baltic Sea. The Neolithic settlements, which were occupied both before and after 3000 BC, were located on former islands and along the shore of a lowland lacustrine environment into which the fjord was transformed. The depression received freshwater from numerous small streams flowing down the low slopes and creating brackish conditions. In such a hydrologically rich environment, was the area within and near the Neolithic settlements suitable for crop cultivation? This poster sheds light on the nature of Neolithic crop cultivation in the Oldenburg micro-region using selected ecological information on potential arable weeds and the ratios of stable carbon and nitrogen isotopes in the remains of major crops – emmer and barley. It appears that the two crops were grown in dissimilar conditions and were managed to varying levels. This may be understood as an adaptation to the potentially challenging farming environment.

P-2234

## In search of the Palaeolithic in Ireland at Ballynamintra Cave, Co. Waterford

Richard Jennings<sup>1</sup>, C oil n   Drisceoil<sup>2</sup>, Ruth Carden<sup>3</sup>, Peter Ditchfield<sup>4</sup>, Ceiridwen Edwards<sup>5</sup>, Erik Ersmark<sup>6</sup>, Barry Fitzgibbon<sup>7</sup>, Christopher Hunt<sup>1</sup>, Linus Girdland Flink<sup>1</sup>, Philip Kenny<sup>2</sup>, Frank McDermott<sup>3</sup>, Pontus Skoglund<sup>8</sup>, Jamile Bubadue<sup>9</sup>, Patrick Randolph-Quinney<sup>10</sup>, Tom White<sup>11</sup>

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### Abstract

The publication of a bear patella that was butchered during the Late Upper Palaeolithic at Alice and Gwendoline Cave, Co. Clare marked a significant advance in the search for the Palaeolithic in Ireland (Dowd and Carden 2016). Nevertheless, not a single stone or bone tool can with certainty be said to represent a human occupation of this island prior to the Holocene and the origin of human settlement here is thus far from resolved. The find makes a compelling case for the need to undertake new fieldwork at cave sites with good potential for yielding Palaeolithic archaeology and/or faunal-bearing Pleistocene deposits. Such evidence can also help to refine windows of opportunity for when people were potentially in Ireland, and can be used to help evaluate models of terrestrial ice cover extent and the timing of the existence of land bridges between Ireland and Britain/mainland Europe.

Many caves in Ireland were excavated in the nineteenth century but we believe that much more work needs to be done to explore for new caves and re-evaluate existing ones. Here we report the preliminary results of new fieldwork undertaken at Ballynamintra Cave, Co. Waterford. This cave was chosen because excavations in the late 1870s in the main entrance passage yielded faunal-bearing stratified Pleistocene/Holocene deposits. We confirmed that Pleistocene deposits do survive in the cave and we discovered remains of dog, wolf, fox, hare, giant deer and brown bear, all of which are undergoing a range of environmental and genetic analyses. Outside of the cave entrance, the removal of an area of roof collapse revealed that the cave once extended outwards by as much as ten metres. Furthermore, an entirely new cave was found beneath the collapsed debris, which we have yet to explore. We thus have a cave with intact deposits that are coeval in age with Upper Palaeolithic sites in Britain and mainland Europe. We believe that further fieldwork at similar caves in Ireland will eventually lead to the discovery of decisive cultural evidence for an Irish Palaeolithic. It is only a matter of time.

Dowd, M. and Carden, R. (2016) 'First evidence of a Late Upper Palaeolithic human presence in Ireland', *Quaternary Science Reviews*, 139, 158-163

P-2235

## Late Pleistocene and Holocene human-environment dynamics in the Stormberg highlands: site formation and palaeoenvironments at Grassridge Rockshelter, South Africa

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### Abstract

Grassridge Rockshelter is located in the high elevation grassland foothills of the Stormberg Mountains in the Eastern Cape of South Africa. This places Grassridge at an important biogeoclimatic intersection between the Drakensberg Mountains, the South African coastal zone, and the interior arid lands of southern Africa. Evaluating occupational pulses in this boundary region sheds light on the timing and nature of adaptation and mobility in the highland grasslands, as well providing insight into socio-cultural exchange networks across biogeoclimatic zones and their relationship to palaeoenvironmental changes.

Grassridge Rockshelter was first excavated in 1979 by Dr Hermanus Opperman. The approximately 1.5 m stratigraphic sequence was initially divided into two major occupational components: a 50-70 cm thick Later Stone Age component dating between 7-6 ka, and an underlying 50-80 cm thick Middle Stone Age component dating to 36 ka. Our team revisited the shelter between 2014-2019 to relocate the original excavation, reanalyse the stratigraphy, and carry out new excavations. Here we summarize our findings and present the results of a multi-proxy site formation analysis and palaeoenvironmental reconstruction of the shelter's stratigraphic sequence. We combine new optically stimulated luminescence, uranium-series, and radiocarbon age estimates with sedimentological, microbotanical, zooarchaeological, and technological analyses to evaluate the relationship between human occupation and environmental change at the site.

Our stratigraphic reanalysis indicates a complex history of geogenic, anthropogenic, and biogenic inputs. The sequence is interspersed with pulsed human occupation spanning the middle Late Pleistocene through the middle Holocene, including multiple new phases of occupation in addition to those identified by Opperman. Occupational intensity is similar throughout the sequence until a dramatic increase in artefact density and sediment accumulation rate in the middle Holocene. There is also evidence for considerable palaeoenvironmental changes during the last glacial maximum, which corresponds to the development of a thin flowstone followed by a millennial-scale depositional hiatus in the shelter stratigraphy. We conclude by placing the results from Grassridge within the regional record to discuss patterns of Late Pleistocene and Holocene human-environment dynamics within the high elevation Stormberg grasslands, and how they relate to the broader record of prehistoric occupation in the high mountains and plateaus across sub-Saharan Africa.

**P-2236**

## **Microblade remains from the Xishahe site, North China, and its implication for the origin of microblade technology in Northeast Asia**

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### **Abstract**

This study discusses the earliest microblade sites in China and the development of microblade technology in Northeast Asia. The Xishahe site has been discovered in the Huli river terrace deposit in the Nihewan Basin, North China. Dating results indicate that the site was used from about 29-28 ka cal BP, while the microblade remains are from about 27 ka cal BP. The discoveries at the Xishahe site provide some of the earliest radiocarbon dates of microblade technology in China, showing that their appearance and disappearance are highly related to climate change. Although microblade technology has been discovered at the Xishahe site, the technique is different from other younger microblade sites in China, specifically from the mature wedge-shaped core technique. Further, although the microblade cores are well shaped, with platform preparation, and can successfully produce parallel flaking, the overall shape of the cores is varied, lacking high-level standardization. An obvious technological divergence can be seen before and after the Last Glacial Maximum, which lasted from about 24 ka cal BP to 18 ka cal BP.

**P-2237**

## **Leaving an imprint: The long term effect of historic mining on a mountain landscape**

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### **Abstract**

Mining is globally one of the most significant means by which humans alter landscapes; we do so through erosion (mining), transport, and deposition of extracted sediments (waste). The iconic Dartmoor mountain landscape of SW England (~700km<sup>2</sup>) has experienced over 1000 years of shallow (Cu & Sn) mining that has left a pervasive imprint on the landscape. The availability of high resolution digital elevation models and aerial photographs, in combination with historic records of mining activity, make this an ideal location to characterise the impact of mining over an entire mountain landscape during the past millennia.

Spatial scaling analysis (curvature & semi-variance) was used to quantify the signature of historic mining and to determine how it differs to 'natural' landforms such as mountain Tors. Other forms of historic activity such as peat cutting and quarrying were also investigated. The existence of ~500 years of historical archives also makes it possible to distinguish between the imprint of differing forms of mine technology and their spatio-temporal signature. Interestingly higher technology 19<sup>th</sup> C mines have left a much weaker imprint on the landscape than lower technology medieval mining; though the former had a much greater impact in terms of heavy metal contamination

P-2238

## New paleoclimate proxies from permanent alpine ice patches document rapid Holocene climate variability paralleling human activity, Beartooth Mountains, Wyoming, USA.

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### Abstract

Permanent ice patches from mountain environments in North America, Europe, and Japan are emerging as valuable archaeological and paleoenvironmental archives. These alpine ice patches have survived perennially for thousands of years, preserving fragile archaeological and biological artifacts and documenting the history of ancient hunters in alpine environments. Permanent ice patches also have the potential to preserve paleoclimate information in the chemical records recorded in the ice. Here, we present a highly resolved 10,000-year ice-core record of northern Rocky Mountain, wintertime climate recovered from an ice patch located on the Beartooth Plateau, Wyoming and compare it with a record of past vegetation and disturbance derived from analysis of plant macrofossils, pollen and charcoal from 29 organic layers in the core. Plant material from each of the 29 organic layers was radiocarbon dated to develop a robust chronology for the 5.5 m-long ice core and pollen and macrofossils were analyzed from each of the organic layers. Water isotopes ( $\delta^{18}\text{O}$ ,  $\delta^2\text{H}$ ) and ice accumulation rates from an ice core from the ice patch suggest a pronounced cooling in the region during the mid-Holocene, consistent with climate inferred from stable isotopes from a speleothem record from the Wasatch Mountains, Idaho and population declines in the nearby Bighorn Mountains. Additionally, radiocarbon dates and a floating chronology of cross-sections of 27 large diameter whitebark pine (*Pinus albicaulis*) trees found entombed in an adjacent ice patch reveal the trees established over 250 meters above current treeline during a warm and dry interval then died as conditions abruptly cooled and became wetter c. 5.3 kcal yrs BP, documenting a period of rapid climatic change. Our findings suggest that these small alpine ice patches preserve regionally-representative climate records that document a sustained 800-year period of peak Holocene warmth centered at 4,100 cal BP followed by a rapid cooling leading to a prolonged era of cooler and wetter winters. The ice-patch records suggest rates of winter temperature changed at the onset and termination of this 1,500-year cold period were as high as observed rates of modern warming. The well-dated ice-patch climate records are consistent with reconstructions of environmental change and closely parallel archeological indices of human activity in western Wyoming throughout the Holocene, with activity suppressed during both especially warm and cold climate periods. The chemical record and diverse assemblages of plant, geologic, and archaeological material contained within ice patches provides a wealth of information about past climate and environmental conditions and archeological resources, presenting an unprecedented opportunity to document and evaluate human use of the alpine during periods of rapid climate and environmental change.

P-2239

## Development of Epipaleolithic in high-altitude Central Asian Mountains (Alay site)

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### Abstract

The Alay site represents the earliest, high-altitude human-occupation site currently known in western Central Asia. Recent recovery and analysis of a lithic assemblage from Alay underlines the importance of this site and its role in the cultural and technological development in later Eurasian prehistory. During the field work we described the geomorphological position of the site, obtained a new series of absolute dates (radiocarbon and OSL). This data and analyses of satellite images allowed us to reconstruct the palaeogeographic conditions during which this high-altitude site was occupied by humans. The main factor that dominated the geomorphological evolution of the Alay depression was glaciation of the southern ridges with highest peaks (Lenin and Dzherzhinskiy). Study of the history of the Pleistocene glaciations of the Pamirs and the high-mountainous Western Asia testifies to the synchronous development of the region's mountain glaciers (Stübner et al, 2017; Zech, 2012). However, an important factor in the evolution of the natural environment was the general trend of increasing climate aridity, which was expressed in asynchrony with the global climate cycles. In this regard, the maximum spread of glaciation, expressed in the remaining moraines, occurred at the end of MIS-4 - the beginning of MIS-3, and apparently for high-altitude glaciers, apparently earlier (MIS-4). The further expansion of the glaciation, despite the greater cooling, was limited by the lack of moisture, an increase in aridity and the influence of the Siberian anticyclone (Abramowski et al, 2006). Thus, geomorphology, stratigraphy and geochronology (new luminescence ages) of the region allow us to estimate the age of the Alay site for a period of time after the LGM, in the warming stages of the Allerød (about 14-12 thousand years ago). We will present new geoarchaeological data for this important site and recently obtained luminescence and rock-surface ages that form chronological basis for our environmental reconstruction.

**P-2240**

## **New tools for Quaternary Geomorphologists**

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### **Abstract**

Public awareness of the Quaternary is handicapped by the absence of any remnants of the thick *mer de glace* and pervasive large icebergs that occasionally covered much of northern hemisphere. Teachers substantiate that chilling image by citing evidence of erosion and deposition as its proxy. To reduce the resulting complexity, they sometimes infer that those processes developed on stable, fixed topography not greatly different from our current familiar surroundings. Anomalous features are attributed to changing sea levels or to sudden melting of the ice sheet. Questions about possible crustal movements are avoided, or adjourned for future consideration by interdisciplinary researchers.

That synoptic picture remained adequate while the public still considered hills and mountains the epitome of venerable stability. —However, careful structural interpretations of representative Irish hills now imply major disruptions of pre-Pleistocene peneplains during the past 3 million years. Isostatic movements produced horsts, grabens, swelling and tilting of the present topography, raising the crust onshore and sinking it offshore wherever thick Pleistocene sediment accumulated. These renewed geological insights need wider dissemination to the public and require a thorough review of their broader implications for Quaternary science.

This preliminary study gives notice of eight places that experienced local differential crustal movements during the Quaternary:

1. Drumlin at Moolagh, Donegal, down-faulted by 26 metres
2. Drumlin swarm east of Donegal Town, tilted *en masse* 1:75 to southwest
3. Sybil Head to Signal Hill at Ferriter Cove, Kerry, raised 160 metres above the Irish peneplain and tilted 1:10 to southeast
4. Croaghleheen mountain, Donegal, a dome that swelled 280 metres above the Irish peneplain
5. Glencolmcille peninsula, Donegal, a horst raised 400 metres above Irish peneplain
6. Three Rock Mountain, Dublin, part of the Wicklow horst raised 300 metres above the Irish peneplain and tilted to the southeast
7. Basal Pleistocene unconformity at Croghan Hill, Offaly, raised by at least 50 metres above the Irish peneplain unconformity
8. Ox Mountains Horst, Sligo & Mayo, raised by 400 metres above Irish peneplain and tilted to southeast.



These examples draw attention to a new set of conceptual tools that could serve future geomorphologists in lieu of continuing reliance on changing eustatic sea levels.

P-2241

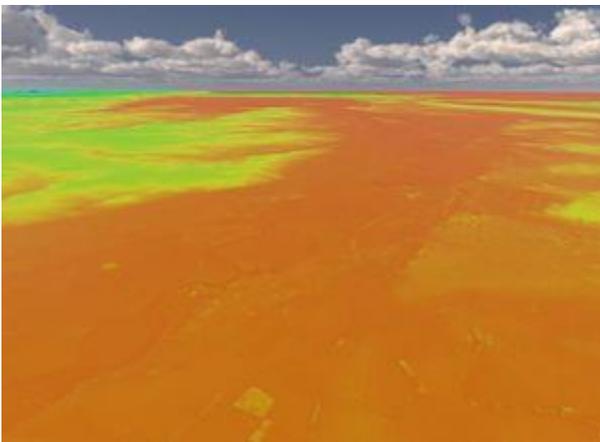
## Late Glacial Journeys: using Citizen Science and 3D-terrains to inform pathways of hunter-gatherer migration. A case study from East Midlands-UK

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<sup>1</sup>British Geological Survey,, Nottinghamshire, United Kingdom. <sup>2</sup>Beeston, Nottingham, United Kingdom

### Abstract

As geospatial technologies develop and become more widely integrated in traditionally non-geoscience subjects, the use of these methods in archaeological research has increased. This has led to opportunities for incorporating geospatial techniques in archaeological outreach and engagement. Historic models of understanding human migration and occupation have relied on 2D maps and terrain defined by contours – an interpretation and context not easily visualised by the non-expert. In this study the authors used an immersive 3D terrain visualisation in ‘GeoVisionary’ to allow volunteers to create a Least Cost Path analysis of human migration between sites of known Late Upper Palaeolithic human occupation in the East Midlands, UK. The quasi-formal group demonstration and ease of route creation in the 3D visualisation software GeoVisionary allowed for a dynamic route to be generated, edited and updated based on paleo-landscape evidence gathered. Compared to contour based route methodologies, there was a greater level of engagement among the volunteers when utilising the 3D visualisation software than other methods.



P-2242

## Making the Quaternary relevant through outreach and fieldwork learning approaches

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### Abstract

The Quaternary Period, comprising the Holocene and Pleistocene Epochs, encompasses the last 2.6 Million years during which time Earth's climate was strongly influenced by bipolar glaciation and the genus Homo first appeared and evolved. Climate conditions required a diet heavy in animal protein so they were sophisticated hunters, although recent discoveries indicate they also cooked and ate plant materials, and eventually developed farming which has had an impact on the environment. The classification and interpretation of the youngest stratigraphic sequences, variously known as Pleistocene, Holocene or Quaternary, have been a matter of much debate. Climate change during the Quaternary has produced a geological record dominated by sediments deposited under glacial, periglacial and temperate environmental conditions that are fragmented. This has raised concerns of climate change impacts on the natural environment. The Quaternary Period is characterised by very variable climatic conditions oscillating between interglacial and glacial stages. These repeated and extensive cold stages have included some intense glaciations and these have wiped much of the preceding record leaving the world with a heavily glaciated landscape with many features of uncertain age. Due to the important role quaternary plays in peoples' lives and the significant impact of humans on the environment, there is a great and growing need to improve links between quaternary science, education, and society. Traditionally, education was responsible for passing on the grand narratives of the society, the frameworks for thinking and being, and practices which yielded ways of organising, thinking, saying and doing. However, today with the knowledge society, education is not only about passing on past knowledge and practices, but importantly about entrusting the future to the next generations, equipping them with capacities to survive, organise, think, plan, and act. Education inspires progress in society but at the same time it must respond with foresight to society by developing adequate strategies for quality learning. In order to promote the development and delivery of quality learning in formal and informal Quaternary education, it is important to make it relevant to society through outreach settings and fieldwork learning methodologies to motivate the assimilation of aspects of Quaternary history, biology and geology and its influence on the modern world. These methodologies include: field trips, research and publication of field guides, consultation with stakeholders, holding field meetings with the community, project based learning, use of guest speakers, use of primary sources, and establishment of centers of excellence in quaternary science. These methodologies give insight into the richness that is aligned to teaching and learning of quaternary science. This paper critically examines the mentioned methodologies with particular emphasis on creating awareness and relevance of quaternary period in education, and to facilitate future debate and application of quaternary science in society.

P-2243

## Short outreach documentary on earthquake geology: increasing the seismic risk awareness through active learning

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### Abstract

People usually become aware of earthquakes after suffering their catastrophic consequences. However, most people facing a damaging earthquake have not experienced any moderate-large seismic event before. This is especially relevant in areas of slow deformation, where time lapse between damaging earthquakes might take decades or centuries. How to sensitize people to potential earthquakes is a major challenge for the Civil Protection and scientific community devoted to Earthquake Risk Reduction. Aiming to increase the Seismic Awareness in the Iberian Peninsula, the active tectonics and paleoseismology team of the RISK-NAT group (UB), and Azora Films have produced a short documentary starting with the following premises: **i)** effective learning occurs when the examples provided are part of our daily lives and our surrounding landscape; and **ii)** learning through games and experiments will help people acquire the desired knowledge and life skills to increase their seismic preparedness. For instance, a seismic crack on a wall of a building that is on the way to school will make us more aware of our seismic exposure than watching a film about earthquakes in a remote part of the world. In addition, making reference to the mountain that we see through our window as the result of repeated seismic movements may help us grasp the idea that earthquakes might happen at any time and that we need to be prepared to reduce the risks they involve. These concepts are reflected in the documentary, in which the main character is an 8-year old girl who experienced the Lorca earthquake (Mw=5.2, 11st May of 2011, southeastern Spain) when she was one-year-old. The story starts as she wakes up after a nightmare with the quake. She wonders if “forgetting about something means that such a thing will not happen again” and she feels highly determined to know more about that event, how earthquakes happen and what she can do about them. Then, her mother takes her to meet her aunt, a paleoseismologist with whom she makes a trip to the world of earthquake geology. The film shows how the tectonic plates move through repeated earthquakes and how this process happens at different scales, including the close example of faults around her city. The adventure ends in a ludic visit to the paleoseismological excavations of the Risknat group near her locality. Through games and experiments with other children of different ages, she learns how the landscapes change earthquake after earthquake, why living on the valley sedimentary infill means that the ground might vibrate more strongly than in other places and how to protect her when land starts to shake. This film is part of a broader outreach initiative on earthquake awareness (included in the PREVENT project), which will be available at [www.latierratiembla.net](http://www.latierratiembla.net).



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**P-2244**

## **Poetry as a tool for Quaternary science outreach**

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### **Abstract**

The potential of poetry for effective science communication is increasingly being recognised, with poetry workshops and residencies included in a number of recent international conferences and collaborations between scientists and poets and other creative writers becoming more common. Reading, composing and/or performing a poem, through the use of imagery, simile and metaphor can inspire interest in scientific ideas and communicate them to new audiences. More work is needed, however, to understand what the most effective approaches are.

Wales's Irish Sea coasts and estuaries include numerous landscapes and landforms of significant interest to Quaternary scientists (e.g. floodplains, moraines, sand dune complexes), especially as records of glaciation, changes in sea level, and historical storminess and flooding. They have also been key features of the country's historical and cultural history and have provided locations for enduring myths, poems and songs. Their essential ecological and geomorphological roles are increasingly recognized by stakeholders and the general public, especially in the context of coastal flood mitigation, but the potential and significance of coastal geomorphology as archives of environmental change is less commonly recognised.

Through illustrations, photographs, prose and particularly poetry, the people of Wales have creatively represented and interpreted Quaternary coastal landscapes for centuries, providing us with clues to the nature of historical and contemporary human-environment relationships. Here I present an overview of the way in which Welsh coastal landforms have been 'mapped' in Welsh poetry from the medieval period to the present and analyse the effectiveness of two of my own poems inspired by coastal Quaternary geomorphology. Welsh poetry has frequently emphasised the dynamic nature of the coast and the illustrate the rich, long-term creative perspective that Quaternary science provides to poets. I suggest that collaboration between poets and Quaternary scientists could be a valuable and effective tool to increase public interest in and understanding of the value of the field.

**P-2245**

## **From achievement of fieldworks to textbook in elementary schools: Introduction of Liu Tungsheng to Chinese public**

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### **Abstract**

Over the past half century, the paleoenvironment group at the Institute of Geology and Geophysics (IGGCAS) plays a leading role in Quaternary research of China, where a globally well-known Quaternary scientist LIU Tungsheng once worked for. Based on his outstanding loess research, Prof. Liu persistently focused on the interactions of paleoclimate and past/modern human activities, and was awarded by the Tyler Prize for Environmental Achievement in 2002 and the State Preeminent Science and Technology Award of China in 2003. After he passed away in 2008, we gradually introduce the Nihewan basin, a cornerstone of Chinese paleolithic archaeology where once he worked, to the public via study tours, involving participants into geological sampling, stone tool making, and archaeological survey. Meanwhile, Liu's former office has been transformed into a memorial room, where the visitors have opportunities to approach his field notebooks from his college days, various samples he collected worldwide over 30 years, and his rich publications since 1940s. Moreover, we also facilitated Prof. Liu Tungsheng, as an outstanding representative of modern scientists, into a state-compiled textbook for elementary school pupils in China. To date, Prof. Liu is survived by his disciples scientifically and his achievements are understood by the public increasingly, as well as Quaternary researches.

P-2246

## "Once upon a time... a scientific fairy tale" – storytelling to share knowledge about climate and ocean sciences

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### Abstract

Humankind is known for practicing storytelling during the Quaternary through various forms of art. Storytelling is therefore one of the oldest ways of sharing and transmitting knowledge and values. It is a worldwide phenomenon, with no political or cultural boundaries. Then why not use it to tell a broad audience about the Quaternary (and beyond)?

Sharing scientific knowledge with the lay public is challenging, even more when there is a desire to inspire change and raise awareness about environmental aspects. The "Once upon a time" team, an international group of marine science PhD and postdoctoral researchers at institutions mainly in Bremen, has applied the longstanding method of storytelling using their personal research, scientific curiosity and environmental concerns. The "Once upon a time... a scientific fairy tale" project was organized in 2016 within the framework of the competition "Show your Science" sponsored by the German science communication foundation "Science in Dialogue" (Wissenschaft im Dialog) with the aim of producing an e-book with stories with scientific content. The project was one of the winners of the competition. In 2017 the first "Once Upon a Time..." volume was published with 12 stories and poems which relate to various marine science themes – from marine biology, ecology, and geology to human interactions with the oceans. The volume was published as an illustrated and free to download e-book in German, English and Spanish. After the competition ended, the team continued working in various directions. Volume I is being translated to Chinese, Filipino, Portuguese and many more languages, to be accessible to as many people as possible. We also perform readings of our stories in schools, art exhibitions and outreach events of our institutions to promote the e-book and generate a genuine dialogue with the public. A second volume of new stories and poems is in progress. Importantly, the group is seeking international collaboration with teachers, citizens, and scientists from other disciplines to improve the pedagogical content and to expand the scope and readership of the "Once Upon a Time..." scientific story network.

**P-2247**

## **Resilience, stability and abrupt changes of ecosystems in tropical South America during the late Quaternary**

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### **Abstract**

Detailed records on vegetation and environmental changes during the late Quaternary provided insights on past ecological response on environmental changes. Several examples of resilience, stability and abrupt changes from South America will be presented. Studies from lowlands, highlands and mountains reflect interesting ecological responses to climate change, fire and human impact. Results from continental as well as marine records show that the response of ecosystems on large-scale climate change can be abrupt in decades or within centuries. Studies from different regions indicate how tropical ecosystems evolved to what they are today. Furthermore, they show how sensitive ecosystems are to climate change and how ecosystems responded to natural and anthropogenic environmental changes during the past. This knowledge will help us to understand how ecosystems might change under the ongoing Global Change.

**P-2248**

## **Resilience versus vulnerability in desert human societies – are they prone to a permanent risk of collapse?**

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### **Abstract**

The great challenges of living in arid and hyper-arid regions around the world are permanent shortage of water, limited food resources and inherent uncertainty regarding water availability, in terms of its quantity and spatial distribution. These challenges dictate the main weaknesses of desert societies that, according to the existing paradigm, are prone to suffer from a permanent risk of collapse.

However, in the Middle East deserts, human societies are known since prehistoric times traversing the entire hyper-dry Holocene. This fact suggests that the simple common paradigm ascribing high vulnerability to desert societies needs to be re-examined.

As desert societies glob-wide deeply assimilated the inherent difficulties imposed by the desert climate into their survival strategies, they developed special behavioral and social structures to cope with the environmental challenges. These strategies included high geographic and social flexibility, high mobilization, low population density and a robust economy. In terms of Social-Ecological systems, these nomadic and semi-nomadic desert societies lived within systems of flexible geographical boundaries. Therefore, their collapse is difficult to define, compared to sedentary societies. The definition we are suggesting here is this: the abandonment of a large portion of the desert region by its inhabitants and the inability of desert nomadic society to return to this region over a considerable long time. This extreme event is supposed to be far beyond the regular desert oscillations.

If this collapse did occur among desert societies, it was most likely the consequence of the fixation of the once nomadic societies to a certain location within their original large wandering region, or the outcome of the inability of the desert environment to support the increasing number of its inhabitants, both human and their livestock.

However, as reflected in the history and archeology of desert societies in the Middle East - a region in which nomadic and semi-nomadic desert societies are known throughout the entire Holocene - this type of collapse was never documented. On the contrary, in the large region including the Sinai Peninsula, the Negev desert, southern Jordan and northern Arabia, such desert societies are known almost continuously during the last 5-6 millenniums, indicating their high resilience throughout historical times. This long-term survival suggests that, contrary to the common paradigm, human desert societies demonstrated a much more robust structure, based on their extensive knowledge of local geodiversity, hydrology and natural resources and their social and geographical flexibility. All these together resulted in a good adaptation to the desert climate.

Regarding our question - are human desert societies prone to a permanent risk of collapse? We think that, in general, they are probably not. However, we call for a re-evaluation of the existing paradigm in light of glob-wide studies of specific desert societies.

P-2249

## Lake ecosystem shift caused by social-economic transitions: case from Yangtze River Basin, China

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### Abstract

Globally, many freshwater lakes have undergone rapid degradation over the past century. Lake scientists and managers are struggling with enhancing lake ecosystem resilience to cope with escalating anthropogenic pressures. A better knowledge on how lakes and social systems evolved up to the present is vital for understanding, modeling and anticipating the current and future ecological status of lakes. By integrating paleoenvironmental, instrumental and documentary sources at multi-decadal scales, we demonstrate how typical shallow lake socio-ecological systems evolved over the last century in the Yangtze River Basin, a biogeographic region containing hundreds of shallow lakes. We find that an abrupt ecological shift, expressed as a significant reorganization of lake aquatic species and communities, occurred around the AD 1970s. Land reclamation, hydrological modification, and pollution seem to have acted directly and synergistically to cause this shift. We argue the lake socio-ecological systems went through three stages as society transformed from a traditional agricultural to an urbanized and industrialized society. The dominant feedback has changed from conventional farmer-ecosystem feedback to newly formed socio-economic and ecosystem feedback, due to increasing population, social wealth and resource demand during the last decades. Our results highlight the importance of accounting for the long-term dynamics and feedbacks between ecological, social and economic changes when defining safe operating spaces for sustainable freshwater ecosystem management.

P-2250

## A 260 000-year reconstruction of diatom community dynamics in Lake Chala, a tropical crater lake

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### Abstract

Lake Chala is a c. 90 m deep meromictic, oligotrophic crater lake near Mt. Kilimanjaro in equatorial East Africa. This sub-humid tropical region experiences two rainy seasons separated by a long dry season in June-August, when deep mixing fuels the epilimnion with nutrients resulting in increased phytoplankton primary production. Within the ICDP DeepCHALLA project, a 215-m long continuous sediment sequence was obtained, which provides a unique opportunity to study long-term climate dynamics and aquatic ecosystem response during the past c. 260 000 years. Here we analyzed fossil diatom assemblages to reconstruct temporal dynamics in the lake's diatom community structure with millennial-scale resolution. A minimum of 400 valves were counted and identified with best-possible taxonomic discrimination from sediment samples taken at c. 800-yr intervals throughout the last glacial cycle (back to c. 160 kyr BP) and at c. 1600-yr intervals throughout earlier lake history. At the base of the sequence (c. 260 kyr BP) the diatom community is dominated by a small cyclotelloid diatom resembling the tychoplanktonic *Discostella stelligera*; we tentatively interpret this to reflect open-water conditions with near-presence of littoral habitat during the early filling stage of lake ontogeny. High proportions (20-50%) of an *Encyonema* species c. 240-230 kyr BP indicates increased prevalence of benthic habitats, possibly because of a pronounced low-stand at the time when the central ash cone on the basin floor was still free of overlying sediments. Other prominent but short-term appearances of benthic species occur at c. 140 kyr BP (*Gomphonema* sp., up to 100%) and c. 130 kyr BP (*Epithemia* sp., 20%). At all other times between c. 230 and 140 kyr BP the diatom community is dominated by fluctuating abundances of small, medium-sized and long *Nitzschia* species. After that time the diatom community starts to resemble the present-day community with dominance of the planktonic *Afrocybella barkeri* and *Nitzschia fabiennejansseniana*, which currently bloom at the end of the long dry season when the lake is deeply mixed. Between c. 110 and 90 kyr BP, i.e. broadly during the pronounced low-stand attributed to MIS5 African megadrought, all small *Nitzschia* species are lacking and *A. barkeri* reaches a relative abundance of up to 100%. An as yet undescribed second *Afrocybella* species replaced *A. barkeri* during the Last Glacial Maximum (c. 22-17 kyr BP). Superimposed on these long-term changes in diatom functional groups, we found many strong but short-term fluctuations in the appearance of different small *Nitzschia* species, which may reflect stochastic colonization and extinction events rather than marked climate-driven fluctuations in the abiotic environment of Lake Chala. This may also apply to the occasional appearances of *Aulacoseira* species; alternatively they indicate periods of increased water-column turbulence that allowed these typically strongly-silicified, fast-sinking cells to remain in suspension.

**P-2251**

## **Climate-vegetation turnover relationships in at the Pleistocene-Holocene transition**

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### **Abstract**

Regime shifts are large, abrupt, and persistent transitions in the function and structure of ecosystems and may become more in the face the projected climate changes expected by the mid-21<sup>st</sup> century. Regime shifts in vegetation can either be driven by a large, extrinsic-forcing variable (e.g. abrupt climate changes at the Younger Dryas resulting in widespread- and abrupt vegetation changes), or represent a non-linear response to a climate forcing (e.g. a critical transition between alternative stable states resulting from a positive feedback). Depending on a combination of historical disturbance regimes, and the contemporary vegetation structure and functioning, recent research from satellite data indicates that contemporary biomes can be more or less sensitive to climate variability. As a consequence, different ecosystems may exhibit different sensitivities to climate driven regime shifts in the 21<sup>st</sup> century.

Regime shifts are also commonly identified in palaeoecological records, and long-term ecology may therefore provide a useful set of tools to understand the factors leading to abrupt changes in ecosystems. Specifically, periods of abrupt warming in the past can be used as natural experiments to learn about how different ecosystems respond to climate change. Here, we investigate the patterns and drivers of abrupt vegetation change in Northern Hemisphere biomes across a period of abrupt climate warming at the Pleistocene-Holocene boundary. Our analysis is based on the following questions: i) which biomes demonstrate higher or lower sensitivity to climate and other land-use changes? ii) can we identify periods when the relationship between ecological turnover and climate change is linear or non-linear? These questions are relevant for predicting the type and nature of abrupt ecosystem change as a result of the projected changes in the 21<sup>st</sup> century.

P-2252

## Ecosystem responses to abrupt climate change: insights from the Mediterranean

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### Abstract

Palaeoenvironmental sequences from the Mediterranean have, for many years, been a cornerstone of our understanding of ecological responses to Quaternary climate change. Lake Ioannina, North West Greece, is one such archive, with a record which spans the last 245 kyr (Tzedakis, 1994; Roucoux et al., 2008). Previous work at the site identifies less pronounced vegetation responses to sub-orbital climatic change to those identified in pollen records elsewhere in the Mediterranean, with the suggestion that local conditions buffered the extreme effects of Quaternary climate variability (Tzedakis et al., 2002). New work, presented here, seeks to test this hypothesis. Two visible tephra layers, the Pantelleria Green Tuff (~45 ka BP) Campanian Ignimbrite (~39 ka BP) provide a temporally well-constrained “window” for palaeoecological study at decadal resolution. These tephra isochrons facilitate precise correlation of the Ioannina pollen record with key local and regional archives of palaeoecological change such as Lago Grande di Monticchio (Italy), Lake Ohrid (Albania), and Tenaghi Philippon (Greece). Such tephra correlations allow comparison of the nature of vegetation response at different sites to the same climatic oscillations with less ambiguity than work reliant on traditional geochronological approaches. In doing so this work will provide an insight into differences in ecological resilience (see: Davies et al., 2018) to millennial scale climatic variability between multiple Mediterranean ecosystems.

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P-2253

## Long-term post-fire resilience of the Ericaceous belt, Bale Mountains, Ethiopia

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### Abstract

Fire is the most frequent disturbance in the Ericaceous belt, the dominant plant community of the Afromontane environment (3300-4000 m asl). By resprouting after fire, *Erica* establishes a fire-trap feedback in which a positive relationship exists between certain fire regimes and *Erica* spp. occurrence. However, present-day human activities in the Bale Mountain National Park (BMNP, Ethiopia) constitute a fire and grazing regime that may have a negative impact on the resilience of the Ericaceous ecosystem. Current knowledge of *Erica*-fire relationships is based on modern investigations, lacking a longer time perspective that can shed light on potential baseline conditions for the fire-trap. We hypothesize that fire has always existed in the BMNP, and has a long-lasting influence on the *Erica* vegetation. To test this, we aim to: 1) identify the fire history of the BMNP at millennial time-scales through a 14 kyr-long charcoal and pollen record from Garba Guracha, a lake at 3950 m above sea level (asl); and 2) describe the long-term bidirectional feedback between wildfire and *Erica*, which defines the ecosystem's resilience. Applying transfer functions to our charcoal record, we reconstruct the fire magnitudes in terms of burnt area, number of fires per year and fire radiative power. We fit a generalised least squares (GLS) model on lagged data to establish the effect of fire on *Erica* species and vice-versa. Our results indicate that fires have always occurred in the BMNP, with a particularly intense early Holocene burning phase equivalent in magnitude to the present-day fire regime. Our model proves that the bidirectional relationship between fire and *Erica* is positive; *Erica* presence is in part explained by fires that occurred in previous centuries and decades. Similarly, *Erica* fuel accumulation at decadal to centennial scales reinforces fire occurrence. We find that the Ericaceous belt is thus a long-term fire resilient ecosystem and that fire should be integrated in landscape management at the BMNP.

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P-2254

## Exploring vegetation resilience of the Subantarctic Patagonian communities by ecological modeling and the analysis of Holocene records.

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### Abstract

Subantarctic Patagonian ecosystems might experiment important changes under future climate warming. The precipitation and temperature gradient at the southernmost Andes determines a clear zonation of High Andean dwarf shrubs communities, mid-altitude *Nothofagus* forests and shrub-grass communities in the lowlands. In this research we show how ecological and paleoecological methods provide interesting results to study Subantarctic Patagonian vegetation long-term ecological resilience. We focus on the analysis of modern and paleo vegetation arrangements and diversity patterns variability. First we explore modern patterns of vascular plant taxonomic and functional diversity through generalized linear models. Second we evaluate modern vegetation diversity representation by pollen diversity collected at moss polster samples. Third we interpret past vascular plants diversity patterns and past vegetation changes during the last 12.000 cal yrs BP through the analysis of pollen, charcoal and macro-remains of a peat bog at Parque Nacional Los Glaciares, Santa Cruz, Argentina (50.26°S; 72.85°W). We identified 4 different vegetation arrangements during the Holocene: High Andean grass-dwarf shrubland, dwarf shrubland, forest and grassland. We evaluated past vegetation and diversity changes related to past disturbance regime (fire occurrence and tephra deposition) and climate variability (mean annual precipitation and temperature). The analysis of the proxy record and the comparisons with past climate reconstructions suggest that High Andean grass-dwarf shrublands are more resilient to fire regime changes than forest communities. Also we detected that the replacement of High Andean grass-dwarf shrublands by forests since ca 8000 cal yrs BP which produced a high decrease in plant diversity has never been reverted. Since the last 7000 cal yrs forests communities have been quite stable despite to climate variability except during the Little Ice Age (LIA) where there was a sharp replacement of forest by grasslands. Forest recovery after LIA took a hundred years to recover to values similar to those recorded at 400 cal yrs BP. Modern rates of forest recovery after human induced fires during the early 20s century are much slower than those registered by the proxy record after LIA. The decrease in forest recovery rate may be related to the introduction of cattle and the European hare since European settlement in the area ca 1880s.

The long term perspective warns us about possible vegetation displacements in the future. The continuous reduction of the high Andean communities during the last 12.000 cal yrs alert us about possible local or regional extinctions of different vascular plants adapted to these cold Patagonian environments and its consequences to other insects, mammals or birds that depends on these unique flora.

P-2255

## Network-based metrics of community resilience and dynamics in lake ecosystems using palaeoecological data

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### Abstract

Rather than respond gradually to stressors, ecosystems can suddenly undergo a critical transition to a new regime state after reaching a tipping point, such as a lake shifting from a clear to turbid state as a result of eutrophication. Much effort has been employed in developing robust resilience metrics that could act as early warning signals of impending tipping points by monitoring system metrics for statistically observable changes such as increasing autocorrelation and variance. However, these metric-based techniques have not always been found to be reliable in detecting critical transitions in a wide range of systems. More recently novel methodologies focusing instead on the changing structural composition of an ecosystem, such as compositional disorder and food web stability, have been developed that offer an alternative means of assessing ecosystem stability.

Here we present two novel network-based methodologies for estimating past community stability from palaeoecological abundance data by inferring community structure over time, and their application to diatom abundance data spanning several decades from a selection of Chinese lakes at differing points of eutrophication. We find evidence of increasing diatom community instability during eutrophication in lakes Taibai, Erhai and Longgan, while there are no consistent long-term signals in the unpolluted Shade Co and Moon lake. These results compare favourably against classical early warning signal and compositional disorder metrics when applied to the same data.

P-2256

## Make lake go green- a hybrid agent-based model simulating eutrophication in Lake Erhai, China

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### Abstract

Lake ecosystem is regarded as an ideal experiment field for exploring complexity and system dynamics due to being reasonably self-contained. Eutrophication, notoriously known as an ecological problem induced by nutrient, has been studied a lot due to biological amplification of water deterioration. Numerous empirical studies investigated and reconstructed rich data in limnology and paleolimnology to reveal environmental and ecological changes in system. To understand the cause-and-effect relationship between species and function groups, ecological modelling is a good complement to bridge such a gap, testing hypothesized mechanisms of dynamic change and simulating what scenarios the increased nutrient input results in. Here, we use a novel approach of hybrid modelling Lake Erhai, in southwest China. It is well studied empirically and owns abundant spatial and temporal data sets. Though Erhai lake has not facing large-area algal bloom yet, it was reported to have passed a critical transition to turbid water state in 2000s and there are cyanobacteria bloom near shore in recent years. Besides ecological monitoring and investigation, lake sediment records including diatom were successfully revealed during the past 130 years. Our methodology takes both ABMs' (Agent-Based Models) strength in simulating stochasticity and emergence and SDMs' (System Dynamic Models) advantage in anticipating changes over time in complexity systems. Different from regular setting of agents in ABMs as individual species, we nominate key function groups related to nutrients as agents interacting in specific rules. In phytoplankton, diatom and cyanobacteria have been listed separately for monitoring. Preliminarily, the model named "make lake go green" comprises of two main submodels. The ABMs submodel simulates how biological communities change and the SDMs submodel runs an empirical hypothesis of potential feedback loop network to compare. However, due to the difficulty of whole-lake ecosystem modelling, our scope will zoom out from unstratified water, then gradually combining cooperative partial systems to enhance complexity. Carrying out repetitive experiments, we expect to get validation from empirical evidence and try projecting various scenarios for prediction. To achieve this aim, we will use HPC (High Performance Computer) IRIDIS4 in University of Southampton to run ABMs on Netlogo and R. Results will be produced from hundreds thousands agents and all variables in experiments by modifying different parameters.

**P-2257**

## **Tipping Points?: Rapid Neo-glacial transitions in Greenland**

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### **Abstract**

Possible 'Tipping Point' behaviour has been identified across a spectrum of palaeoclimatic studies, for example, the relatively rapid climatic changes associated with shifts from glacial to interglacial conditions, or short-lived excursions such as the 8200 yr BP cold event. The majority of these changes can be attributed to external forcing mechanisms, such as orbitally-forced changes in insolation, or to internal mechanisms or feedbacks such as pro-glacial lake drainage, changes in ice-sheet extent and sea-level changes.

This study explores a pronounced climatic cooling event. The transition from the generally warmer conditions of the Holocene Thermal Optimum (HTO) to the cooler Neo-glacial is recorded across much of the northern Hemisphere and in a range of proxy records, although, the date for this event at individual localities ranges between 4000 and 6000 yr BP. The signal is particularly clear in Greenland ice-core borehole temperature profiles and ice-rafted debris content of ocean cores from east of Greenland. The underlying mechanism for this climatic transition remains undetermined. Our objective is to investigate the cause(s) for this event by developing new, high temporal resolution palaeoclimatic records from Greenland, using complementary climate proxies, including pollen, Chironomidae and diatoms.

This poster presents new palaeoclimate reconstructions following pollen and chironomid analysis from two lakes close to the ice sheet in the Nuuk fjord area, Southern Greenland. These new palaeoclimate records are based on quantitative temperature models which use enhanced modern training sets of pollen and chironomid data from the Nuuk fjord area (chironomids) and the local area alongside data from elsewhere in the north Atlantic arctic region (pollen). The Neo-glacial transition is identified in the lake cores and its characteristics are discussed within the framework of existing records from the region. These new quantitative reconstructions based on local modern training sets allow a much more accurate understanding of past Greenland climate dynamics than has hitherto been possible.

P-2258

## Holocene trends in phototrophic communities from four lakes in south-western Greenland: the role of ontogeny, climate and climate-catchment interactions

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### Abstract

Fossil diatom assemblages from lake sediment records across the Arctic have been widely used to reconstruct palaeoenvironmental, palaeoclimate and palaeoecological change. In the low arctic region of south-western Greenland, diatoms have been used alongside chemical and sedimentary proxies to investigate Holocene scale trends in lake development, a process termed ontogeny. These Holocene age lakes demonstrate comparable long-term trends in the nature and pace of lake ontogeny, regardless of climatic setting. However, periods of climate change can cause excursions from the long-term ontogeny trajectory in some lakes; lakes and their catchments filter the impacts of climate change differently depending on their geomorphology, soil and vegetation cover and lake depth. Unlike diatoms, which represent one algal group, sedimentary pigment analysis allows for all components of the phototrophic ecosystem to be integrated and investigated, yet there is an absence of high-resolution, Holocene-scale sedimentary pigment data from Greenland. It remains unknown how different phototrophic groups (e.g., chrysophytes, cryptophytes and cyanobacteria) respond to lake ontogeny and climate change.

Lakes in south-western Greenland provide an opportunity to investigate long-term changes in climate, the lake catchment and ontogeny independent of human influence. We present continuous, Holocene-scale records of phototrophic communities from two paired lake sets from south-western Greenland. In the Kangerlussuaq region, there is a marked shift from a warmer continental climate inland to a wetter, cooler maritime climate at the coast, allowing the effect of climate on phototrophic communities to be investigated. Therefore, using HPLC we investigated sedimentary pigments from two lakes from the coast and two from the inland area to allow comparisons over Holocene timescales. The results demonstrate comparable long-term trends overall biological production as a result of lake ontogeny. However, periods of climate change which can initiate changes in catchment vegetation (e.g., soil and catchment deterioration) lake depth and thermal structure (e.g., arid periods and lake level lowering) can result in rapid regime shifts in autotrophic community composition. Although, not all lakes register regime shifts simultaneously in response to climate change and the associated climate-catchment interactions. These results suggest that phototrophic communities may undergo rapid regime shifts in response to future climate change. Furthermore, phototrophic lake communities experiencing the same climate forcing may demonstrate contrasting responses to climate change.

P-2259

## Applying deep learning convolutional neural networks for improved automated classification of pollen

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### Abstract

Pollen-based vegetation reconstructions underpin much of our understanding of late Quaternary ecological and climate change. Yet pollen analysis is a time-consuming and subjective process. Thus it is no surprise that the automation of pollen counting has increasingly featured within the literature, especially with the rapid enhancements of computing and imaging technology in recent decades. While the results of existing studies can be regarded as promising, they are limited in that they typically deal with a relatively small number of taxa (max 26, mean 8), and accuracy rates vary. While some palynological applications may require a lower level of taxonomic diversity than others, it is arguable that many real world pollen problems, such as those faced in Quaternary vegetation reconstructions, will require higher diversity than that of most of the existing studies. Previous reviews have suggested that the minimum number of taxa for paleoecological applications would be around 40 types.

Here we have applied two types of deep learning convolutional neural networks (AlexNet and DenseNet) to classifying pollen images from 46 different taxa. Our dataset includes several pairs of morphologically similar types which human analysts traditionally have difficulty separating (*Leptospermum scoparium* and *Kunzea ericoides*, *Fuscospora truncata* and *Fuscospora fusca*, *Brachyglottis* and *Olearia*). Images were captured automatically using the Classifynder™ automated palynology system.

The DenseNet and AlexNet CNNs achieved 99% accuracy in classification. 97 - 99% on a 46 class problem is the highest success rate, when weighted for the number of taxa, of any attempt at automated pollen analysis currently documented in the literature. Our next steps are to modify the algorithms to provide a classification confidence measure to help with 'unknown' pollen types and other objects not featured within the training library, and to test the systems on broken and deformed pollen, such as those encountered in Quaternary samples.

P-2260

## Paleoecological Late Holocene tale of varved Lake Kuninkaisenlampi, eastern Finland – Diatoms, natural eutrophy, and erosion intensity changes

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### Abstract

Varved (i.e. annually laminated) lake sediments allow high temporal resolution studies of short- and long-term environmental change. Several varved lakes have been documented in Finland. Most have clastic-organic laminae and are located on catchments comprising till, bedrock, and fine-grained materials. The clastic laminae typically reflect the intensity of spring floods, but recently a marked difference has been discovered in the climate-catchment interaction of lakes located on fine-grained basal till in central Finland. Lakes in this fine-grained till region are also naturally eutrophic, in contrast to the nutrient-poor lakes in areas with coarse-grained basal till. Fine-grained tills occur sporadically in regions once covered by the Eurasian and Laurentide ice sheets. Their occurrence has been associated with ice sheets overlying sedimentary bedrock. However, the fine-grained till overlying crystalline bedrock in central Finland formed under inactive continental ice between actively flowing ice streams. Its fine fraction includes redeposited interglacial sediments. Despite the important contribution of fine-grained till to the functioning of lakes, studies on such lakes are limited.

We deepen the knowledge on these exceptional lakes by examining the varve-dated diatom assemblage responses of Lake Kuninkaisenlampi to natural and anthropogenic drivers during the Late Holocene. The small and naturally eutrophic Lake Kuninkaisenlampi is located in the fine-grained till area of central Finland and it is connected to a larger drainage system via a narrow channel. Our sample resolution increases from centennial to decadal towards the top of the sediment core. The rate of diatom assemblage change remained stable until the 19th century, when small cyclotelloid and elongate pennate taxa became more abundant, diatom-inferred electrical conductivity (DI-EC) increased, and diatom-inferred total phosphorus (DI-TP) decreased. Similar conditions existed also prior to 2.7 kBP. The first axis of principal component analysis (PCA), i.e. the largest variation in the diatom data, correlated strongly with DI-EC ( $r = 0.88$ ,  $p < 0.001$ ), whereas DI-TP had weaker but statistically significant correlations with the first and second PCA axes ( $r = -0.32$ ,  $p = 0.012$  and  $r = -0.56$ ,  $p < 0.001$ ). Both the 2.7 kBP and the 19th century diatom assemblage shifts could be related to changes in erosion intensity, the prior possibly linked with the transition from Subboreal climate to Subatlantic and the latter with intensified land use.

P-2261

## The climate condition and vegetation change by flood during the Late Yayoi period in Wakasa region, central Japan

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### Abstract

Five Lakes of Mikata, i.e., Lake Mikata, Lake Suigetsu, Lake Suga, Lake Kugushi and Lake Hiruga are located in the lower stream of Hasu River along the Japan Sea coast of Wakasa region, central Japan. Flood layers formed in the Late Yayoi period (1<sup>st</sup> century AD to 3<sup>rd</sup> century AD) are intercalated in the sediments of Lake Suigetsu, Lake Suga and Lake Hiruga in the region. Ego archaeological site in Hasu River basin was hit by a debris flow disaster during the Late Yayoi period. The pottery was dated to be 37 cal BC - 76 cal AD. During the same period, Kurota lowland which is located in the upper stream area of the lakes was a lake judged from the sediment condition. It is said that the Japanese islands were politically unstable and the Chinese history books, Book of Later Han and Record of Three Kingdoms described that many internal disturbances occurred in the Late Yayoi period. It is considered that cold and unstable precipitation during the Late Yayoi period caused the disturbances based on the oxygen stable isotope analysis of Kiso-hinoki cypress and the description in the history book of Silla.

Pollen analysis of the sediment recovered from Lake Hiruga was conducted from the lakes and Kurota lowland to see if the vegetation changes were related to debris flow disasters that can be detected during late Yayoi period. Climate conditions were quantitatively reconstructed by the modern analogue method.

The lake area was covered with a dense *Cryptomeria* and evergreen broad-leaved forest, while, the upper stream area was covered with a *Cryptomeria* and *Alnus* forest from the Yayoi period to the 8th century according to the results of pollen analysis. The annual mean temperature became low from the 1<sup>st</sup> century AD based on the climate reconstruction. The reconstructed annual precipitation was high throughout the time, but it became higher during the Late Yayoi period. The high precipitation period continued to the 10th century. Several floods occurred during the high precipitation period. The pollen record of Lake Hiruga indicated that floods seemed to destroy the vegetation cover around the lakes. All pollen taxa decreased at one of floods during the Late Yayoi period. Just after the flood, pollen of *Alnus* which grows in wetlands increased. The vegetation was recovered in 50 years. Rice cultivation seemed to become active in the upper stream area around the 1st century AD during the wet period.

This research was supported by the Environment Research and Technology Development Fund (4-1505) of the Ministry of the Environment, Japan and the Research Institute for Humanity and Nature (RIHN), Japan (no. 14200103). The coring of Kurota lowland was conducted by students at Wakasa High School, Obama city, Japan.

P-2262

## The Holocene vegetation dynamics and human influence on the alpine environment in the Julian Alps, Slovenia

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### Abstract

The presence of people in the high elevation alpine areas has long been discussed, mostly by trying to understand the main reasons for human occupation of such an extreme habitat. In many regions in the Alps, human settlements have been well documented but in the area of Julian Alps (Slovenia), few evidences have been reported until recent archaeological data. These data indicate that people have been living in the area since the Mesolithic (Cevc & Horvat, 2006). However, the Holocene environment and the human activity (pastoralism, metallurgy) are poorly investigated. In order to recognize vegetational changes and possible human influence throughout the Holocene, microcharcoal and pollen analyses of mountain lake sediments were made. Two lake systems located at different altitudes are 'Jezero na Planini pri jezeru' (1450 m a.s.l.) and 'Jezero v Ledvicah' (1830 m a.s.l.). At lake 'Jezero na Planini pri jezeru', three cores with an entire depth of 237 cm were sampled and cover the last 8000 years and at the 'Jezero v Ledvicah' two cores with a total depth of 212 cm represent the last 5000 years. Pollen results indicate that since c. 4700 cal. BP forest composition was mixed with dominant *Fagus* and *Picea*. Preliminary results also show intensive land use including pastoralism (*Plantago l.* and decline of *Abies*) and agricultural activity (*Cerealia* type, *Secale*, *Cannabis*, *Fagopyrum*), which would indicate continuous human influence on this alpine environment, especially in the Modern period (since the 15<sup>th</sup> century AD onwards).

**P-2263**

## **Multi annual- to decadal NAO and AO spring season signals reflected in leaf morphology in Greenland and Finland.**

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### **Abstract**

Climate change is affecting (sub-)Arctic environments, causing a significant lengthening trend of the vegetation growing season in the Northern Hemisphere. This has great impact on vulnerable polar ecosystems and affects the carbon and hydrological cycle. In NW Europe, winter and spring climate conditions are related the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO). Past dynamics of these atmospheric circulation systems can be tested on localities at endpoints of the bipolar circulation systems. By using paleobotanical techniques, including the Undulation Index-based growing season length proxy, past growing degree days (GDD) can be reconstructed. The Undulation Index-proxy is obtained by cuticle analysis and reflects the duration and thermal properties of the plants growing period. Applied to leaves from herbarium records from Greenland and fossil leaves from young peats in Finland, we determine growing season dynamics over the past 200 years. The study areas are in the opposite response region of the NAO, and therefore representative for the expression of temperature changes and spring season dynamic trends on annual to decadal scale. Meteorological data are used for calibrating the UI-proxy against modern local GDD, as they capture the growing season duration and thermal intensity. The recorded spring dynamics in the leaf morphology of subarctic *Betula* can subsequently be compared against instrumental records of the atmospheric circulation systems. Constructed proxy records will provide insight in the expression and dynamics of the rapidly changing spring season over NW Europe, as spring dynamics heavily influence overall growing season properties, resulting in important future implications on agriculture and ecology management.

P-2264

## Ice records provide novel insights into climatic vulnerability of Central Asian forest communities

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### Abstract

The Central Asian forest-steppe ecotones are highly vulnerable to environmental shifts such as drought and overgrazing (Lkhagvadorj et al. 2013). Knowledge about past vegetation and fire responses to environmental change may contribute to a better understanding of future ecosystem dynamics. However, paleo records are scarce in the region.

Our novel high-alpine ice record from Tsambagarav glacier (4130m a.s.l.) in the Mongolian Altai provides unique paleoenvironmental information at the landscape scale with an exceptional temporal resolution and a sound chronology covering the past 5500 years (Herren et al. 2013). We use pollen as proxies for vegetation composition and structure, microscopic charcoal as a proxy for fire activity, and spheroidal carbonaceous particles (SCPs) to infer fossil fuel combustion (Brugger et al. 2018).

We present the first microcharcoal-inferred fire history record from Mongolia which can be directly linked to past vegetation dynamics. Reconstructed mid to late Holocene forests collapsed and fire increased, likely in response to climate change. Our results underscore the vulnerability of relict forest ecosystems in the Mongolian Altai and imply that in these steppic areas, moisture is more important than temperature for tree growth. We conclude that Central Asian forest ecosystems including the Russian Altai are highly vulnerable and may collapse rapidly in the future, if global warming will be associated to moisture declines as anticipated by regional climate models.

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P-2265

## The Holocene fire history and development of lower mountain/foothill forest in the Western Carpathians, southern Poland

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### Abstract

The aim of this study was to compare forest and fire history recorded in small mires that developed within landslide depressions in Western Carpathians. The analysed sites are located in the Beskid Makowski (lower mountain forest zone) and Beskid Wyspowy Mountains (foothill forest zone). The profiles retrieved from both sites were densely dated using <sup>14</sup>C AMS method and subjected to pollen, charcoal and plant macrofossil analyses. The profile from the Beskid Makowski Mountains dates back to ca. 11,200 cal. BP when *Pinus sylvestris*, with an admixture of *Betula*, *Picea abies*, *Populus*, *Pinus cembra*, and *Larix decidua*, were the main constituents of the woodlands. About 11,090 cal. BP *Ulmus* advanced rapidly (>10 % of pollen) contributing to the withdrawal of *L. decidua* and *P. cembra*. During the period of ca. 11,230–10,710 cal. BP high fire activity was identified. About 10,280 cal. BP *P. abies*, afterwards ca. 10,030 cal. BP *Corylus avellana*, and ca. 9930 cal. BP *Tilia* started to expand, which contributed to the retreat of the *Pinus–Betula* woodlands. About 4400–4000 cal. BP *A. alba* spread restricting *C. avellana* and *Tilia*, and gradually *P. abies*. About 2700 cal. BP *Fagus sylvatica*, being earlier an admixture in *Abies–Picea* forests, became more frequent, whereas ca. 2020 cal. BP it reached an optimum. The topmost layer, covering the last ca. 400 years represents increased human activity and vast deforestations. The profile from the Beskid Wyspowy Mountains reached at the bottom ca. 9500 cal. BP. *C. avellana* dominated in the site vicinity until ca. 8540 cal. BP which was related to high fire activity, contrary to patterns revealed by the site from the Beskid Makowski Mountains. This was also a period of gradual spread of *P. abies* which dominated in the local forest from ca. 8520 to 3120 cal. BP. From ca. 4920 cal. BP *A. alba* and *F. sylvatica* became probably regular but scattered component in local forests. About 3120 cal. BP *A. alba* started to dominate (up to ca. 20 cal. BP) simultaneously to the spread of *P. sylvestris* and to a lesser degree of *F. sylvatica*. It probably contributed to *P. abies* withdrawal. The beginning of *A. alba* domination was connected with a rapid increase in fire activity (ca. 3320–3030 cal. BP) as well as a gradual human-induced decline of this species and of *F. sylvatica* (since ca. 740 cal. BP). Both sites, even if situated relatively close to each other, revealed different patterns in terms of timing of major forest changes and fire activity with its impact on vegetation changes.

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P-2266

## A multi-proxy high-resolution insight into *Carpinus betulus* (palaeo-) ecology during the last 1800 years: a case study from northern Poland

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### Abstract

Small peatlands are sensitive archives recording local to global environmental and climate changes. The aim of the research is to reconstruct vegetation, water table and fire activity changes in relation to human impact and climate changes. We selected 118 cm of the peat profile and contiguous 1-cm subsamples were selected for: pollen, non-pollen palynomorph (NPP), plant macrofossil, testate amoebae (TA), microcharcoal (0.01-0.1 mm), macrocharcoal (>0.1 mm) and geochemical analyses. The absolute chronology is based upon a Bayesian age-depth model comprising 18 <sup>14</sup>C AMS dates and <sup>210</sup>Pb dates. The analysed section of the profile spans 1800 calibrated years with a hiatus between ca. AD 1300–1890. Hydrology of the peatland was very unstable through time, reconstructed testate amoeba-based water table depth revealed a decreasing trend up to the present times. The results revealed the domination of a *Pinus sylvestris*-*Betula-Quercus* forest in the peatland vicinity during the entire studied period. Distinct agricultural activity and strong deforestation before ca. AD 370 were related to the occupation during the Roman Period of the Wielbark Culture communities. From ca. AD 400 hornbeam (*Carpinus betulus*) started to spread along with the significant weakening of human activity during the Migration Period and it reached an optimum (pollen >10 %) during the period of ca. AD 630–1060. Around AD 670 *Tilia cordata* started to occur regularly which might indicate the establishment of forest type similar to the modern *Tilio cordatae-Carpinetum betuli* association. Our results showed that a period of ca. 300 years after the decline of agricultural activity is necessary for the establishment of this forest type. Simultaneously *Fagus sylvatica* became more regular, but as a scattered forest component. The stage of *C. betulus* optimum in the forest was characterised by many quasi-regular increases in fire activity as reflected by the microscopic charcoal data. The occurrence of a local peat fire, which is indicated by high concentrations of macrocharcoal (probably during the 19<sup>th</sup> century AD) contributed to the loss of the peat layer spanning the period of ca. AD 1300–1890. The reliable chronology of the profile combined with the palaeoecological analyses of the contiguous samples give a unique opportunity to investigate the long-term ecology of naturally regenerated forests. This research was funded by National Science Centre (Poland), grant 2015/17/B/ST10/01656 and the funds of National Programme for the Development of Humanities (Project: NPH012; PI: Piotr Guzowski).

P-2267

## Vegetation changes during the last 4 millennia in west tropical Africa

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### Abstract

Compared to the large-amplitude changes in vegetation that characterized the tropical regions during the last glacial-interglacial transition, the last millennia appear to have been relatively "stable". At the end of the Holocene Humid Period (HHP), all the forests which widely expanded throughout the tropics dramatically decreased and the environment switches to its modern aspect (e.g., Vincens et al., 1999; Hély and Lézine, 2014). However, increased lines of evidence show that the 3 to 5 millennia that followed the end of the HHP have also recorded noticeable environmental changes (Nash et al., 2016).

In this study we analyse how ecosystem vulnerability in response to climate hazards has developed in the past at both large and small time scales. We investigate changes in vegetation during the last 4 millennia in two sectors of West tropical Africa: the gallery forests of Senegal (Mboro and St Louis) and the montane forests of Cameroon (Bambili). New, high resolution pollen analyses are used to discuss the following questions: (1) did the dramatic switch from forest to grassland communities which occurred at the end of the HHP result from a crossed threshold or from a longer process characterized by successive disappearance of forest tree species? (2) what was the timing and amplitude of the environmental changes which punctuated the last millennia? A focus is put on the last millennium and the key environmental and/or anthropogenic factors at play.

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P-2268

## Decadal environmental change in the Marrakech High Atlas: Impacts of snow melt on alpine ecology during the last 500 years

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### Abstract

In arid and semi-arid mountainous regions, the role of meltwater is especially important for agricultural activities, human development and the wider economy. In Morocco, fluctuations in snow and ice in the Atlas Mountains directly impacts on the fluvial regimes of rivers throughout Morocco. Therefore, past environmental changes, driven by changes in winter snowfall, may have influenced human development over time. Currently, very little is known about the state of the cryosphere in North Africa during the Holocene.

Here, we present a new high-resolution (12 year) pollen and non-pollen palynomorph (NPP) record for the last 500 years from a spring-fed alpine marsh at Oukaimeden, located in the Marrakech High Atlas, Morocco. The site is set within a largely open but dynamic landscape influenced by several forcing factors which affect the alpine ecology (including snow melt). Arboreal pollen is largely absent, while non-arboreal pollen reveals shifts between wet and dry conditions, inferred to be driven by changes in winter snowfall and subsequent spring snowmelt. Wet periods have high Cyperaceae pollen abundance and corresponding increases in NPPs indicative of wet environments. Conversely, drier periods see low abundance of these taxa, while Poaceae abundances are high. Basal radiocarbon ages indicate that the marsh formed near the time of the onset of the northern hemisphere Little Ice Age (LIA). Recurrent (multi-decadal to centennial) wet intervals appear to correlate with reduced drought stress in Moroccan tree rings, increased humidity as indicated in Middle Atlas speleothems, and phases of glacier advance in European mountains. There is evidence of pastoral exploitation of the marsh throughout the record highlighting the importance of such alpine wetlands for mountain societies and the wider regional economy.

Our working hypothesis is that intervals of high snowfall during the LIA (and possibly other Holocene cooling episodes) allowed permanent snowpack and glacier development in the High Atlas. The cryosphere expansion contributed to sustained year-round wetter conditions in the alpine valleys, promoting wetland development and increased productivity of alpine pastures. An enhanced pastoral economy ensued which underpinned societal development, urbanisation and trade in southern Morocco.

P-2269

## A severe drought homogenizes the diatom composition of two shallow lakes in southwest China

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### Abstract

In the context of global warming, extreme droughts have occurred more frequently and this is projected to continue in the future in many parts of the world. However, their ecological consequences on shallow lakes are not well studied. Here we compare the succession of diatom assemblages of two medium-sized shallow lakes in southwest China during the past ~70 years and under the impact of an extreme drought event between 2009 and 2013. Before the drought, Lake Yuxian was characterized by a stable diatom composition which was dominated by *Fragilaria* sensu lato (e.g., *F. construens/pinnata* complex) and *Achnanthes minutissima*. In contrast, the diatom composition of Lake Chahei was increasingly affected by eutrophication from the 1970s as inferred by enrichment of sedimentary  $\delta^{15}\text{N}$  values. The pioneer species *Achnanthes minutissima* increased at the expense of *Epithemia sorex*. In both lakes, the most striking change occurred with the recent drought event when species of the genera *Nitzschia* and *Navicula* and *Surirella angusta* (NNS group) became abruptly dominant. This is also reflected in a strong decrease in the Jaccard dissimilarity index, indicating increased homogeneity in the previously distinct diatom compositions of the two lakes. The increased abundance of the NNS group was preceded by a peak in the percentage of silt in both study sites, suggesting more turbid conditions in the remaining lake water during the drought event. Species of the NNS group are characterized by motility, which allows them to actively seek out optimal habitats and makes them well adapted to conditions that prevail in shallow lakes during severe droughts. For the study region, several drought events are documented since ~1950. However, the diatom composition at both study sites displayed no or a relatively muted response, suggesting that a threshold level of hydrological fluctuation may exist beyond which the resilience of diatom communities is significantly reduced. Hence, this study finds that diatom species of the NNS group can serve as paleo proxies for the reconstruction of severe drought events (with a large magnitude of hydrological fluctuation) in shallow lakes.

P-2270

## High-resolution palaeoecological analyses reveal tree plantation, hemp cultivation, and neophyte immigration in the Alps, Switzerland, since the 16th century AD

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### Abstract

Palynological and plant macrofossil analyses performed on a 82 cm long stratigraphy from the small Alpine peatland „Blackenalp-Oberes Moor“ (Attinghausen, Canton Uri, Switzerland, 1820 m a.s.l.) allowed detailed insights into the local flora, vegetation and landscape development since the late 16<sup>th</sup> century on a ca. 20 year-resolution. At that altitude, a treeless open pastoral landscape prevailed during the Little Ice Age, whereas fruit trees such as chestnut (*Castanea sativa*) and walnut (*Juglans regia*) were planted in the lowlands. From ca. AD 1650–1900, the nearby valleys of Engelberg in the West and the Reusstal in the East were also used for the cultivation of hemp (*Cannabis*) and for the agricultural production of cereals (incl. rye – *Secale cereale*). Since AD 1900, a continuous record of *Ambrosia* pollen gives evidence for the regional immigration and expansion of this neophyte. Pollen from corn (*Zea mays*) around AD 1930 hints at the introduction of this crop for fodder purposes. These pollen evidences do well correlate with written sources on the intentional and non-intentional introduction of above-mentioned plants.

P-2271

## Vegetation responses to abrupt climatic shifts during the Last Glacial-Interglacial Transition: evidence from a north-south transect across the British Isles

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### Abstract

The Last Glacial-Interglacial Transition (LGIT; 16-8 ka BP) in northern Europe is a well-characterised period of abrupt climatic change where millennial-scale oscillations in climate led to large-scale reorganisation of ecosystems. Imprinted upon these longer-term episodes are a series of centennial-scale climatic oscillations which are far less well understood. These short-lived events appear to be spatially and temporally complex across northern Europe and frequently have either not been identified or are shown to have limited impact. Furthermore, many sequences have not been studied for proxies that provide evidence of a palaeoclimatic driver and vegetative response, or they are not resolved in sufficient detail. Consequently, landscape responses to these abrupt events are largely unknown and phase relationships cannot be adequately constrained.

We present research from a number of sites spanning a latitudinal and climatic gradient across the British Isles, from northern and central Scotland, north-east England and south Wales. The sites contain high-resolution palaeoclimatic reconstructions, including oxygen isotopic data ( $\delta^{18}\text{O}$ ), chironomid-inferred summer temperature reconstructions (C-IT) and biomarker compound-specific isotope data ( $\delta\text{D}_{\text{wax}}$ ) as a palaeohydrological proxy. These data occur alongside high-resolution palynological and charcoal records and have been chronologically constrained through radiocarbon and/or tephrochronology. In general, the sequences demonstrate vegetation responses to abrupt climatic change across millennial and centennial climatic transitions during the LGIT. However, the characteristics and dynamics of vegetation responses vary between individual sites and across time-periods. For example, during the Lateglacial Interstadial, following climatic deteriorations, upland locations demonstrate wholesale landscape change with concomitant increases in herbaceous taxa with ecologies of landscape disturbance; whereas, lowland sites show an 'opening' of the landscape under similar climatic stress. In contrast, during the early Holocene vegetation change at the centennial-scale appears muted.

The collection of data presented here also allows for an understanding of the phasing between climate and landscape response within the sequences. Early Interstadial and early Holocene vegetation changes appear not to exhibit a significant lag with climatic shifts. This is in contrast with the greater lag in vegetation response observed during the later Interstadial. The data suggest that the magnitude of the climatic event, non-linearity in vegetation response and stages of vegetation development are important controls over the phasing between climatic drivers and vegetation responses during the LGIT. These effects may be further mediated by the role of fire across each of the sites.

P-2272

## Neolithic forest use and dynamics around Lake Mondsee, Austria, revealed by palynological analyses at decadal resolution

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### Abstract

Our comprehension of past ecosystem changes lies on palaeoecological studies. The vegetation is a major component and one of the main descriptors for an ecosystem. Palynological analyses can reliably reconstruct past vegetations. However, they are time consuming, and high resolution is rarely achieved. We achieved such a resolution with contiguous sampling for the Neolithic Period of well-dated sediment cores from Lake Mondsee, Austria. Our continuous record of 166 1-cm thick sediment samples runs from 4600 to 1950 BC, covering the archaeologically defined, so-called *Mondsee Culture*. Each sample contained the pollen signal of 2 to a maximum of 35 years of the surrounding vegetation (median 14 years). Sequences of higher pollen amounts of *Corylus avellana*, *Betula sect. alba*, *Fraxinus excelsior*, and *Fagus sylvatica* were regularly found along the record. Assuming that they derive from secondary vegetation succession, we questioned possible triggers for these successions. Three origins are plausible: stochastic, climatic, or anthropogenic. To address this question, we compared the palynological signal of these forest cycles with possible erosion and flooding events provided by  $\mu$ -XRF analyses, with climatic data, and with archaeological evidence. Finally, we compare the forest vegetation dynamics with fire events through the micro-charcoal signal, using cross-correlations. These comparisons suggest that the *Mondsee Culture* populations may have practised a particular forest management, using fire to open the landscape, and that their practises were the main (if not the only) driver of vegetation change in the area, leading to secondary forest successions during periods of lower anthropogenic and livestock pressure.

P-2273

## A glimpse into Neolithic pile-dwelling societies: Multi-proxy study of the 3550 BC old lake-littoral settlement Mooswinkel, Lake Mondsee, Austria

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### Abstract

Cultural sediment layers of the short-lived Neolithic lake village of Mooswinkel (Upper Austria) radiocarbon dated to  $3542 \pm 153$  BC were analysed in an interdisciplinary study between palaeoethnobotanists, palynologists, wood-anatomists, sedimentologists, radiocarbon specialists and archaeologists within the International D.A.CH-Programme „Beyond Lake Villages“ (2015–2019). This study was performed on a 1.15 m long sediment core with a diameter of 9 cm extracted 2 meters underwater in the southwestern part of the former village area, and comprised Neolithic cultural layers 50 cm thick. The high-resolution sedimentological, XRF-scanning ( $\mu$ -XRF), palynological, and palaeoethnobotanical analyses revealed that these cultural layers were quickly deposited at the littoral north-eastern edge of Lake Mondsee in a humid, non-inundated state, attesting therefore an at least 2 meters lower lake level during Neolithic Times than today. It also revealed a huge amount of plant macrofossil remains such as from strawberry (*Fragaria vesca*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*), pomaceous fruit trees (*Malus/Pyrus*), hazel (*Corylus avellana*), flax (*Linum usitatissimum*), and cereal chaff (such as from *Triticum monococcum*) within the cultural layers, all witnessing Neolithic fruit collection and crop production practices. However, whole cereal grains were not found, implying eventually the presence of a Neolithic refuse heap in this near-lake, southwestern part of the former pile-dwelling village. The determination of several wood and charcoal remains to species level added massively to the palynological reconstruction of the tree and shrub vegetation in and around the site, and the according use by Neolithic societies. Pollen finds of mistletoe (*Viscum album*) and ivy (*Hedera helix*) do hint at the use of these species as winter fodder for livestock, and pollen of boneset (*Symphytum*) might be the result of the palaeoethnobotanical use of this taxon for medical purposes. High elemental copper values within the organic cultural layers might have been the result of local copper smelting and production within the prehistorical settlement. In addition, some bones, silex radiolarite, gem (epidot), slag, ceramic, coleopteran, and twined fiber remains give detailed insights into prehistoric live of these Central European Neolithic societies belonging to the so-called Mondsee-Culture.

P-2274

## Centennial and millennial-scale dynamics in *Araucaria-Nothofagus* forests in the southern Andes

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### Abstract

We aim to assess the relative roles of long-term role of climatic change, fire and volcanic disturbance on the dynamics of *Araucaria-Nothofagus* forests of south central Chile. We developed a new 8500 year (8.5 kyr) pollen, charcoal and LOI dataset from Lago Cilantro, Chile (38°51'36.71"S, 71°17'14.17"W). The new dataset was compared to proxies of regional climatic change and Superposed Epoch Analysis was employed to test the relationship between tephra depositions and pollen composition. Millennial-scale trends are dominated by a shift from *Araucaria* to *Nothofagus* dominance in concert with increasing regional precipitation and decreasing local-scale fire activity between ca. 8.5-5.5 ka, with a reversal of this trend after ca. 4 ka in concert with a reduction in regional precipitation. Centennial-scale increases in *Araucaria* are associated with a reduction in the fire-return-interval. Tephras >2 cm thickness are associated with short-term (<100 year) compositional shifts in the pollen spectra, while a single large (255 cm) tephra at ca. 3 kyr is associated with a substantial reduction in *Nothofagus* and no change in *Araucaria*. Our data indicates that climate and climate mediated fire activity are the dominant drivers of millennial-scale *Araucaria-Nothofagus* dynamics at our study site. A shortening of the fire-return-interval is associated with an increase in the importance of *Araucaria*, supporting the notion that recurrent fires are required to allow this tree species to compete with *Nothofagus*. Tephras drive a short-term, compositional response in this system that appears to be overwhelmed by climate and fire at longer-timescales. *Araucariaceae* survive and potentially take advantage of very thick tephra deposits relative to *Nothofagus*, likely due to the physiological traits of thick bark and tall canopy (>15 m).

**P-2401**

**The interstadial/stadial type changes during the Late Saalian and three abrupt intra-Eemian climatic events - the Boćki site, E Poland**

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**Abstract**

About 100 samples of palaeolake sediments from the profile coring at the Boćki site, E Poland, were examined by pollen analysis. On the basis of obtained results, we determined that the studied sequence span the closing phase of the Warta Stage of Odranian Glaciation (Late Saalian), and Eemian Interglacial. The studied profile turned out to be unique, because it contains the pollen record of almost all abrupt climate-vegetation events registered already earlier for this part of the Upper Pleistocene in Central Europe and other regions of the world, including: (i) the interstadial/stadial type changes at the end of Late Saalian, (ii) climatically induced intra-Eemian break in sediment accumulation (hiatus) that was covered the end of hornbeam phase (E5) and the whole spruce phase (E6) and (iii) temporary cooling in the middle part of the pine phase (E7) of the last interglacial that was resulted in the decrease in forested areas and the increase in open plant communities of a cold step type. Additionally, in the investigated profile there is also a record of the sedimentation gap during the oak phase (E3). Similar event has recently been recognized in several other profiles from E and NE Poland.

P-2402

## A 27 ka paleoenvironmental lake sediment record from Taro Co, Tibetan Plateau: implications for the interplay between monsoon and Westerlies

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### Abstract

The interaction of the Indian Ocean Summer Monsoon (IOSM) and the Westerlies is a crucial scientific issue to understand how they impact the climate on the Tibetan Plateau (TP), especially in the geological times. Here we present a lake sediment record retrieved from Taro Co covering the last 27 ka to elucidate how the IOSM and the Westerlies interact.

Taro Co (486 km<sup>2</sup>,  $D_{max}$ : 132m, 4565 m a.s.l., currently closed), located on the central TP, is a fresh lake with the major supply from glaciers. Two parallel piston cores as well as several gravity cores were retrieved from the deepest parts. These cores were correlated based on high resolution XRF scanning and a continuous 1069 cm-long core was finally integrated. Chronology was determined by <sup>210</sup>Pb, <sup>137</sup>Cs and AMS <sup>14</sup>C measurements. Multidiscipline analyses including grain size, total organic carbon (TOC), total nitrogen, diatom, pollen and n-alkanes were accomplished to reconstruct paleoenvironmental changes.

The lake level of Taro Co was low since 27 cal ka BP indicated by very coarse materials and diatom assemblages. The terrestrial water input decreased continuously reflected by such elements as Si, Ti, Fe, K. It is likely that there was a sedimentation gap between 961-954cm, corresponding to 23.4 to 18.6 cal ka BP probably demonstrated Taro Co was very shallow at that period. The first prominent abrupt change of most proxies was observed at 14.7 cal ka BP showing a great lake deepening which likely indicated an enhancement of IOSM. There were several spells with abrupt changes of cold/warm stages before the Holocene and the Younger Dryas event occurred at 11.8 cal ka BP. During the Holocene, carbonate dissolution was identified at 9.76 to 3.44 cal ka BP which indicated a high moisture availability hence high lake level even the lake became an open system.

P-2403

## Differential response of vegetation in Hulun Lake region at Northeast China to extreme cold events of the last deglaciation

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### Abstract

The response of vegetation to extreme cold events during the last deglaciation is important for assessing the impact of possible extreme climatic events on terrestrial ecosystems under future global warming scenarios. Here, we present a detailed record of the development of regional vegetation in the northern margin of Asian summer monsoon during the last deglaciation (16,500–11,000 cal yr BP) based on a radiocarbon-dated high-resolution pollen record from Hulun Lake, northeast China. The results show that the regional vegetation changed from subalpine meadow-desert steppe to mixed coniferous and deciduous forest-typical steppe during the last deglaciation. However, its responses to the Heinrich event 1 (H1) and the Younger Dryas event (YD) were significantly different: during the H1 event, scattered sparse forest was present in the surrounding mountains, while within the lake catchment the vegetation cover was poor and was dominated by desert steppe. In contrast, during the YD event, deciduous forest developed and the proportion of coniferous forest increased in the mountains, the lake catchment was occupied by typical steppe. We suggest that changes in Northern Hemisphere summer insolation and land surface conditions (ice sheets and sea level) caused temperature and monsoonal precipitation variations that contributed to the contrasting vegetation response during the two cold events. We conclude that under future global warming scenarios, extreme climatic events may cause a deterioration of the ecological environment of the Hulun Lake region, resulting in increased coniferous forest and decreased total forest cover in the surrounding mountains, and a reduction in typical steppe in the lake catchment.

**P-2404**

## **Climate evolution since 9.4 ka in Keluke Lake, northeastern Qaidam Basin, China**

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### **Abstract**

Core sediments from Keluke Lake in transitional zone between arid central Asia and monsoon Asia, provide insights into the advance-retreat history of the summer monsoon and the Westerlies. Sediment grain size and  $\delta^{13}\text{C}$  of authigenic carbonate reveal paleoclimatic evolution since 9.4 ka: a dry-cold climate in the early Holocene, a wet-cold climate in the early stage of mid-Holocene, a relatively dry-warm climate in the late stage of mid-Holocene and, a moderately wet and frequently oscillating climate after 2.5 ka. Keluke Lake area was mainly controlled by the Westerlies from 9.4 to 5.8 ka, and was dominated by the East Asia monsoon during 5.8-2.5 ka. While in the late Holocene, this area was re-controlled by the Westerlies since 2.5 ka. The boundary line between the Westerlies controlled arid central Asia and monsoon Asia varied during the Holocene. When the Westerlies strengthened and the East Asian summer monsoon weakened, the boundary line may be pushed southeastward, and vice versa. Generally, the climate in this area showed a wet-cold and dry-warm variation. In arid northwestern China, the effective moisture mainly depends on the degree of evaporation. High evaporation in a warm climate leads to a low effective moisture and, consequently a dry-warm climate.

P-2405

## A 1000-year record of centennial-scale cyclic vegetation change from Maar Lake Sanjiaolongwan in northeastern China

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### Abstract

We present a high-resolution 1000-year pollen record of vegetation change from Sanjiaolongwan Maar Lake (SJML) in northeastern China. An age model was established using analyses of  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$  and AMS  $^{14}\text{C}$ . Our aims were to examine possible relationships between regional changes in vegetation and climate and fluctuations in solar activity. The pollen assemblages indicate that during the last millennium the vegetation of the study area was temperate coniferous and deciduous broadleaved mixed forest. Although *Pinus* is the most abundant pollen type, various lines of evidence suggest that it is not especially temperature-sensitive. However, from an analysis of changes in pollen assemblages over the past 1000 years and a comparison with pollen records from other lakes in the region, we conclude that *Quercus* frequencies can be used as a relatively sensitive temperature index for the study area. Several notable cold periods, with lower *Quercus* frequencies, occurred at approximately 1200 AD, 1410 AD, 1580 AD, 1770 AD and 1870 AD. These century-scale cold periods basically correspond to major minima in solar activity, leading us to conclude that variations in solar activity may have been an important driver of climate and vegetation change in the study area during the last millennium.

P-2406

## Postglacial fire history and interactions with vegetation and climate in southwestern China based on charcoal and pollen records

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### Abstract

A high-resolution, continuous 18.5 kyr (1 kyr=1000 cal yr BP) macroscopic charcoal record from Qinghai Lake in southwestern Yunnan Province, China, reveals postglacial fire frequency and variability history. The results show that three periods with high-frequency and high-severity fires occurred during the periods 18.5–15.0, 13.0–11.5, and 4.3–0.8 ka, respectively. This record was compared with major pollen taxa and pollen diversity indices from the same core, and tentatively related to the regional climate proxy records with the aim to separate climate- from human-induced fire activity, and discuss vegetation–fire–climate interactions. The results suggest that fire was mainly controlled by climate before 4.3 ka and by the combined actions of climate and humans after 4.3 ka. Before 4.3 ka, high fire activity corresponded to cold and dry climatic conditions, while warm and humid climatic conditions brought infrequent and weak fires. Fire was an important disturbance factor and played an important role in forest dynamics around the study area. Vegetation responses to fire after 4.3 ka are not consistent with those before 4.3 ka, suggesting that human influence on vegetation and fire regimes may have become more prevalent after 4.3 ka. The comparisons between fire activity and vegetation reveal that evergreen oaks are flammable plants and fire-tolerant taxa. *Alnus* is a fire-adapted taxon and a nonflammable plant, but density of *Alnus* forest is a key factor to decide its fire resistance. The forests dominated by *Lithocarpus/Castanopsis* and/or tropical trees and shrubs are not easy to ignite, but *Lithocarpus/Castanopsis* and tropical trees and shrubs are fire-sensitive taxa. Fire appears to be unfavourable to plant diversity in the study area.

P-2407

## Special features of the Eemian pollen succession from the Struga site (Garwolin plain, Central Poland)

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### Abstract

The study reports high resolution pollen analyses of the palaeolake sediment samples at G-120 Struga site in the Garwolin Plain (Central Poland). The pollen succession covers Late Saalian (MIS-6) and fully developed Eemian (MIS-5e) interglacial and has been divided in detail into regional zones and subzones according to Kupryjanowicz et al. (2018). The Late Saalian section contains sub-zones reflecting the alternating dominance of steppe-tundra and boreal forest communities. The analysed Eemian sequence is an uncommon succession described as a variant with early appearance and high culmination of *Tilia* (Granoszewski 2003). In these terms, the succession of the Struga site resembles those of sites of Eemian interglacial known from the vicinity of Warsaw: Błonie, Warszawa-Żoliborz and Warszawa-Wola. In the E5 *Carpinus* regional pollen zone, the individual *Fagus* grains are noticeable. It may suggest the presence of beech trees associated with excellent climatic conditions. The Struga site is one of several recently discovered fossil sites of the Eemian lakes in the Garwolin Plain, constituting the southern fragment of the extensive Eemian lakeland in the Polish Lowlands. Their pollen sequences differ in terms of thickness of deposits representing the same regional zones in spite of the fact that the palaeolakes are situated close to each other.

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**P-2408**

## **Response of diatom biodiversity at Huguangyan Maar Lake, in tropical-subtropical South China, to abrupt climate change during the last deglacial**

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### **Abstract**

Lakes are an important component of global ecosystems. Although the biodiversity of lake primary productivity plays a very important role in the lake ecosystem, little is known about how the biodiversity of lakes in tropical regions responded to climate change on the millennial timescales that are the most relevant for predicting future changes. In this study, we analyzed millennial-scale biodiversity changes during the last deglacial at Huguangyan Maar lake (HML), in tropical-subtropical South China. We used diatom records to reveal biodiversity changes, since diatoms are an important component of the primary productivity in lakes and are well-preserved in the sediments. Diatom biodiversity changed synchronously with millennial-scale climate change during the last deglacial at HML. Species diversity decreased rapidly at the end of abrupt cold events with the weakening of the East Asian Winter Monsoon (EAWM) decreased. These events include Heinrich 1 (H1) and the Younger Dryas (YD). The significant relationship between diatom diversity and the short-term changes in the EAWM may have been mediated via factors such as the role of water column stratification in affecting diatom suspension and nutrient availability. Our results suggest the possible occurrence of abrupt lake ecosystem responses to future human-induced climate change.

P-2409

## Asynchronous 500-year cyclic summer monsoonal rainfall change between north and south of East Asia associated with low latitude climate changes

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### Abstract

The summer monsoon plays a dominant role in the precipitation of East Asian Monsoon Region (EAMR), yet a long-standing unclarity exists concerning the spatial and temporal process and dynamics of precipitation in this region on centennial time scale. A decadal-resolution pollen record obtained from annually-laminated Maar Lake in Northeast China provided unambiguous evidence for vegetation and summer monsoon variability in EAMR. The Pollen record reflects ~500-year quasi-periodic vegetation and warm-humid/cold-dry changes in the north of EAMR throughout the past 9300 years. The speleothem record from previous studies also shows a ~500-year cyclic rainfall change in the south of EAMR during the Holocene. The humid (dry) phases in the north of EAMR nearly correspond to dry (humid) phases in the south of EAMR. Thus, the ~500-year periodic anti-phased precipitation change between the north and the south of EAMR are discovered for the first time during the Holocene. During the ~500-year periodic monsoonal change, "North Drought South Flood" condition prevails in El Niño-liked phase, whereas "South Drought North Flood" stage occurs in La Niña-liked (or normal) phase. Asynchronous ~500-year cyclic monsoonal climate change between the north and south of EAMR may be influenced mainly by El Niño-Southern Oscillation (ENSO), linked to the low-latitude oceanic and atmospheric process. These findings are particularly valuable in providing strong long-term evidence for our understanding of the climate mechanism in global monsoon regions, and may shed light on forecasting of future monsoonal rainfall changes.

P-2410

## A mid-Holocene dry event (~7.0 ka BP) recorded by pollen data from the Mu Us Sandy Land, China

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### Abstract

High resolution pollen record from Qigai Nuur, which lies between the steppe-dominated margin of the Loess Plateau to the southeast and the Tengger Desert to the northwest, showed that there was an obvious dry event (7.4-6.4 ka BP) lasting about 1000 years under the warm and humid mid-Holocene. The most remarkable feature of pollen record is considerable increases in *Chenopodiaceae* and *Ephedra* pollen percentages. This dry event was consistent with the pollen record from Diaojiaohaizi lake at a distance about 200 km. The event also has been recorded in the Chinese Loess Plateau, the western desert region of China, the Qinghai-Tibet Plateau and so on. There are two possible mechanisms leading to this event: one is drought caused by the decrease of precipitation caused by the recession of summer monsoon, the other is drought caused by the decrease of effective precipitation and the increase of evaporation caused by high temperature climate. This work need further study.

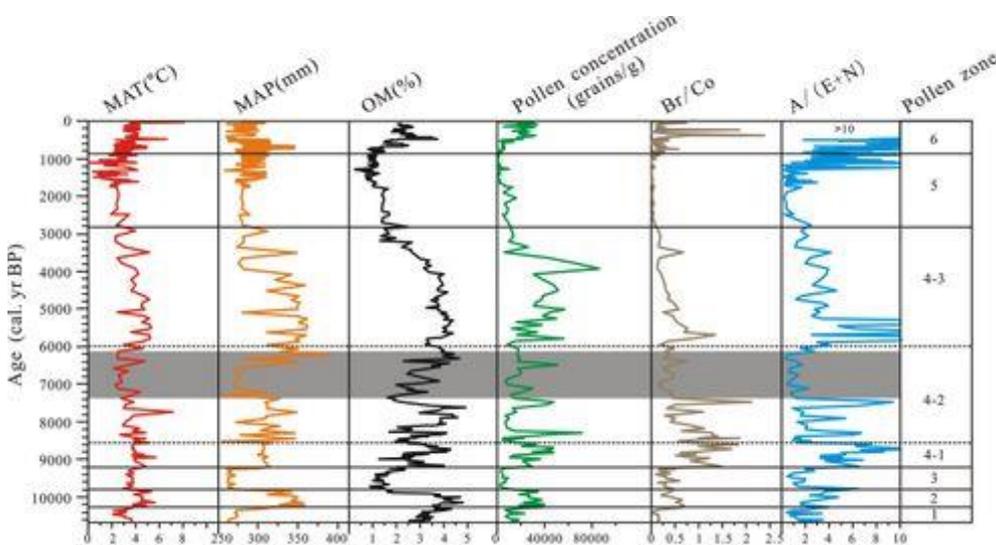


Figure. Comparison of reconstructed mean annual temperature (MAT) and mean annual precipitation (MAP) with other proxy data including OM (%) and pollen concentration (grains/g). Two pollen ratios are also presented for comparison and they are Br/Co (Br: Broadleaved tree pollen percentage, Co: Coniferous tree pollen percentage) and (E+N)/A (E=*Ephedra* pollen percentage, N=*Nitraria* pollen percentage, A=*Artemisia* pollen percentage). The dark-shaded strips marks the Holocene cool and dry stages (i.e., Pollen Zones 1, 3 and 5) and the light-shaded strips mark the mid-Holocene cool and dry epochs. The dash lines mark the trends of MAT and MAP changes.

P-2411

## The seasonal characteristics of Younger Dryas event inferred from the lacustrine records in the Great Khingan Mountain range, Northeast China

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### Abstract

The Great Khingan Mountain range, Northeast China, is located on the northern limit of modern East Asian Summer Monsoon (EASM) and the most active region of the East Asian Winter Monsoon (EAWM), thus highly sensitive to the variability of the East Asian Monsoon (EAM) from glacial to interglacial modes. The vegetation and climate change of this region should response to the Younger Dryas (YD) event, nevertheless, the seasonal characteristics of YD event in this region is still ambiguous. Here, we present high-resolution records covering the late glacial and the early Holocene from two closed crater lakes (Lake Moon and Lake Sifangshan) based on pollen, stomata, total organic carbon (TOC) and total nitrogen (TN), to reconstruct vegetation history and climate change during the glacial-interglacial transition and thus register the evolution of the EAM during the YD event. The results of pollen and stomata analysis indicate that the vegetation history of the Great Khingan Mountain range has remained forest steppe dominated by *Betula* and *Artemisia* from the late glacial to the early Holocene, and an expansion of the conifers dominated by *Larix* and the shrink of broadleaves and herbs from 12.8 to 11.8 ka BP. On the other hand, the values of TOC and TN do not have obvious change from 12.8 to 11.8 ka BP, which shows that the productivity of the lakes and coverage of land plants do not deteriorate during the YD event. All this results do not agree with the description of the YD event as simple climate deterioration, but the seasonal characteristics as a mild summer and extremely cold winter temperature caused by the enhancement of the EAWM in Northeast China. The seasonal characteristics and long duration of the YD event might provide the conditions for the pre-domestication of crops and the origin of the agriculture.

**P-2412**

## **Study on fluviolacustrine cyclic stratigraphy and its environmental significance in the Weihe Basin**

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### **Abstract**

The Weihe Basin is a mid-sized basin formed in Central China, which located at the margin of the Asian monsoon region, therefore sensitive to changes in monsoon precipitation. Long fluviolacustrine sediments are developed in the Weihe Basin. On the basis of a series of records from a fluvial sediment(HX core) in Huxian, Xi'an, we discuss the environmental significances of different proxies and attempt to discover more details about glaciation. Paleomagnetic results reveal that the Brunhes/Matuyama(B/M) boundary is in 177m, According that the 320-m HX sequence accumulated after 1.3 Ma. The lightness(L\*) shows a dominant 100-kyr glacial-interglacial cycles, the gamma-ray(GR) and susceptibility exhibit combined 100, 41, and 23-kyr cycles, whereas the apparent resistivity( $\rho_s$ ) displays clear precession oscillations over last 1.3 Ma. These proxies reflect different climate characteristics and may reveal varied responses of astronomical and ice forcing.

P-2413

## Vegetation and climate history in the arid inland area during the H1: multi-proxy date of the Balikun Lake

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### Abstract

Reconstructing the vegetation and climate in the arid inland areas during the Heinrich 1 (H1) event is beneficial for us understanding the relationship between arid ecosystem and abrupt climate change. We use multi-proxy analyses (e.g., lithology, grain size, LOI, XRF-Ti, pollen) of a sediment core obtained from Balikun Lake, eastern Tianshan Mts., to elucidate variations in sedimentation, vegetation and climate during the postglacial, with emphasis on the H1 event. The results show that: 1) the H1 deposition was dominated by sandy silt or silty sand, along with the high value of XRF-Ti, both indicated a high frequency of dust storm around the Balikun lake, which in turn brought more coarse material to the lake. Grain-size distribution of the H1 samples showed a similar mode to the modern aeolian dust collected from Balikun region. 2) the regional vegetation around Balikun Lake during the H1 was mainly dominated by desert and/or desert-steppe, with low vegetation cover reflected by the low pollen concentration, suggested a degraded environment, also the watershed bio-productivity showed a relatively low value. 3) a synchronous cold-dry climate prevailed over the mid-latitude inland areas of the Eurasia during the H1, and it caused a catastrophic drought condition along these areas with an (a) increase in aeolian input, shrink in lake area, and degradation of vegetation. The general pattern of widespread aridity in the arid inland areas during the H1 was generally caused by decreased evaporated water vapor along the westerlies linked to the low temperature, together with limited meltwater contributions of the mountain glaciers.

**P-2414**

## **Diatom recorded climate change in the Altai Mountains over the last 15 cal. kyr BP**

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### **Abstract**

Lake Kanas (48°11'-49°11'N, 86°23'-88°05'E; 1370 m a.s.l) is a large deep lake located in the southern Altai Mountains, fed by rainfall and melt water from Kanas Glacier in the high mountains. Regional climate is determined by the westerlies in summer and influenced by the Asian anticyclone in winter. In its sedimentary core, there is a high content of well-preserved diatom with rich species. Here presents the results of diatom analysis of the last 15 cal. kyr BP based on AMS <sup>14</sup>C dates of terrestrial plant materials, combined with environmental proxies such as grain size, biogenic silica, to reconstruct the regional abrupt climate changes and palaeoecological evolution of diatoms. The diatom assemblages in Kanas are dominated by various species since Holocene, four stratigraphic diatom zones could be distinguished. Before 11.5 cal. kyr BP, very few diatoms could be counted. From 11.5 to 7.8 cal. kyr BP, benthic species *Staurosirella pinnata* was the most abundant, which indicated that lake water was more transparent in the early Holocene. During this period, larger grain size indicated a higher in erosion processes on the near slopes, and relatively high alkalinity was in accordance with high Chrysophycean percentage, which might be connected with lower vegetation cover on the nearby slopes. From 7.8 to 3.5 cal. kyr BP, more planktonic diatom taxa appeared and increased in abundance together with benthic species *Karayevia suchlandtii*, indicating that the lake became more productive as diatom concentration increased, coincided with high content of biogenic silica, which might indicate warm summer and more nutrients input. Since 3.5 cal. kyr BP, the planktonic species *Pantocsekiella gordonensis* is largely dominated with smallest grain size, indicating more glacial rock flour deposits from Kanas Glacier in a colder climate.

P-2415

## Extant Ostracoda and their importance in Quaternary hydrological changes in Lake Nam Co, Tibetan Plateau, China

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### Abstract

Quaternary ostracod records from the Tibetan Plateau (TP) China show dramatic changes taking place during the Pleistocene and Holocene, including the occupation of large basins by freshwater lakes and their subsequent salinization and desiccation. Nam Co (30°30' - 30°56' N, 90°16' - 90°03' E) is the highest (4718 m a.s.l) and second largest (1962 km<sup>2</sup>) saline (1.3 ‰) lake system on the southeastern part of the TP. Its closed-basin and its maximum depth (> 100 m) allow a good sediment record for detecting past hydrological changes based on ostracods remains. Because ecological information is still poorly known, we determine the ecological preferences of extant ostracods from Lake Nam Co, in order to provide a reliable basis for the interpretation of Quaternary ostracod assemblages from sedimentary sequences. A total of ninety water and sediment samples were collected in 2018 from the lake and nearby rivers and lagoons. Modern sediment samples were taken to determine ostracode species composition and relative abundances from different depths using an Ekman grab and a hand net (125- $\mu$ m mesh) for littoral zone and rivers (0.5 – 1 m). Water samples were collected for chemical analysis (cations, anions, and isotopes [ $d^{18}O$  and  $d^{13}C$ ]); and physical variables (temperature, dissolved oxygen, conductivity and pH) were measured *in situ*. Characteristics such as proximity to glacier meltwater input, presence of slopes and macrophytes, anthropogenic influence, etc. were taken into account. Preliminary results based on taxonomic and quantitative analyses along with limnological information of the extant ostracod fauna identified distinct ostracod associations as a function of conductivity and water depth. Ostracod associations are related to: (1) rivers, characterized by low conductivity (300  $\mu$ S cm<sup>-1</sup>); (2) Nam Co Lake, characterized by high conductivity (1800  $\mu$ S cm<sup>-1</sup>); and (3) lagoons or ephemeral lacustrine environments, generally characterized by higher conductivity (<2000  $\mu$ S cm<sup>-1</sup>). Results suggest that quantitative-ecological significance of shell morphological variations such as nodding or shell size must be emphasized, including more samples from higher conductivity sites to establish accurate conductivity inferences. In addition, our approach serves as a model for future paleoecological studies that employ other aquatic bioindicators in Nam Co, such as testate amoebae, cladocerans, and chironomids.

P-2416

## Holocene abrupt climate change: the view from Crudale Meadow, Orkney Mainland.

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### Abstract

Utilising oxygen isotope ratios as tracers of past climate change is a well-established technique because of the range of materials (e.g. bulk carbonates, diatom silica etc.) that can be analysed and the sensitivity of isotopic composition to changes in temperature and precipitation, among other factors. This work uses the oxygen isotope composition of calcite from ostracod shells. These data will be used to reconstruct palaeotemperature and palaeoprecipitation of abrupt climatic events during the early-mid Holocene. The aim is to understand the driving mechanisms of palaeoclimatic change and the environmental and potential archaeological responses associated with them.

Crudale Meadow, SW Orkney Mainland, Scotland, has been identified as an ideal site to develop an ostracod derived oxygen-isotope record. Current sites demonstrating early Holocene oxygen-isotope records produce a SW to NE transect and includes sites from W. Ireland<sup>1</sup>, NW England<sup>2</sup> and extend into Scandinavia<sup>3</sup>. Crudale Meadow will contribute an additional site on this transect. Whilst there is an existing high-resolution bulk carbonate oxygen isotopic record for Crudale Meadow<sup>4</sup>, the skeletal chronology limits its usefulness for comparing with regional trends.

Here, a new multi-centennial scale oxygen isotopic record from ostracod shells covering the early-mid Holocene from Crudale Meadow is presented. The isotopic data from Crudale Meadow are produced from winter calcifying *Candona* species; these have proven an ideal choice due to their abundance, good preservation and presence throughout the sequence, and well characterised vital offset<sup>5</sup>. Moreover, because they are known winter calcifiers, the impact of isotopic enrichment due to lake water evaporation in the summer months is reduced. This work also provides additional chronological constraint by presenting a tephrostratigraphy for the Holocene Crudale Meadow sequence, anchored by the Saksunarvatn visible tephra layer at the base of the studied sequence section which is dated to 10,210 ± 70 cal. years BP<sup>6</sup>.

Overall this research contributes both an additional site to the existing SW-NE transect across NW Europe, and a northernmost British record. It further allows us the potential to reconstruct atmospheric circulation changes by compiling isotopic data from multiple NW European sites during the early to mid-Holocene and comparing these with outputs from an isotope-enabled General Circulation Model, allowing for research into driving mechanisms. This is important for furthering understanding regarding the relationship between palaeoclimatic change and proxy  $\delta^{18}\text{O}$  data.

**References:** <sup>1</sup>Holmes, J.H. *et al.* (2016) *QSR*, p.341-349; <sup>2</sup>Marshall, J.D. *et al.* (2007) *Geology*, 35, p.639–642; <sup>3</sup>Hammarlund, D. *et al.* (2002) *The Holocene*, 12, p.339–351; <sup>4</sup>Whittington, G. *et al.* (2015) *QSR*, 122, p.112–130; <sup>5</sup>Holmes, J.H & Chivas, A. (2002) *AGU Geophysical Monograph*, p.118-204; <sup>6</sup>Timms, R.G.O. *et al.* (2018) *Quat. Geochron.* 46, p.28–44.

**P-2417**

## **The Dark Age Cold Period recorded in lake sediments in the Netherlands.**

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### **Abstract**

Here we present the first chironomid-inferred summer-temperature reconstruction for the late Subatlantic in the central Netherlands. A core segment from lake Uddelermeer covering the period 2500 cal. yr. BP to 400 cal. yr. BP was analysed on a high-resolution for organic content, pollen, spores and NPPs, and chironomid head capsules. In the temperature record, we could identify the presence of a Roman Warm Period, the Dark Age Cold Period and the Medieval Warm Period. The reconstructed temperature drop from the Roman Warm Period to the Dark Age Cold Period is 1.5 °C. These warm and cold periods have been identified in a range of proxy records throughout NW Europe indicating a regional climate trend. In this record the Dark Age Cold Period seems contemporaneous with a reforestation phase. This reforestation phase is recognized in numerous palynological records throughout the Netherlands and is commonly linked to a drop in population density following the decline of the Roman Empire. Additionally, this period appears to be characterized by large scale landscape changes in the Netherlands. The timing of all these changes might suggest that climate developments had an (in)direct influence on landscape developments and cultural trends.

**P-2419**

## **Sedimentary Records from Lakes Reconstructing Late Quaternary Paleoclimate Changes in Mongolia**

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### **Abstract**

This study reconstructs the Late Quaternary paleoclimatic history of Mongolia based on multi-proxy sedimentary records from lakes in Mongolia. The high-proxy data show that in the Late Pleistocene, the cold and dry and cold and wet climates dominated in western and northern Mongolia, respectively. In the Holocene, paleoclimates in Mongolia differ from region to region depending on each landscape driven by local atmospheric circulations. In the early Holocene the warm and wet climates prevailed in western, central and southern Mongolia, while the cold and wet and cold and dry climates existed in Lake Darkhad and Lake Khuvsgul basins, and the valley between Khuvsgul and Khentii Mountain Ranges in northern Mongolia, respectively. In the middle Holocene, the warm and dry climates prevailed in northern (Lake Khuvsgul basin), western (Lake Khoton, Lake Achit and Lake Uvs basins), central and southern Mongolia, whereas the warm and wet climates dominated in western (the Depression of Great Lakes) and northern (Lake Darkhad basin and the valley between Khuvsgul and Khentii Mountain Ranges) Mongolia. In the late Holocene, the warm and wet climates prevailed in western, central and southern Mongolia, whereas the cool and dry and cool and wet climates differ in the Lake Darkhad basin and the valley between Khuvsgul and Khentii Mountain Ranges, and Lake Khuvsgul basin in northern Mongolia, respectively. A few high-proxy series of acceptable quality reflecting Holocene climates review with relatively precise dates from the lake sediments. Therefore, more precise investigations with detail dates from the lakes throughout Mongolia are needed to review the Late Quaternary paleoclimatic history in Mongolia and Central Asia.

**P-2420**

## **Late Glacial and Holocene vegetation and climate change in Western Sayan mountains derived from peat-lake sediments of mire Buibinskoye**

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### **Abstract**

Buibinskoye mire is located in central part of the Western Sayan Mountains in Ergaki Nature Reserve. This present day moss mire originated from lake and most of its 600 cm deposits are composed by lake sediments - gyttja. Sedge-moss peat forms only upper 130 cm of sediments. In common, peat and lake's sediments cover without interruption Late Glacial and Holocene time. Five radiocarbon dates were obtained by AMS method for this sediment section. Spores-pollen diagram reflects changes of the three main types of vegetation which dominated the study area from the Late Glacial to modern time. The beginning of the lake sedimentation started in the cryo-arid landscapes of the Younger Dryas covered by unique complex vegetation of forest-tundra-steppe. About 11000 cal. yr BP this type of vegetation was quickly replaced by mountain forests dominated by fir (*Abies sibirica*) and Siberian pine (*Pinus sibirica*). Pine forests with birch spread on foothills of the Western Sayan Mountains. During next stage of vegetation, which started about 5000 cal. yr BP domination in mountain forests passed from fir to Siberian pine. This type of vegetation cover is characteristic also for modern mountain forests of the Western Sayan. With the reduction of the role of fir in mountain forests the belt of subalpine shrubs began to expand like during Late Glacial time. Quantitative palaeoclimatic reconstructions based on palaeopollen data with use of transfer function evidence about cryo-arid climate in Late Glacial till 11000 cal. yr BP, humid moderate cool climate in Middle Holocene and humid and cool climate - in late Holocene after 5000 cal yr BP.

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P-2421

## Ancient algae and crater chemistry: A 5,000-year record of environmental change from an Ethiopian crater lake

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### Abstract

Babogaya is a small (~500 m diameter), 60 m-deep maar lake, part of the Bishoftu Crater Lakes (BCLs) system, 50 km south of Addis Ababa, Ethiopia. Environmental conditions at the BCLs promote a seasonal cycle of lake mixing (dry season; November-February) and stratification (wet seasons). This cycle stimulates varying levels of nutrient circulation leading to the deposition of light-coloured, aragonite-rich lamina in the dry season, alternating with darker, more organic layers deposited in the wet season. Consequently, the sediments of this lake facilitate the high-resolution analyses of past climatic changes in a region sensitive to fluctuations in both Pacific and Atlantic moisture sources.

Diatom analysis of ~13 m of partially-laminated core, combined with bulk (C/N and  $\delta^{13}\text{C}$ ) and XRF-derived sediment geochemistry, are used to infer past environmental changes in the area. A chronological framework from the radiocarbon dating of micro-charcoal fragments reveals a high sedimentation rate, with a basal date of ~5,500 cal BP.

Laminated sections of the core (500–3,200 cal BP, and ~4,000–5,500 cal BP) are characterised by organic rich, aragonitic sediments, dominated by small, planktonic *Nitzschia lancetulla*, with high abundances of Fragilaroid species characteristic of shallower (but still fresh) waters, (predominantly *Pseudostaurosira brevistriata* and *Staurosirella pinnata*), towards the base of the core. However, between 3,200 and ~4,000 cal BP the core is characterised by organic-poor, clastic sediment bounded at the base by a *Gastropod* shell layer, underlain by further laminated sediments. Lithogenic element (Ti and Fe) content through this clastic section is comparatively high, with decreased organic matter and biogenic silica (Si/Ti), interpreted as a period of low productivity in dry conditions. The record from Lake Babogaya illustrates a complex environmental history, including evidence for intense, abrupt Holocene aridity and potential desiccation, despite its depth.

P-2422

## The palaeolakes in Gorzów Wielkopolski (Poland) with *Stephanorhinus kirchbergensis* and their significance in stratigraphy and palaeoenvironmental reconstruction of Central Europe.

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### Abstract

A very peculiar profile with two palaeolakes divided by peat layer was discovered in the surroundings of Gorzów Wielkopolski, NW Poland. Sediments of the lower reservoir beared almost complete and well-preserved skeleton of rhinoceros *Stephanorhinus kirchbergensis* (Jäger, 1839). Above the skeleton, also a single bone of a fallow deer *Dama dama* (Linnaeus, 1758) was found. Some other faunal remains, lake fish and snails were also abundant in the profile. The analysis of pollen and plant macro-remains show, that during the deposition of lacustrine sediments, there were several changes in climate and environment. Research done so far, together with the obtained OSL and <sup>14</sup>C dates, point out that this is a profile unique in Central Europe, covering the upper part of Saalian glaciation (MIS 6) and Eemian interglacial (MIS 5e, in the lower lake). The upper lake formed in the last glaciation, after Hengelo and Denekamp interstadials (MIS 3). The reservoirs are overlain by LGM sediments, and those are covered with Holocene sediments. The palaeobotanical research proves that the rhino skeleton comes from the optimal phase of Eemian interglacial with warm hornbeam forests. Also presence of a fallow deer confirms the warm climate. The lake was broad and diversified in its depth. The geochemical and palaeobotanical survey enabled to reconstruct several phases of the Gorzów Wielkopolski lakes' development in accordance to environmental changes in Upper Pleistocene and recreate the living conditions of *S. kirchbergensis*. It inhabited forests and scrublands, feeding mostly on the branches of birch, hazel and alder. This skeleton represents an adult specimen in the age exceeding 30 years. Except some minor pathologies bound with its age, there is a single bite mark on its pelvis. It was probably bitten when the carcass was floating in the water.

P-2423

## Controlling processes of diatom assemblages and their distribution in Lake Nam Co, Tibetan Plateau

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### Abstract

In arid and semi-arid regions with high variability of precipitation and evaporation, such as the Tibetan Plateau (TP), lakes react more sensitive to climate change and hydrological variations. Diatoms from Nam Co, the second largest (~1920 km<sup>2</sup>) saline lake (1.3 %) on the Tibetan Plateau are used as indicators for variations in hydrological balance and lake water quality including lake level, salinity and trophic state. Preliminary results from Nam Co sediments show climate-induced shifts in diatom communities during the late Holocene (Kasper et al., 2013), however, the autecology of modern diatom flora and their relationship with environmental conditions still remains unclear. Furthermore, high spatial heterogeneity of such a large lake should be considered because this can change sedimentary transportation processes, alter water physical and chemical parameters, and influence diatom community structure, diversity as well as distribution patterns. In order to characterize the ecology of living diatoms and to provide a reliable basis for paleoenvironmental interpretation from lake sedimentary sequences, twenty water samples and seventy sediment samples were collected in 2018 with a phytoplankton net (mesh size: 20 µm) and an Ekman grab from different water depths in the lake, incoming streams and nearby ponds. The diatom species composition and their planktonic: benthic (P:B) ratios were calculated and spatial distribution patterns were mapped. Other habitat properties such as macrophyte cover and anthropogenic influence were taken into consideration to better understand autecology of diatom species. Furthermore, we measured water physical parameters (temperature, dissolved oxygen, conductivity and pH) and water chemical variables (anions, cations, δ<sup>18</sup>O and δ<sup>13</sup>C isotopes) as well as grain size and loss on ignition for surface sediments. Redundancy analysis (RDA) was conducted to help identify the main drivers of diatom succession and to quantify their relationships with environmental conditions. Our results suggest that Nam Co is still an oligotrophic lake, and diatoms display high spatial heterogeneity, which could represent a response to the climate-induced changes of water conductivity and hydrological processes. Overall, this study will enhance the development of regional diatom datasets and understanding of diatom autecology, which can be used to interpret diatom-based reconstructions of environmental change on the Tibetan Plateau.

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P-2424

## High-resolution hydroclimatic reconstructions through the Last Glacial-Interglacial Transition from the Vale of Pickering, Northeast England

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### Abstract

The Last Glacial to Interglacial Transition (LGIT; 18-8 ka BP) was a climatically dynamic period characterised by abrupt changes in temperature and precipitation regimes across the European continent. Recent hydroclimatic research has demonstrated that spatially heterogeneous and diachronous hydrological shifts occurred across the European mid-latitudes, associated with abrupt temperature changes through the LGIT. This is particularly evident from hydroclimatic (lake-level) records through abrupt climatic events in the Early Holocene (e.g. the 8.2 ka event) which are bifurcated, with mid-European latitudes becoming more arid (with lower lake-levels), and lower and higher latitudes becoming more humid (with higher lake-levels) in response to cooling. Whilst shifts in temperatures (namely TMax/Mean July temperature estimates) are relatively well established through similar abrupt climatic events in the preceding Lateglacial Interstadial (i.e. c. 14.7-13 ka BP), hydrological shifts associated with these events are poorly understood, particularly in Northern Europe. This is pertinent as hydrological parameters are a primary control on the growth and decay of ice masses, the expansion and distribution of flora and fauna, and the mode and intensity of fluvial systems. Temporal and spatial changes in hydrology is therefore an important variable to reconstruct, in order to explain and quantify palaeoenvironmental/ palaeogeomorphic variability to abrupt climatic events.

This presentation will summarise work undertaken in the Vale of Pickering (VoP) in NE England (54.22 °N, 0.65 °W), aimed at reconstructing changes in hydroclimate through the LGIT via the multiproxy analyses (sedimentology, plant macrofossils, carbonate stable isotopes) of high-resolution palaeolake records, constrained by precise radiocarbon-based chronologies. Lake-level fluctuations in the VoP occurred in close association with threshold shifts across abrupt climate change boundaries, typically lowering in response to cooling. These fluctuations occurred at similar times (although in some cases were anti-phased) to hydrological changes in other European record. This presentation will summarise by discussing the implications of these findings, most notably the need for more high-resolution mid to high latitude hydroclimatic records, covering intervals of abrupt climatic change prior to the present interglacial.

P-2425

## Climatic variations in Central Brazil during the Mid-Holocene recorded in lacustrine sediments from Lagoa Feia- GO

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### Abstract

Climatic changes and their socio-environmental impacts are an issue of constant debate. Besides the instrumental data collected over the last 150 years, the climate variation before the instrumental period have been studied by sedimentary records, such as lakes, rivers, speleothemes, among others. The study of these records is part of paleoclimatological research through paleoenvironmental proxies to infer about climates of the past (e.g. pollen assemblages, stable isotope analysis, and environmental magnetism). In recent years, several paleoclimatic studies have identified lacustrine environments as important records of climatic and environmental changes because they integrate atmospheric and environmental variations. In this framework, paleoclimatic studies in lakes in the South American region are modest when compared to other parts of the world. An example of this gap in paleoclimatic studies is Central Brazil area. Central Brazil's predominant biome is the Cerrado (Brazilian savanna) and this is an important region to the water resources dynamics. This environmental data gap impairs the validation of global numerical simulations and, consequently, the improvement of future climate projections representing a limiting factor in climate change analysis and a challenge for the Brazilian and the international scientific community. The Federal District (FD, included in Central Brazil area) presents many small lakes located in several river basins affected by different contexts of land use evolution. Climate of the FD is driven by the South American Monsoon System, that establishes well-marked dry and wet seasons. Therefore, this study aims to contribute to the understanding of the South American climate during the Mid-Holocene in Central Brazil by investigating lake records in the FD and surroundings. Here, we will discuss the results for the Lagoa Feia, one of surrounding FD lake. These results comprise environmental magnetism data (e.g., magnetic susceptibility, MRN, ARM and S-ratio) and geochemical data (major and minor elements), obtained from a holocenic 6-m-length core collect in the Lagoa Feia. Mid-Holocene climate variations recorded in this core will be discussed.

P-2426

## Distribution features of organic matter in sediments of small lakes of tundra and taiga in Western Siberia (Russia)

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### Abstract

Bottom sediments are one of the few sources of information about the genesis and lakes dynamics for a long time. Bottom sediments indirectly reflect the climate change of their territories. The layer-by-layer study of their chemical composition with a high resolution is of particular interest. Special interest is a layer-by-layer study of the chemical composition of bottom sediments with a high resolution. Columns of bottom sediments from 5 small lakes located in different climatic zones of Western Siberia were selected for study. The columns were divided into layers in 1 cm increments. The content of total carbon (TC), total nitrogen (TNb), as well as the organic and inorganic form of their being was determined in each layer. It should be noted that organic substances are unevenly distributed in depth and accumulate mainly in the upper 10-25 cm of bottom sediments. The total carbon content in the tundra lakes is insignificant and makes up less than 1% of the mass of bottom sediments. The total carbon content increases markedly to 5-25% in taiga lakes. The definition of water-soluble TCW showed that its average content varies in the opposite direction (see table), despite the increase in total carbon content.

Table. The content of total (TC,%) and water-soluble (TCW, mg / kg) carbon in the bottom sediment columns of tundra and taiga lakes in Western Siberia

Area	Tundra	Taiga		
Lake	Langotibeyto	Gol'tsovoye Lokhtokurt Rangetur		
	Total carbon (TC,%)			
Average	0,34	0,31	2,39	8,28
Median	0,30	0,15	2,72	0,35
Minimum	0,11	0,03	0,54	0,23
Maximum	0,94	1,19	5,77	26,04
	Water soluble organic matter (TC <sub>w</sub> , mg/kg)			
Average	815	324	239	185
Median	805	299	222	173
Minimum	534	6	149	122
Maximum	1192	1102	385	338

Layer-by-layer analysis shows that determining the average content of organic matter (and other indicators) is not very informative and does not reflect its distribution over the column profile. The spectra of the most enriched sediment layers were taken to clarify the differences in the distribution of organic matter in the sediment profile. Potentiometric titration of isolated humic and fulvic acids was also carried out.



Thus, a comprehensive layer-by-layer study of bottom sediments allows one to assess its content in bottom sediments, as well as to establish possible causes of changes in its content and establish its relationship with changes in climatic and environmental conditions during the period of their formation.

#### ACKNOWLEDGEMENT

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P-2427

## The terrestrial Eemian to Vistulian sediment from Beckentin (NE-Germany) – results of palaeobotanical research

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### Abstract

Eemian Interglacial (MIS 5e) represents an important analogue for the current Holocene period and provides crucial knowledge into the paleoclimatology and paleoecology of interglacial environments developed without human impact. Outcrop Beckentin site is located in the SW of the federal state of Mecklenburg-Vorpommern (NE Germany). The study site lies outside the Weichselian zone of glaciation, approximately 25 km, which marks the southernmost ice marginal position reached by the Scandinavian Ice Sheet (SIS) during the Last Glacial Maximum. The Beckentin sequence of lake sediments provided rich plant micro- and macroremains along with cladoceran fauna, which permitted a palaeoenvironmental reconstruction between MIS 6 and MIS 4.

The Beckentin pollen sequence begins in the Late Saalian Glaciation (MIS6) when the landscape was dominated by Poaceae and Chenopodiaceae and was almost treeless. The beginning of the Eemian Interglacial shows a presence of pioneer forests with *Pinus* and *Betula* and followed by *Pinus* with *Quercus* and a raised participation of *Tilia* and *Corylus*. Next phase was characterized by an expansion of mixed deciduous forest with a dominance of *Corylus*. Also, riparian forests with *Alnus*, *Salix*, *Ulmus*, *Fraxinus*, *Taxus baccata* and *Humulus lupulus* developed. *Tilia* was increasingly important in the local forest communities. During the Eemian climatic optimum an expansion of *Carpinus* and *Picea* was observed, accompanied by *Ilex aquifolium*, *Buxus sempervirens*, and *Abies*. Deterioration of climatic conditions at the end of this interglacial led to a predominance of *Pinus-Betula* forests. The sedimentation in the palaeoreservoir ended in the Early Vistulian (MIS 4), when the steppe-tundra communities and especially heathlands created the landscape. The oligotrophy is confirmed by the numerous spores of *Isöetes lacustris* and peat bog with *Sphagnum*.

The results of palynological analyses were supported by plant macrofossil data, including fruits, seeds and wood remains that corroborate the palynological sequence. The most outstanding is a presence of thermophilous taxa typical of the Eemian climatic optimum such as *Brasenia* sp., *Dulichium arundinaceum*, *Najas minor*. Also, an occurrence of megaspores of *Salvinia natans* was of a special importance as it grows in warm climate.

The subfossil cladoceran fauna in Beckentin profile is represented almost only by the Chydoridae family (16 species), which lives in shallow water associated with water plants. The most abundant were remains of *Alona affinis* species. Only one marked species – *Bosmina longirostris*, originated from open water zone. Climatic and hydrological changes in the Eemian Interglacial from the Early to the Late Eemian resulted in improved living conditions of zooplankton, which was reflected in the increase in number of individuals and species diversity.

P-2428

## Stable isotope records of pollen fossils in Lake Suigetsu, Japan, during the Last Glacial-Interglacial Transition

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### Abstract

Interactions of atmospheric, marine, terrestrial, and cryospheric realms are important factors in considering climate change mechanism (Lowe et al., 2008). Temporal difference between these realms is one of the keys to clarify cause/effect of palaeoclimate changes. Pollen analysis traditionally used as a one of the important methods to provide terrestrial proxy but involves a question that vegetation responses with lags to climate changes. Stable isotopic analysis is one of the solutions to this issue. Pollen is composed of sporopollenin and potentially provides isotopic signals which has applications within palaeoclimatology (Loader and Hemming, 2004). In this study, we therefore established a new method for concentrating pollen fossils using cell sorter and reconstructed a new proxy data of pollen stable isotopes using varved sediments obtained from Lake Suigetsu, Japan.

Lake Suigetsu (35°35'N, 135°53'E, 0 m a.s.l.), Fukui prefecture, central Japan, is one of the Mikata Five lakes, which measures 3 km east-west by 3 km north-south and the maximum water depth of ca. 34 m. Lake Suigetsu preserves annually laminated sediments over the last ca. 70 kyr with a significant number of event layers. Two long cores (SG93, SG06) have previously been recovered from the centre of the lake and an exceptionally precise age model has been established for the cores through a combination of over 800 radiocarbon (<sup>14</sup>C) dates and high precision varve counting (Staff et al., 2011; Marshall et al., 2012; Schlolaut et al., 2012; Bronk Ramsey et al., 2012).

In this study, we used well-dated SG06 cores and extracted pollen fossils using cell sorter. Cell sorter is able to separate specified particles using electrostatic deflection relying on differences in size, shape, and fluorescence. Pollen fossils can be sorted using cell sorter because sporopollenin constituting pollen fossils is naturally auto-fluorescent (Tennant et al., 2013). After pre-treatments with acid, alkali, and heavy media, pollen-enriched suspension was introduced into cell sorter to make high-purity pollen pellets. In this study, we collected half a million pollens per sample. After drying and weighting,  $\delta^{18}\text{O}$  and  $\delta\text{D}$  of the pollen pellets were determined using High Temperature Conversion Elemental Analyzer (TC/EA, Thermo Scientific).

Purity of pollen in the concentrated pellets were >98%. The pellets contained multiple pollen species, and their composition slightly varied depending on the age. Pollen  $\delta^{18}\text{O}$  fluctuates in synchronism with that of NGRIP but deviated after 11 ka. The fluctuation is more similar to that of Hulu. As a result, pollen isotopic changes include at least valuable global signal and has a potential as quantitative indicator of not only past terrestrial palaeoclimatological changes but also vegetation response. This research is still under development and requires more data points in order to discuss interaction between terrestrial and other regions.

P-2429

## Contribution to the evidences of an interhemispheric cosmic impact during the younger dryas. Distinctive proxies from Central and South Mexico

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### Abstract

The Younger Dryas chronozone is the last and coldest abrupt climatic change that took place at the end of the late Pleistocene producing a significant environmental disruption in America Europe and Asia. These changes include diversity and abundance of vegetation, and are often associated with a large amount of charcoal recorded in several paleoenvironmental records and coincide with high mortality of large vertebrates. This abrupt YDB (Younger Dryas Boundary) change has been always associated with major drainage of Lake Agassiz producing a major change in southern overturning driving freshwater draining into the western Arctic Ocean. The mechanism of this overturning is not well understood. Several authors suggest that there was a comet affecting the atmosphere that occurred at around the YD Boundary as observed in a widespread anomaly in 50 YDB sites in all latitudes. This anomaly is found in lacustrine, fluvial, glacial and aeolian systems that date to around 12,800 y BP. The YDB layer has been proposed as a widespread correlation datum in America (North, and South), Europe and Asia. In order to investigate in Mexico sites potentially affected by the Younger Dryas event, we collected sediment samples from four ancient lakes in central Mexico (Chapala, Cuitzeo, Acambay, Chalco lake) and two rivers in the south Mexico (Oaxaca and Chiapas). All contain distinctive characteristics as determined by sedimentological, geochemical, micropaleontological and paleopedological analyses. The retrieved and dated lake and fluvial sediments encompass the Pleistocene-Holocene transition and provide good materials for studying the YD transition. The detailed stratigraphical analyses in the buried YDB layer intervals show anomalous values for bulk chemistry, pollen, stable isotopes, diatoms, nanodiamond polytypes, TOC, charcoal, soot, and platinum. All show higher concentrations than average background values associated with numerous quenched Fe spherules. These are morphologically and geochemically identical to quench-textured YDB spherules found elsewhere.

The nanodiamonds in the Mexican samples show the skeletal iron crystallization typical of rapid quenching, with about 96% iron oxide. Ternary diagrams make it clear that the spherules are not cosmic, volcanic, or anthropogenic in origin. In some river systems in Oaxaca Mexico, the quaternary landscape displays widespread evidence of outburst floods that produce extensive lag deposits. These sedimentological characteristics may indicate a sudden flood event that buried Late Pleistocene vertebrate remains. In Chiapas State, river sediments show clear fluvial traction deposits, with large channels, associated with lag deposits which incorporated Late Pleistocene vertebrate fossils.

All the anomalous changes found could be associated with a large extraterrestrial object, possibly a comet that produced abundant debris. The evidence suggest that the impact event causes a sudden influx of water into the atmosphere inducing abundant rainfall that may have caused a major shift in precipitation and fluvial patterns across the Northern hemisphere.

P-2430

## Timing of Quaternary glaciations in eastern Turkey, inferred from $^{36}\text{Cl}$ cosmogenic dating

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### Abstract

Two mountain belts in Turkey, which are extending parallel to the coast in the north and south, give rise to moist air masses to leave precipitation substantially in the coasts. For this reason, the central Turkey receives lower precipitation than coastal regions, and thus continental climate prevails. This contradiction causes the coastal and inland equilibrium line altitudes (ELA) be different. To find out how this difference was in the past and how it changed in time, we focused, in this study, on significant geomorphological evidence of past glaciations in the eastern Turkish mountains. We investigated Quaternary geology and glacial geomorphology in the Kavuşşahap Mountains (3634 m above sea level, asl), Mount Bingöl (3193 m asl), Munzur Mountains (3462 m asl) and Tahtalı Mountains (2967 m asl) in detail and reconstructed the glacial chronology with surface exposure dating. In the field, we prepared detailed geomorphological maps for glacial landforms in the field and collected surface samples from glacially transported boulders on the moraines for cosmogenic  $^{36}\text{Cl}$  analysis.

Our results indicated that these mountains have experienced several glacial advances. Palaeoglaciers reached their maximum positions in Tahtalı Mountains prior to the MIS-4 (Marine Isotope Stage 4); in Munzur Mountains during the MIS-3 and at Mount Bingöl during MIS-2. For instance, we reconstructed Late Pleistocene glacial chronology of four advances in the Narlıca valley system in the Kavuşşahap Mountains. The oldest and most extensive glacier advance occurred at ca. 48 ka (ka: thousands years) during the MIS-3. During this advance, the equilibrium line altitude (ELA) was 1150 m lower than today and mean temperature was ca. 10 °C colder than today. The second advance was ca. 32 ka prior to the global Last Glacial Maximum (LGM;  $22.1 \pm 4.3$  ka). Third advance was occurred ca. 21 ka during the global LGM. In the Narlıca valley system, last advance of glaciers occurred ca. 16 ka during the Lateglacial period.

**P-2431**

## **The deglacial history of the Donegal ice dome**

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### **Abstract**

Accurately reconstructing the history of paleo-ice sheets is critical for understanding climate and ice sheet dynamics which is important if we are to better understand the future trajectory of the Greenland and Antarctic Ice Sheets in a warming world. Ice sheets have long life cycles and the best way of understanding their response to climate change is to investigate the geological record of paleo-ice sheets which provides a record of former ice sheet behaviour through full glacial cycles. The former British-Irish Ice Sheet (BIIS) is known to have been sensitive to climatic signals from the North Atlantic making it a good proxy for examining these long-term climate/ice sheet relationships. During the Last Glacial Maximum in Ireland (~27 ka), the BIIS covered all of Ireland, extended to the continental shelf edge and then retreated to a coastal position as an ice dome by ~21ka in the North. After ~18 ka it is thought to have retreated into the Donegal Mountains and down-wasted to lower altitudes during its final stages. However, to date the full retreat pattern has not been mapped and new dates are required to fully age constrain the final deglaciation in this region. This PhD project addresses these issues through geomorphological mapping and dating using Schmidt Hammer Exposure Dating (SHED), a technique which has been shown to accurately constrain the timing of BIIS deglaciation in granite lithologies (Fig 1). This will be achieved by: 1) The identification and mapping of deglacial geomorphological features using high-resolution aerial imagery. 2) Dating of these features to reconstruct the deglacial chronology of the Donegal Ice Dome. 3) Using both datasets to develop an age-constrained conceptual model of the final deglacial chronology of the Donegal Ice Dome constraining down-wasting and retreat. This poster presents results from 30 sites that have been dated using SHED across the Derryveigh Mountains in northwest Donegal (Fig. 2) providing deglacial ages ranging from 19.58 ka to 11.85 ka. This research will further our understanding on the pattern and timing of deglaciation of this significant ice source and provides a framework investigating the drivers glacial change in this region.



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Figure 1: A Rocks Schmidt hammer being used to measure surface hardness (Rebound value) of glacially abraded granite bedrock in the field.

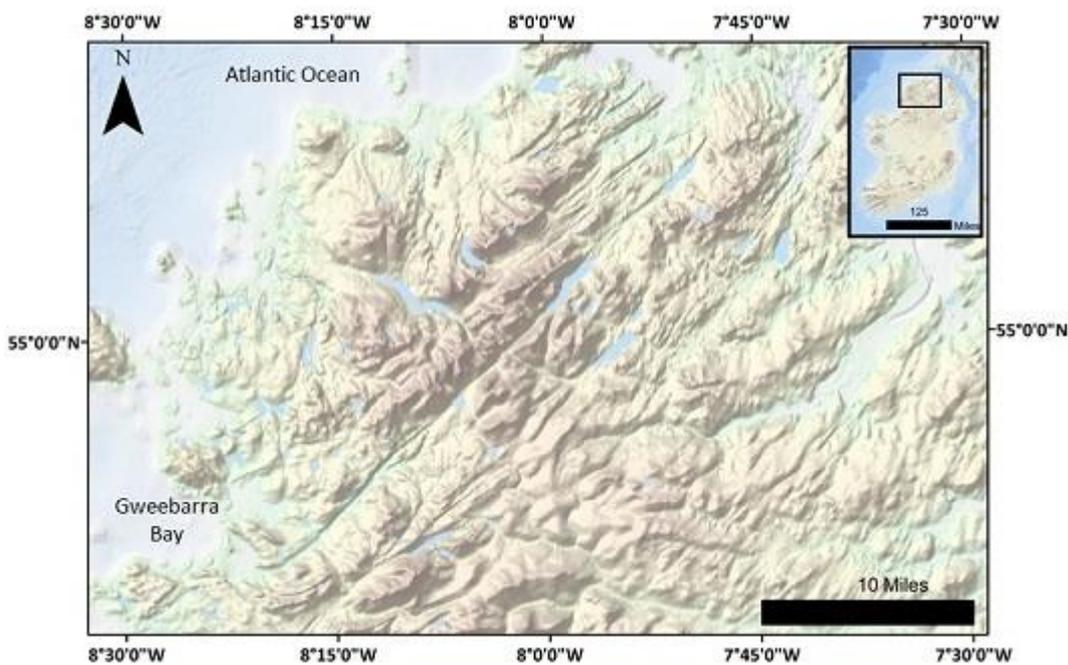


Figure 2: Map (main) showing an overview the Derryveigh mountain study area in Co. Donegal. Inset: Location of study area in Ireland.

P-2432

## Reconstruction of climate from the high altitude glacial lakes of the Ladakh range, Trans Himalaya, India.

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### Abstract

The glaciers of the Ladakh Range are retreating and depleting over time and as this is taking place, a new landscape with lakes commonly behind the newly exposed moraines are being observed all along the ridge line. Hence a detailed multi-proxy study (mineral magnetism, textural analysis, loss on ignition, pollens, algae and testate amoebae) from the sediment archive of these glacial lakes was undertaken to decipher the climatic fluctuations during the Holocene as these lakes directly recharged by melt-water from glaciers and melt snow provide complete record of past climatic variability due to a continuous sedimentation. The region is located in a junction zone of Indian Summer Monsoon (ISM) and Westerly wind influence, which makes it an ideal region for studying the regional response on global climatic changes. The Ladakh range is a prominent range trending NW-SE for ~350 km (length) and varying from ~50 km in the west and pinching towards the eastern side to 20 km (width) and tectonically active placed between the Indus Suture Zone in the south and the Karakoram Thrust in the north making its position all the more vital to study the climate-tectonic interaction as well. Two types of lakes are exposed, one with peak primary productivity comprising of the pro-glacial lakes which occupy the higher elevations and the other ones positioned in lower altitudes are seen as remnant/palaeolakes scattered over the abandoned moraines. The pro-glacial lakes of the Chang La- Tangtse basin were examined on the basis of the preserved biota, which includes pollen, algal and testate-amoebae concentration. The relative percentage of the palynomorphs recorded constitute Pollens (13%), Bryophytic spores (0.9%), Algae (25.3%), Algal cysts (7.6%), Fungal spores (5.6%), Testate amoeba (46.7%), Insect wing (0.3%) and Sponge spicule (0.3%). High percentage of testate amoebae indicates oligotrophic ecosystem with sufficient dissolved oxygen and optimum pH levels, whereas enhanced algal growth suggests prolong summer season and sufficient nutrient supply. About 12 species of testate amoebae have been recorded from the lake, out of which *Centropyxis pontigulasiformis* has been observed for the first time from the Indian subcontinent. From a biological perspective an understanding of climate in the high altitude regions is especially important because even slight shifts in climate can affect the biota of the region. In the other study a palaeolake section bracketed between 1737 to 6529 cal yrs BP, the multi-proxy results indicate a cold and harsh condition prevailing between 6529-6039 cal yrs BP with glacial advancement and a shift to slightly better conditions from 6039 cal yrs BP and three spells of abrupt monsoon phases (ISM) are recorded. Five cycles of cold and warm episodes are evidenced from ~5000-1700 cal yrs BP with peak aridity between 3099-2826 cal yrs BP.

**P-2433**

## **Dating the last British–Irish Ice Sheet from basin-fill sediments in the Vale of York, UK**

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### **Abstract**

We report an age model for the Devensian (Weichselian) glacial Stage (marine isotope stages (MIS) 4–2) from basin-fill sediments in the Vale of York, and use it to constrain the advance and retreat of ice lobes of the British–Irish Ice Sheet (BIIS) in this region during this time. Our age model is based on optically stimulated luminescence (OSL) dating, and relative palaeointensity (RPI) measurements calibrated to a RPI record from deep-sea sediments in the northeast Atlantic Ocean. Four near-continuous cores drilled to bedrock indicate the basin-fill sediments comprise alternating units of reddish brown to dark greyish brown laminated to faintly stratified silty clay, and dark greyish brown silt interbedded with yellowish brown silty sand. To assess climatic variability recorded in them we quantified colour variations using the CIELAB colour space and compared  $a^*$  reflectance—a measure of sediment redness—with the GICC05 NGRIP  $d^{18}O$  chronology. We draw two conclusions from our sedimentological and chronological data. (1) Basin sedimentation began at c. 40.25 ka (MIS 3) and ceased at c. 16.10 ka (MIS 2). This timing corroborates ice-rafted debris records of the BIIS from the northeast Atlantic Ocean, but is inconsistent with the most recent palaeoenvironmental reconstructions derived from OSL dating of glaciogenic sands in our study region. (2) Our  $a^*$  reflectance records identify millennial-scale variations during MIS 3 that we attribute principally to periglacial weathering and transport of frost-susceptible reddish brown Permo–Triassic bedrock underlying the Vale of York.

P-2434

## Quantifying long-term processes of moraine evolution: Implications for terrestrial cosmogenic nuclide dating and moraine age interpretations

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### Abstract

The Quaternary glacial record is a valuable resource, which underpins palaeoclimate reconstructions and chronicles links between terrestrial ice masses and climatic variability. In turn, this information provides context for modern climate change and the widespread global pattern of glacier mass loss. However, determining causal links between palaeoclimate and periods of glacier advance/retreat is predicated on the development of robust chronological frameworks. The widespread application of terrestrial cosmogenic nuclide (TCN) dating on glacial moraines has transformed our understanding of past glacial cycles but considerable challenges remain: in particular the degree to which moraine ages accurately record the timing of deglaciation. Processes of moraine stabilisation and nuclide inheritance can result in erroneously 'young' and 'old' TCN ages respectively, introducing considerable complexity to moraine age interpretations. The most significant barrier to isolating biased ages is the cost of TCN dating, which often precludes a large number of samples ( $n \geq 30$ ) and prevents statistically robust identification of outliers. As a result, the best resource-limited strategy is to perform a careful geomorphological assessment prior to sample selection. However, current sampling approaches, which prioritise moraine crest boulders and derive landform ages from the mean of few TCN ages (typically  $n \leq 6$ ), appear to be at odds with models of moraine evolution (which predict the greatest ground lowering at the crest) and guidance on interpreting moraine datasets as minimum limiting ages. In this project, we investigate four moraines in the Pyrenees mountains of France and Spain, deposited at  $\sim 27$ ,  $\sim 23$ ,  $\sim 12$  and  $\sim 3$  ka, in order to assess the suitability of current TCN sampling approaches. Through intensive Schmidt Hammer (SH) sampling ( $n$  boulders = 505), we show that the spatial distribution of "good" and "bad" boulders is complex and does not conform to existing crest or slope models. For some moraines, the distribution is effectively random and the probability of selecting "good" ages is not significantly improved by sampling on moraine crests, ice-proximal or -distal slopes. Exhumation is a significant post-depositional process for the large lateral LGM moraines deposited in the Aranser (*IQR* 7.8 ka, *Skew* -1.02, *Exhumed* 52%) and Gave de Pau catchments (*IQR* 3.6 ka, *Skew* -1.47, *Exhumed* 36%). While exhumation is generally less significant for post-LGM cirque moraines in the Noguera Riborgçana catchment, topography can control the distribution of TCN ages through post-depositional avalanching and incorporation of pre-existing deposits. Importantly, these data indicate that spatial criteria alone cannot be used to isolate exhumed boulders, and that current sampling approaches are indistinguishable from random boulder selection. As such, the abandonment of a crest-only strategy widens the population of suitable boulders for TCN dating; in turn producing more consistent datasets, better moraine age interpretations and more robust links to palaeoclimate drivers.

**P-2435**

## **Impact of glacial isostatic adjustment on surface-exposure dating**

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### **Abstract**

Calculating cosmogenic-nuclide surface-exposure ages is critically dependent on a knowledge of the altitude of the sample site. Changes in altitude have occurred through time as a result of glacial isostatic adjustment (GIA), potentially altering local nuclide production rates and, therefore, surface-exposure ages. Here we assess the impact of GIA on surface-exposure dating by calculating global time-dependent production rates since the Last Glacial Maximum (LGM) using surface elevations that were corrected and uncorrected for GIA. We find that the magnitude of the GIA effect is spatially and temporally variable. Nuclide production could be reduced by up to 50% in the interior of large ice masses (in North America, Scandinavia and West Antarctica) at times of maximum glacial isostatic depression. Although smaller, the effect is still significant at ice sheet margins, where nuclide production is reduced by >5% and potentially >10%, making exposure ages older in those areas. Away from the ice sheet margins, land surfaces may have been isostatically elevated during the LGM, which can increase nuclide production by >5% and, therefore, make exposure ages younger. Areas that were more recently exposed or that are distal to large ice masses will generally be less affected. Importantly, we find that the effect at the primary  $^{10}\text{Be}$  production calibration sites is <1%. Applying a GIA correction to surface-exposure data may help resolve mismatches between some chronologies, but not necessarily in all regions, implying that additional factors may need to be considered. Past atmospheric changes could amplify or reduce the impact of GIA on nuclide production, and the combined effects should be fully accounted for in the future. These time-dependent influences on surface-exposure dating have potentially large implications for interpreting chronologies and for using the data to constrain ice sheet models.

P-2436

## The significance of local topo-climatic factors for cirque glacier formation during the Younger Dryas in the Wicklow Mountains, Ireland

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### Abstract

The Wicklow Mountains are a key area for understanding glaciation extent in the east of Ireland during the Younger Dryas (YD; 12.9 – 11.6 ka BP). Due to its location between the mountains of western Ireland and mainland Britain, the region offers an important insight into the understanding of both local and regional palaeoclimate. Similar work has recently been undertaken in the Mourne Mountains and Snowdonia, increasing understanding of restricted upland glaciation during the YD. Traditionally, the Wicklow Mountains have been considered marginal for YD glaciation, characterised by small cirque glaciers in limited upland locations. Yet, the only thorough investigation of YD glacier extent is at the Irish type-site, Lough Nahanagan, where a series of moraines within the cirque lake have been radiocarbon dated to 11.5 ka BP. Here, we present the first detailed examination of YD glaciation extent and style in the Wicklow Mountains. The limits of six viable YD glaciers are identified using a combination of geomorphological mapping, morphostratigraphy, and radiation and snowblow modelling. A total glacierised area of 2.33 km<sup>2</sup> is reconstructed, with an average glacier area of 0.39 km<sup>2</sup>. Reconstructed ELAs (AABR  $1.9 \pm 0.81$ ) range from  $467 \pm 9$  to  $739 \pm 8$  m, with a regional average of  $621 \pm 9$  m. We demonstrate that not all cirques in the Wicklow Mountains were occupied during the YD. Geomorphological evidence supportive of YD glaciation is absent in all cirques with southern and south-eastern aspects. Radiation modelling shows that these sites received the highest levels of solar insolation, up to 7000 Wh/m<sup>2</sup>. In contrast, all proposed YD sites identified through the use of morphostratigraphy received lower levels of solar insolation (up to 5000 Wh/m<sup>2</sup>) than surrounding areas, due to a combination of topographic shading and aspect. A glacier-derived sea-level equivalent precipitation range of  $1648 \pm 569$  to  $2476 \pm 273$  mm<sup>a-1</sup> implies wetter conditions than at present in the Wicklow Mountains. We suggest that calculated precipitation estimates actually reflect the influence of topographically enhanced snow accumulation. Snowblow modelling suggests that glacier mass balance was augmented by the redistribution of snow by wind, lowering glacier ELAs from 'true' climatic ELAs. Both snowblow and enhanced topographic shading were key factors in YD glacier initiation and survival in the region. Our research adds to the growing evidence for cirque glaciation in upland areas of Ireland and Britain during the YD and provides important insights into the importance of topo-climatic factors.

P-2437

## Alpine glacier fluctuations and paleoclimate reconstruction: post-LGM glacial history of Aosta Valley (Italian Alps)

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### Abstract

Past-ice extent and thickness fluctuations can be used as quantitative paleoclimate proxies since glacier mass-balance is sensitive to both temperature and precipitation changes (Kerschner and Ivy-Ochs, 2008). Paleo-glacier reconstructions in the Alps, together with speleothem records and other proxies (Heiri et al., 2014), suggest that a shift in Alpine atmospheric circulation took place during the Last Glacial Maximum (LGM), at or just before the onset of Alpine glaciers retreat. A major change occurred from south-westerly moisture advection from the Mediterranean to northerly moisture advection from the Atlantic, due to the northward migration of the North Atlantic storm track (Florineth and Schlüchter, 2000). However, both the exact timing of this shift and the resulting change in precipitation and associated alpine glacier responses remain elusive (Luetscher et al., 2015; Monegato et al., 2017).

This study aims to improve our understanding of the paleoglacial and paleoclimate conditions in the Western Alps since the LGM. We here focus on the Dora Baltea valley and its tributaries (Aosta Valley, Italy). Few chronological constraints are available for the post-LGM glacial history of Aosta Valley, mainly related to the Ivrea Amphitheatre and the Mont Blanc massif (Gianotti et al., 2008; Wirsig et al., 2016). However, differences in glacier responses between tributary valleys may be expected, because of distinct local geomorphological and climatological conditions between the glacial catchments. The main glacial subsystems of Aosta Valley are indeed related to prominent Alpine massifs (Mont Blanc, Grand Paradiso and Monte Rosa) that are fed by different moisture sources.

Following a detailed geomorphological mapping of glacial landforms and deposits in Aosta Valley, moraine boulders and glacially-polished bedrock along formerly-glaciated valleys were sampled for *in situ* <sup>10</sup>Be surface exposure dating. We specifically targeted the Mont Blanc and Monte Rosa glacial subsystems, in order to obtain a high-resolution reconstruction of post-LGM glacier retreat. Morphometric and especially hypsometric analyses were conducted on the different drainage subsystems to investigate the possible influence of local factors (e.g. topography, aspect, glacier geometry...) on potential variability in post-LGM glacier fluctuations, before isolating a climatic signal from our paleoglacial reconstructions. To further study the sensitivity of glacier systems to climate forcing in Aosta Valley, geomorphological evidence and geochronology data will be included in ice-dynamics numerical simulations (iSOSIA model, Egholm et al., 2012).

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**P-2438**

## **Integrating near surface geophysical and sedimentological techniques to assess proglacial sediment properties at Midtdalsbreen, southern Norway.**

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### **Abstract**

The impact of sediment availability and mechanical properties on moraine production and preservation is currently poorly understood, particularly at small mountain glaciers where responses to climate change are rapid. To maximize the potential of moraines as proxies for former glacier geometries and palaeoclimate indicators, a thorough understanding of the controls on landform genesis and subsequent evolution is required. Traditionally, moraines have been studied using glacial geological techniques such as sedimentary logging. While this provides valuable, in situ information, there are numerous limitations, namely poor availability and spatial extent of exposures. Geophysical methods, such as ground penetrating radar (GPR) and seismic reflection and refraction, offer a means to undertake non-destructive subsurface exploration of sedimentary sequences. However, the full potential of these methods has yet to be exploited in the proglacial environment.

This study is combining near surface geophysical and sedimentological techniques to image the proglacial sediments and detect buried glacier ice across the foreland of Midtdalsbreen, an outlet glacier of the Hardangerjøkulen icefield, southern Norway. Initial processing of trial seismic refraction data, using 48 geophones at 1 m spacing along the 2001 terminal moraine at Midtdalsbreen suggests a refracting interface at 0.5 m - 0.8 m depth between layers with seismic velocities of ca. 1200 ms<sup>-1</sup> - 1600 ms<sup>-1</sup> and ca. 2800 ms<sup>-1</sup> - 3500 ms<sup>-1</sup>. There are four possible interpretations of these values: coarse material with abundant air filled voids underlain by (1) permafrost (2) ice core (3) frozen, water saturated sediments or (4) compacted, consolidated sediments. Each of these scenarios has significant implications for interpreting past glacier dynamics, landscape geomorphology and preservation potential and the associated palaeoclimate. Therefore, it is important that further geophysical surveys and sedimentary logging are carried out to provide a robust interpretation of the foreland composition at Midtdalsbreen.

To overcome the inherent limitations of each geophysical technique, namely the non-uniqueness of interpretations, multiple methods are being deployed. Seismic reflection and refraction and GPR surveys are being applied across the glacier foreland to image the depth to the bedrock and reveal the internal structure and sediment properties of moraines, including whether they are ice cored. Sedimentary logging and laboratory-based geotechnical analysis of sediment samples from across the foreland will be carried out to provide empirical data, enabling robust interpretations of the geophysical datasets.

Through integration of these techniques this study looks to provide more extensive knowledge of the proglacial sediments and sedimentary structures present within the foreland of Midtdalsbreen. This will improve our understanding of the controls on moraine morphology and preservation, in turn, leading to an advanced understanding of past ice dynamics and the associated palaeoenvironments at Midtdalsbreen and the future stability of the Hardangerjøkulen icefield.

P-2439

## Comparison of equilibrium line altitudes calculated from glacier topography versus directly measured equilibrium line altitudes for glaciers in Scandinavia

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### Abstract

Palaeo-glaciers are increasingly being used to infer palaeo-climate conditions. They are typically reconstructed using numerical (recommended) or cartographic methods to generate a 3D surface from which the glacier equilibrium line altitude (ELA) is calculated. At the ELA climate is linked, by empirical relationships, to summer temperature and annual precipitation. Here, we present a validation of the Area-Altitude Balance Ratio (AABR) and Accumulation-Area Ratio (AAR) methods typically used to estimate palaeo-glacier ELAs. We utilise an existing ArcGIS toolbox to extract the ELA of 11 extant glaciers based on DEMs of their surface area. These measurements are then compared to direct ELA measurements of the same glaciers. The extant glacier ELAs were calculated using the Area-Altitude Balance Ratio (AABR) and Accumulation-Area Ratio (AAR) methods, using AABR and AAR value of  $1.5 \pm 0.4$  and 0.58. This approach implicitly assumes that the glacier is in equilibrium with climate so in order to compare like-with-like we calculated the zero net mass balance for the 11 glaciers. The annual specific net balance was plotted against the ELA, as measured by the Norwegian Water Resources and Energy Directorate (NVE). The zero net balance ELAs are correlated to the AABR/AAR calculated ELAs, with an  $R^2 = 0.996$  and  $0.992$ . The minimum difference between the measured and calculated ELAs is 6m and the average is 26m. These results indicate the validity of the AABR approach to estimate the ELA, for extant and palaeo-glaciers. This work is being further validated against other glaciers worldwide, for which a zero net balance can be calculated and a DEM of the glacier surface is available.

P-2440

## New luminescence dating from glaci-fluvial and glacial-lacustrine deposits from South-Central and South-eastern Pyrenees (Noguera Ribagorzana, Noguera Pallaresa, Valira & Segre)

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### Abstract

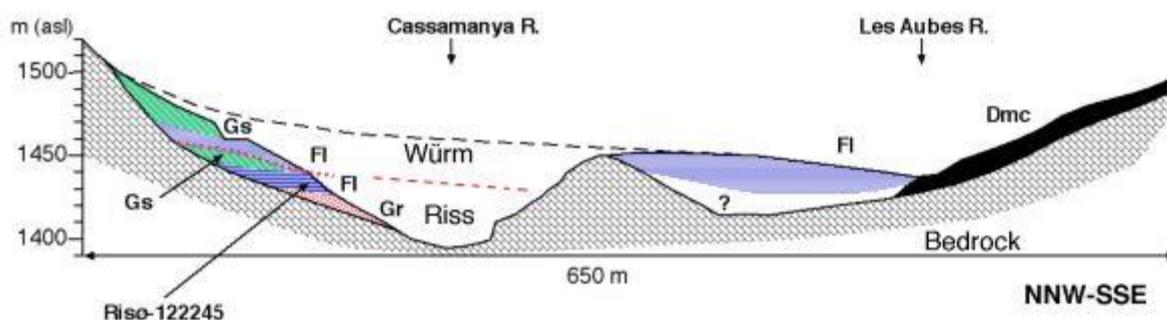
New OSL dating from the Southern slope of the Pyrenees are present in this work. Such a datations update the most relevant glacial phases identified by previous authors. From our data two glacial cycles are clearly dated, the penultimate and the last glacial cycle. The last glacial cycle can be divided in four major phases:

1. An early glacier extension at MIS5c
2. Glacial readvance at MIS4, when the Last Maximum Ice Extent (LMIE) occur in most of the Pyrenean range
3. Glacial fluctuations during MIS3 and MIS2
4. Deglaciation phase starting at the MIS2 end.

We focus our results in three questions:

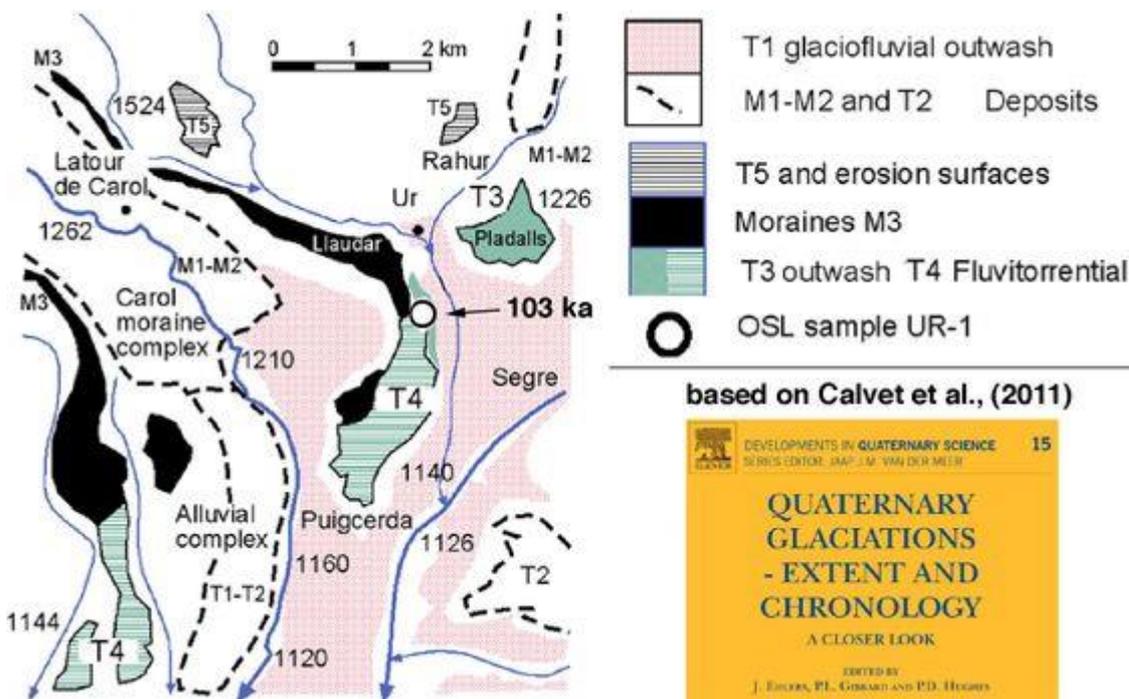
- What is new from the penultimate glacial cycle
- Did the LMIE coincides with an early Würmian stage?
- Were the Last Global Maximum (LGM) and the LMIE coincide.

A MIS6 glacial cycle is asserted at both extremes of the Southern Pyrenees (this work and García-Ruiz *et al.*, 2013), however our datings improve its knowledge in the Valira valleys, were we found a two fold sedimentary sequences starting at MIS6 (**Figure 1**).



**Figure 1:** NNW-SSE section from the Segudet kame and glaciolacustrine complex in Andorra (SE-Pyrenees). Gr: Imbricated gravels (kame). Fl: Laminated fines (Glaciolacustrine). Gs: Stratified gravels (colluvium). Dmc: Massive diamicton rich in boulders (Würmian supraglacial till).

The Würmian cooling start close to 90 ka (MIS5c), being synchronous in both Pyrenean slopes, at least in its Eastern side (French Cerdagne and at La Margineda in Andorra, this work, the French Niaux cave, Pallàs *et al.*, 2006). From La Margineda (980 m a.s.l.), this first glacial advance is behind the LMIE (< 845 m a.s.l.). This also happen in the South-Central Pyrenees (Noguera Ribagorzana, Cinca-Cinqueta, Ara, Gallego and Aragon; Sancho *et al.*, 2018), however at the Easternmost side of the Southern-Pyrenees not. This is the case of Puigcerdà (Cerdagne), were the LMIE from the Carol glacier coincides twice in MIS4 and in MIS2. However an early Würmian glacial front behind this LMIE position might be expected since we got a MIS5c glaci-fluvial deposits at LMIE position (**Figure 2**).



**Figure 2:** Geomorphological sketch at Puigcerdà. Previous authors dated Moraine M2 as from MIS4 and moraine M1 as from MIS2 (LGM). Outwash T3 early Würm (this work).

The idea of an LMIE-like for the LGM phase (Pallàs *et al.*, 2006) still remains in the literature, however updated data denies this, almost at the southern slope of the Pyrenees. However this glacial feature seems occur only at the Easternmost Pyrenees (Carol valley) but further work is still needed.

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P-2441

## Timing of the local Last Glacial Maximum and deglaciation on Pico de Orizaba and Cofre de Perote volcanoes (Mexico)

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### Abstract

Glaciers are highly sensitive indicators of global modern and past climate change especially in the tropical region (Kaser and Osmaston, 2002). In Mexico, the glacial history has been studied extensively, but the chronology of the local Last Glacial Maximum and deglaciation remain poorly constrained in some mountains such as Pico de Orizaba and Cofre de Perote stratovolcanoes. Both stratovolcanoes are located in the eastern part of the Pliocene-Quaternary Transmexican Volcanic Belt, ~100 km to the west of the Gulf of Mexico.

*In situ*-produced cosmogenic <sup>36</sup>Cl ages of moraines and glacially polished bedrocks from Iztaccíhuatl volcano, which present the most accurate dated glacial record in central Mexico, suggest that the local Last Glacial Maximum took place between 20 and 14 ka whereas the deglaciation began ~ 14 ka ago (Vázquez Selem and Lachniet, 2017). Based on the well-constrained glacial chronology of Iztaccíhuatl volcano, we expect to obtain a similar chronology of the local Last Glacial Maximum and deglaciation on Pico de Orizaba and Cofre de Perote volcanoes. To verify this hypothesis we also used <sup>36</sup>Cl cosmic ray exposure (CRE) dating to determine the age of moraines and glacially polished bedrocks from both stratovolcanoes.

The <sup>36</sup>Cl CRE ages of a moraine of the local Last Glacial Maximum from Pico de Orizaba range from 20.9 ± 2.3 ka to 16.7 ± 2.8 ka. Regarding the deglaciation, two glacially polished bedrocks yielded the following <sup>36</sup>Cl CRE ages: 13.6 ± 2.8 ka and 11.0 ± 1.7 ka. Cofre de Perote presents similar <sup>36</sup>Cl CRE ages: 20.4 ± 1.1 to 13.2 ± 1.0 ka from three moraines (n=6 samples) of the local Last Glacial Maximum; and 14.1 ± 1.0 ka to 11.4 ± 0.6 ka from glacially polished bedrock (n=4). Overall, these <sup>36</sup>Cl CRE ages reveal a similar glacier behavior between the central and the eastern part of Mexico during the local Last Glacial Maximum and the beginning of deglaciation. Moreover, it must be noted that the local Last Glacial Maximum coincides with the global Last Glacial Maximum and the onset of the deglaciation could correspond with the Bolling-Allerod. However, these connections must be confirmed through more dating efforts due to the high uncertainties that present the <sup>36</sup>Cl CRE ages.

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**P-2442**

## **Quaternary South glacial advancement in the Andes at ~ 37° S and the discussion about paleoglacial meaning**

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### **Abstract**

In Chile between 30°S - 40°S little is known about the Last Glacial Maximum (LGM) because of the gap in studies about palaeoenvironmental changes. Few studies in Laguna del Maule (~ 36° S) and el Yeso (~ 33° S) showed that LGM glacier advances in this area of the Andes have not been neither synchronic nor equal and have presented lags related to weather conditions. Moreover, the geomorphological registers are no continuous due to the activity of volcanos during Quaternary in the area and landslide events.

The present work shows results of a geomorphological study focused on determining the maximum glacier advancement in the Diguillín valley at ~ 37° S. The valley presents typical characteristics of U-shaped valleys and glacial evidences such as moraines, erratic rocks and outwash deposits. The geomorphological cartography of the valley shows that the action of glaciers had a great importance in the formation of relief in the area.

The moraines studied along the Diguillín valley are dissected by recent alluvial channels and covered by alluvial fans showing different degrees of preservation and extension. These morphologies are the result of glacial retreat since the Pleistocene. Related to glacial body descendent erratic rocks deposits has been observed at 697 m.s.n.m suggesting the existence of glacier development formed by the Diguillín and its tributaries, which would have reached a level below 700 m.s.n.m. The fluvioglacial deposits constitute the most western glacial deposits in the hydrographic basin of the Diguillín River. These results imply that the maximum local advance of the glaciers during the Last Glaciation reached levels of 630 m.s.n.m. over the west side of the mountain range.

Through the identification of glacial deposits this study shows the first evidence of Quaternary glacial advancement below 900 m.s.n.m between 30°S - 40°S in Chile and contributes to the knowledge of the geomorphological and paleoclimatic evolution glacier advancement of the late Quaternary South Andes. To determine the glacial chronology events, it is necessary to complemented this study with ages of exposure through cosmogenic methods. That will provide absolute age control on the palaeoenvironmental history and the differentiation between global Last Glacial Maximum (LGM) (21 ka BP) and to the Younger Dryas/Antarctic Cold Reversal (10 ka BP) event will be possible.

P-2443

## The rapid deglaciation of the La Vega gorge (Sierra de Gredos, Spain) following the Last Glacial Maximum

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### Abstract

The highest Iberian mountains have been intensely affected by Quaternary glaciations. One of them is the Central Range in Spain where local maximum glacial advances have been dated between  $\sim 33$  ka and  $\sim 21$  ka using cosmic ray exposure dating. However, the deglaciation following the Last Global Maximum has been poorly constrained. The existing evidence in other Iberian mountains such as the Central Pyrenees show a massive and rapid pattern of glacier retreat. A similar glacier behaviour has been also reported in the large ice sheets of the Northern Hemisphere and the Alps where by  $\sim 18$  ka the Rhine Valley had lost 80% of its ice mass.

To confirm that a massive deglaciation took place in other Iberian Mountains following the Last Glacial Maximum, we dated moraines, glacially polished bedrock surfaces and lacustrine and aluvial deposits from La Vega gorge located in the northern slope of the Sierra de Gredos. These ages were obtained using  $^{10}\text{Be}$  cosmic ray exposure (CRE), Optically Stimulated Luminescence (OSL) and radiocarbon dating.

The results derived from  $^{10}\text{Be}$  CRE dating indicate the deposition of the mayor moraines in La Vega gorge took place between  $\sim 25$  - 19 ka in agreement with the Last Glacial Maximum. Furthermore,  $^{10}\text{Be}$  CRE dating from glacially polished bedrock surfaces, located upvalley from the dated moraines, suggest that the glacier retreat began  $\sim 19$  ka ago, interrupted by minor advances, and the valley was ice-free shortly after  $\sim 17$  ka. This rapid glacier retreat is confirmed with OSL and radiocarbon dating of lacustrine and aluvial sediments in basins closed by the mayor moraines located at the bottom of the valley, indicating that the depositional process began  $\sim 18$  ka ago and the filling lasted until  $\sim 4$  ka ago.

Therefore, the new ages obtained in La Vega gorge suggest that a rapid and massive deglaciation occurred after the Last Glacial Maximum in the Iberian Central Range. This drastic retreat agrees with the data reported in Central Pyrenees, the Alps and the large ice sheets of the Northern Hemisphere.

P-2444

## Reconstruction of the deglacial chronology based on geomorphological survey and surface exposure dating on Soya Coast, East Antarctica

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### Abstract

A better reconstruction of past deglaciation history in East Antarctica since the Last Glacial Maximum (LGM) is important in order to constrain ice sheet and glacial-isostatic adjustment models and to anticipate their contribution to global sea-level rise. Geomorphological studies and surface exposure dating (SED) will provide direct evidence of the timing and potential magnitude of ice retreat on coastal oases and nunatak regions in East Antarctica. Recent studies have reported ice sheet retreat ages based on SED at the Skarvsnes, southern part of Soya Coast, East Antarctica. However, deglacial history remains unclear, because a limited number of surface exposure ages were reported by a previous study, and the results were not interpreted based on field-based geomorphological data.

This study reconstructs a detailed deglacial history since the LGM of the East Antarctic Ice Sheet based on geomorphological field survey at the Skarvsnes ice-free area on the Soya Coast, Dronning Maud Land. Thus, it is revealed that the basement rocks higher than 250 m asl were more weathered than those below ca. 250 m asl. The extensively weathered basement rocks at the highest peak (ca. 400 m asl) at the Skarvsnes are quite similar to those of the other ice-free areas of the northern part of Soya Coast, where have been estimated as had been remained ice-free throughout the LGM based on some previous results of <sup>14</sup>C dating of fossil shells in the marine sediments. Therefore, the differences of weathering features are interpreted to be indicating the upper limit of the ice surface elevation during LGM in this area. Judging from the multiple directions of glacial striae, the ice sheet covering the area had retreated while changing the flow direction under the influence of the basement topography after LGM.

Several surface exposure ages were obtained from different altitude and distance from the current ice margin. These ages are consistent with the above geomorphological interpretation, suggesting that the ice sheet retreating history as follows; the ice was extended out of 5 km from the current ice margin at 13.7 ka; then it retreated almost to the current ice margin at about 9 ka. Finally, the deglaciation in this region was generally completed by the early Holocene.

**P-2445**

## **Dating the last British-Irish Ice Sheet using luminescence dating of glacial cobbles**

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### **Abstract**

Understanding the response of glaciers to past climate change is vital to help predict the response to modern drivers, and future climate change. An accurate chronology is key to interpreting the glacial deposits and landforms which may serve as excellent archives of the extent and timing of previous glaciations. However, dating glacial deposits is notoriously difficult. Optically stimulated luminescence (OSL) dating of unconsolidated, sand-sized sediment grains, is one of the few techniques capable of providing a chronology for glacial sediments. One of the key issues for this technique is the potential for incomplete resetting ('bleaching') of the previous OSL signal prior to deposition. If unresolved, this incomplete bleaching of the signal used for dating the sediment grains will cause overestimation of the true depositional age. Small aliquot and single grain methods have been applied to date glacial sediments, using statistical models to identify the well-bleached grains and hence to assess the depositional age of the sediments. However, the choice of the statistical model employed, and estimation of key parameters within the model, are somewhat subjective.

An alternative approach is luminescence dating of large clasts (e.g. Sohbaty et al., 2012), where cobbles can be examined instead of unconsolidated sediment grains. Dating involves drilling into the surface of the cobble, and making measurements of the OSL signal as a function of depth; this provides an unambiguous assessment of the degree to which the OSL signal was bleached on deposition prior to subsequent burial, and hence also gives a clear indication of the likely reliability of the ages generated. This approach has been successfully applied to glaciofluvial cobbles from a known-age sandur on the Isle of Man (Jenkins et al., 2018). This presentation applies this method to a range of other sites.

Glaciofluvial cobbles were collected at sites along a transect from the British Midlands to northwest England, along the line of retreat of a land-terminating lobe of the last British-Irish Sea Ice Sheet. The results from these cobbles have been integrated with ages from the BRITICE-CHRONO project, obtained using cosmogenic radionuclides (CRN) and OSL dating of unconsolidated glacially-derived sediments. Bayesian analysis is used to assess the consistency of this data set and to integrate the geomorphological and chronological data.

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P-2446

## <sup>10</sup>Be exposure dating on moraines in the Sayan Mountains, Siberia

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### Abstract

Mountain glaciers are very sensitive to (past) climate changes. Paleoglaciation of the Tibetan Plateau and the Himalaya received plenty of attention for the reconstruction of past climate and environmental conditions, whereas few studies have been conducted so far in the adjacent Altai and Sayan Mountains in Siberia, although they promise a complex history.

The investigated Sayan Mountains in the Russian Altai indicate extensive glacial activity during the Pleistocene and a shifting of the local Last Glacial Maximum (LGM). Rich glacial residues in terms of moraine ridges and erratic boulders in the region provide excellent opportunities to establish a detailed age chronology using *in-situ* cosmogenic <sup>10</sup>Be surface exposure dating and derive information about paleoclimatic conditions.

We present 28 <sup>10</sup>Be surface exposure ages from the Ergaki Range and Tuva Uplands in the western Sayan Mountains. Distinct lateral moraines document the extents of former glaciation during a last glacial maximum. Several recessional moraines in the Ergaki Range additionally record stand stills or readvances during the last glacial termination.

The prominent lateral moraine in the Ergaki Range yields three exposure ages of ~19 ka, indicating a MIS 2 glaciation. The maximum advances correlate with the end of the global LGM. Concluding, glaciers in the Ergaki Range existed continuously during the late Pleistocene only varying in their extent. The well-clustered ages of the Ergaki Range provide a robust deglaciation chronology. The readvances/ stand stills consistently date to ~18 ka (three boulders), ~17.5 ka (two boulders), ~17 ka (three boulders), and ~16 ka (two boulders), with a deglaciation starting after 16 ka. The valley is not elevated enough to record younger, less extensive glaciation, e.g. during the Younger Dryas and the Holocene. Exposure ages from the Tuva Uplands are more difficult to interpret: The lateral moraine documenting the most extensive glaciation yields two exposure ages of ~22 ka. The immediately adjacent inner lateral moraine has two slightly younger and stratigraphically consistent ages of ~21 ka, yet two more boulders from that moraine are ~27 and 43 ka. At this point, we suspect these older boulders to have inheritance, but we cannot confidently exclude a much older deposition age for both moraines. Planned are analyzes of other cosmogenic nuclides, such as <sup>26</sup>Al and/or *in situ* <sup>14</sup>C, which might help to more robustly identify inheritance and complex exposure histories.

P-2447

## Late Pleistocene Cosmogenic $^{36}\text{Cl}$ Glacial Geochronology and *PISM* Ice Flow Model of the Central Taurus Range, Turkey

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### Abstract

The glacial geochronology of the Taurus Mountain Range is well-studied thanks to several works that use quantitative methods. Here, we report the timing of deglaciations in the central part of the Taurus Range, in the Mount Karanfil and Aladağlar during the Late Pleistocene. In the light of terrestrial cosmogenic nuclide  $^{36}\text{Cl}$  surface exposure ages and glacial geomorphology, we use the Parallel Ice Sheet Model (PISM) to model Last Glacial Maximum (LGM-20 ka) cycle in central Taurus Range. Aladağlar Massif, covers an area of 800 km<sup>2</sup>, composed mainly of Mesozoic carbonate rocks and shows the evidence of Late Pleistocene glaciations. We carefully carried out glacial geomorphological map of Aladağlar and Karanfil mountains and collected moraine boulder samples for cosmogenic  $^{36}\text{Cl}$  surface exposure dating. We collected 21 samples from Karanfil Mountains and 39 from Aladağlar to assess the timing of paleoglaciations. The ages obtained from W-NW-facing Körmenlik Valley indicate a deglaciation starting from ca. 35.000 years (35 ka) in Aladağlar which give substantial evidence regarding ice accumulation before the global LGM. Moraines of ca. 20 ka in age are observed in higher altitudes in Aladağlar and Mount Karanfil. Late Glacial (ca. 15 ka) moraine ages are also well established from Maden Valley. We also present preliminary field observations as 13 samples are still in progress from Eastern Valleys of Aladağlar. The results from the NW-facing valleys in Mount Karanfil indicate deglaciation starting during local Last Glacial Maximum (LGM), ca. 19 ka. Late Glacial (ca. 15 ka) moraine ages are also well established in Mount Karanfil. Additionally, a rock glacier at ca. 2500 m was dated to early Holocene (ca. 11 ka) indicating periglacial conditions in this mountain. The moraine and rock glacier ages are first dates obtained from this part of the Taurus Range, which is compatible with the glacial chronology of southern Turkey and surrounding regions. In order to obtain glacial conditions of the past, we used simulations of nine conditions, in Mount Karanfil, with open-source PISM, which necessitates 9°C decrease in air temperatures and 25% more precipitation compared to today's conditions. This work was supported by TÜBİTAK 116Y155 project.

P-2448

## Younger Dryas moraines and relict rockglaciers system in the High Tatra Mountains

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### Abstract

The Tatra Mountains witnessed the strongest Pleistocene glaciation amongst all massifs of the Carpathians. The Tatras are also the northernmost mountains with typical alpine relief in Central Europe, in the Alpine and Carpatho-Balkan realm. The key position of the Tatra Mountains on the border of Poland and Slovakia provides a link between the northern cold and southern warm parts of Europe. The Tatra Mountains are currently not glacierized neither were they during the Little Ice Age. There are also no active rockglaciers. Although, the highest parts of these mountains contain a rich archive of well-developed glacial landforms as well as relict rockglaciers. These facts open up a discussion about the development and retreat of glaciers in the area. The youngest glacier advances left sequences of moraines, which indicate that the style of glaciation was marginalised and predominantly controlled by local climate and topography. Boulder-rich, well-preserved landforms, with no developed soil cover are very suitable for surface exposure dating. The <sup>10</sup>Be isotope as well as GIS analysis were used to determine the extent and age of the latest deglaciation phases in these mountains. For each glacier, we reconstructed ice surfaces and calculated the local ELA and rockglacier initiation altitude. Dated landforms are mostly located not further than 500 m from cirque backwalls. In case of such small glaciers, which are strongly influenced by topo-climatic factors, estimation of the ELA using traditional methods is unreliable and gives underestimated results. Those small paleoglaciers and rockglaciers, most probably persisted slightly below the regional ELA in the highest parts of the High Tatra Mountains in the end of last glaciation. The exposure dating of glacial boulders and bedrock together with morphostratigraphy confirmed that the last phases of glacial activity took place within the Lateglacial, during the Younger Dryas cold period, around 12.5 ka. The results indicate lack of activity of glaciers and rockglaciers within the entire Holocene.

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P-2449

## Heinrich1 and Dryas glacier stages in High Asia and their implication for a reassessment of TCN ages in the Himalaya

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### Abstract

Heinrich 1 and Dryas events constitute global signals for which we also find evidence in different climate proxies in China and on the Tibetan Plateau. In the present study, we identified all Heinrich 1/Dryas events among the available  $^{10}\text{Be}$  ages of glacial deposits of the Himalayan-Tibetan orogen. Taken together, we identified 51 localities with outstanding clustering in the TCN-dating results. The corresponding  $\Delta$  ELA depressions of  $\sim 1000\text{--}300$  m are within the range of what is commonly ascribed to the LGM. These localities are clearly distinguishable from the surrounding area as younger glacial stages. By contrast, the stages older than Heinrich 1 cannot be ascribed to any single time frame. We assume that the high inheritance rates of the older, polyglacial till sheets are the result of a glaciation of the Tibetan Plateau under cold-based conditions similar to the polar regions as it is still a permafrost area and suggest that this explains why even the more extensive Heinrich 2 event is not detectable as a distinct signal in the available TCN data. The formerly glaciated regions of the Arctic and Antarctica yield sound evidence of the phenomenon of limited ice sheet erosion and complex exposure histories due to cold-based ice. If this body of evidence is taken seriously, the complicated patterns of TCN ages of glacial deposits in High Asia becomes less of a mystery and is offered an explanation. All of the evidence that is available to us today suggests that the Himalayan-Tibetan orogen did not merely undergo the Late Glacial Heinrich 1/Dryas events but also, indeed, Heinrich 2 and the LGM. The latter (H2, LGM) occurred as an inland glaciation with an extensive network of outlet glaciers. In order to make glacial deposits with high inheritance rates accessible to absolute datings, future research should not only rely on  $^{10}\text{Be}$  and  $^{26}\text{Al}$  data, but also on the determination of *in situ* cosmogenic  $^{14}\text{C}$  nuclides. This latter dating technique is already successfully applied in the formerly glaciated Arctic regions.

P-2450

## Constraining the LGM in the Drau-Glacier Area by Single-Grain-Feldspar Luminescence Dating - Implications for reconstructing Ice Dynamics in the European Alps

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### Abstract

The area of the former Drau glacier system is located in the south-eastern sector of the Alps, and is characterized by extensive sedimentary archives of the last glacial cycle. These can be traced from LGM terminal moraines and proglacial outwash cones to areas close to modern glaciers. This offers the opportunity to constrain glacial chronology and dynamics of the LGM (last glacial maximum), and close the gap in knowledge between the northern and southern flanks of the Alps.

Previous efforts in establishing and improving glacial stratigraphy in the Alps have predominantly been focused on the northern flank of the Alps and its foreland (e.g. Preusser, 2004). However, recent progress in constraining the timing of the LGM was achieved on the southern flank (e.g. Monegato et al., 2007). Despite the progress, even for the short time span of the LGM, our understanding of e.g. climatic gradients across the Alps and their implications for the LGM ice dynamics of the Alpine ice sheet as a function of paleoclimatic forcing factors is still limited due to sparse data especially in the inner alpine areas.

The focus of this study lies on constraining the chronology of proglacial aggradation at the onset and during the climax of the LGM and during Termination I. Recent studies applying optically stimulated luminescence dating techniques to glaciofluvial sediments in the European Alpine foreland (e.g. Rades et al. 2018) highlighted the obstacles, but also the chances in deciphering the chronology of processes during the Late Pleistocene period by using numerical dating methods. We present luminescence ages from the tongue basin of the Drau glacier and its forefield, based on single-grain measurements of potassium-rich feldspar, using a post infrared infrared (pIRIR) luminescence SAR (single aliquot regenerative) dose protocol at stimulation temperatures of 50°C (IR50) and 225°C (pIRIR225). Despite methodological challenges, these ages may allow constraining the timing of advance and retreat of the Drau Glacier. In addition, these new results emphasise the urgent need for a synoptic review of available numerical age data from the last glacial cycle of the European Alps and their process-specific (re)interpretation, in order to provide a more robust framework for the reconstruction of over-regional ice dynamics in the context of paleoclimatic change.

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P-2451

## Glacier evolution in the Alps during the early and mid-Holocene – new results from Tschierva and Pasterze glaciers

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### Abstract

Current climate change strongly affects the glaciers in the Alps causing partly fast recession and collapses of glacier termini or even entire glacier tongues. This is a consequence of a strong temperature increase in the Alps that approximately doubles the global warming rates during the last decades. The ongoing recession indicates that extent and length of Alpine glaciers are not in equilibrium with current climate conditions. However, as these glaciers have shrunk, some of them have unveiled displaced and in-situ tree remains as well as other organic material and sediment profiles near their termini. Radiocarbon dates of organic material as well as calendar dates of tree remains established on the base of the Eastern Alpine Chronology prove that most of these finds date back to the early and mid-Holocene, allowing new insights in past glacier variability and evolution. Here we report new results from two Alpine glaciers. At the Tschierva glacier, Switzerland, the tree-ring series established for dozens of tree remains prove three multi-centennial to millennial long retreat phases around 4.0, 7.0 and 9.8 ka. These retreat phases were followed by advances of the Tschierva glacier beyond today's extent. At the glacier Pasterze, Austria, a c. 2.5 m long sediment profile with alternating organic and clastic layers was discovered at a site that got free of ice in 2010. Radiocarbon dates show that sedimentation took place between ca. 7.1 and 3.9 ka. Detrital tree remains sampled in the surroundings of this sediment date mainly into the same time period. A comparison of the results of both glaciers suggests a different sensitivity to past climate variability caused by varieties in size and topography.

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**P-2452**

## **Ages and transport history of moraine boulders from rock surface luminescence profiles**

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### **Abstract**

Moraine deposits are the key to untangling former ice sheet movements. Unfortunately, it is often difficult, sometimes even impossible to date these deposits by currently available methods (e.g. cosmogenic nuclide (CN) or radiocarbon dating) because of problems with inheritance, post-depositional shielding and/or lack of suitable (organic) material. Rock surface luminescence burial dating has the potential to provide not only ages for glacial moraines, but in addition information about past deposition and transport events in the history of individual boulders.

Here, we present rock surface burial ages and rock surface luminescence profiles from moraine boulders to illustrate the potential of the method when applied to previously undateable deposits and to broaden our understanding of glacial transport. In contrast to associative dating methods (e.g. radiocarbon), in rock surface dating all samples are indisputably linked to the event of interest, and samples are generally readily available. The main differences compared to the more common CN dating of moraines lie in the criteria used to select boulders and clasts for analysis. In CN dating, one looks for clasts that have not been exposed at the surface before final emplacement. In rock surface dating using luminescence, one wants exactly the opposite – i.e. significant exposure to daylight before final deposition inside the moraine. Most post-depositional movement within the moraine deposit is irrelevant, as long as the surface of interest remains buried.

A major advantage of rock surface luminescence burial dating compared to conventional luminescence dating using sand-sized or smaller grains arises because boulders are large enough to internally record the degree of bleaching prior to burial. Thus, clasts that have been sufficiently bleached prior to burial can be unambiguously identified from the shape of the luminescence-depth profile close to the rock surface. This is a major factor in ensuring that the age derived from the surface layer is reliable. Of course, only a fraction of the large clasts in a moraine will have received enough daylight exposure to be sufficiently bleached, , nonetheless, we find that 11 out of 19 boulders so far were usable of which 8 boulders showed a bleaching front at a depth of more than 5 mm. However, even inadequately bleached surfaces provide process information as they record histories of surface erosion and/or deposition and subsequent transport without daylight exposure. One of the main challenges in the application of the method remains the efficient identification of suitably light-exposed clasts prior to sampling.

P-2453

## Timing of Lateglacial moraines in the Northern and Western parts of the Ecrins massif (French Alps)

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### Abstract

The Ecrins massif, in the French Alps, is very suitable for TCN dating, due to its quartz-rich rocks (mainly granite and gneiss). Nevertheless, only very few data are available so far on the Lateglacial glacier retreat, mainly because of the sparsity of well-preserved Lateglacial moraine sequences.

For the present study, four moraine sequences were dated by means of <sup>10</sup>Be TCN dating on erratic boulders. Three are collected in the Northern area of the massif, around the Combeynot massif : i) a sequence of four frontal moraines along the Vallon du Fontenil, ii) a set of three latero-frontal moraines from the morainic complex of the Plan de l'Alpe, located just outside of those already dated by Chenet et al. (2016), iii) one frontal moraine of the Arsine glacier, and iv) three subparallel lateral moraines and one frontal moraine at Font Turbat in the Western area of the massif.

The methods include a detailed geomorphological mapping of the whole area, a morphostratigraphical approach into stadials and positions, the reconstruction of the glacier topography for each considered position, and ELA calculations based on the AAR method with a standard AAR of 0.67, in order to ensure comparison with other data from the central and eastern Alps. For each selected landform, at least three suitable boulders were sampled for TCN analysis (collaboration for analysis with the ASTER team, Aix-Marseille). A total of 31 boulders and 4 erosion surfaces, corresponding to 12 positions, was dated.

After removal of a few obvious outliers, resulting from complex exposure histories, results show that all dated moraines fall into the Greenland Stadial 1 (GS-1) cold event and can be attributed to the Egesen stadial of the Alpine Lateglacial morphostratigraphy. The results are fully consistent with the existing data on the massif (Chenet et al. 2016; Hofmann et al. this congress). They confirm:

i) that the Egesen stadial is the only well preserved Lateglacial stadial in the massif. The absence of preserved older moraines is due to the very steep trough topography which may have prevented deposition, and to thick scree and torrential accumulations which may have entirely covered glacial deposits.

ii) the large extent of the Egesen stadial in some valleys. This can be explained by the high altitude of the upper catchment, inducing a large increase of accumulation area even for moderate ELA lowering.

iii) the multiphase character of the Egesen stadial. At Plan de l'Alpe, up to 10 successive frontal positions cluster into two distinct groups of moraines, with a significant thickness and length difference. However, the overlap of dating uncertainties does not allow to distinguish two sub-stadials. At Fontenil and Font Turbat, consistent chronological sequences are obtained.



Chenet et al. (2016). Quaternary Science Reviews 148, 209-221.

P-2454

## Chronology of Laurentide Ice Sheet (Huron-Erie Lobe) fluctuations during the Last Glacial Maximum, Indiana, USA

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### Abstract

The chronology of Laurentide Ice Sheet (LIS) advance to and retreat from its maximum Oxygen Isotope Stage (OIS) 2 limit in central North America is important because it allows evaluation of the driving mechanisms of ice sheet growth and decay and provides a terrestrial chronology that can be compared to the marine record and other paleoclimate proxies. New radiocarbon dating from outcrop and cores in central Indiana, USA, has refined the timing of LIS Huron-Erie Lobe OIS 2 advance to and retreat from the maximum limit. These new ages, combined with previously published radiocarbon ages from the southern Great Lakes region (Illinois, Indiana, and Ohio) within or below OIS 2 till, indicate LIS advances ca. 25.8, 23.7, and 21.5 k cal yr BP. In Indiana and Ohio, these three advances terminated within ca. 25 km of each other, with the 23.7 k cal yr BP advance typically representing the maximum limit across the southern Great Lakes region. The advances were separated by two significant episodes of ice retreat of >50 km, documented by the preservation of organics, terrestrial gastropods, and glacial lake sediments between tills. These millennial-scale fluctuations of the LIS during the Last Glacial Maximum (LGM) [ca. 26 to 21 k cal yr BP] do not correlate with known climatic forcings and point to yet unknown dynamic controls on ice margin position. An additional record of LIS advance is recorded in the timing of outwash aggradation and associated slackwater sedimentation in the West Fork White River valley and tributaries in central Indiana. Eight radiocarbon ages from a core 10 km beyond the OIS 2 limit indicate slackwater sedimentation began ca. 27 k cal yr BP and continued until ca. 20.5 k cal yr BP, representing the timing of ice sheet advance into and out of the paleo-White River drainage basin. Ice sheet advance and retreat rates average ca. 40 m/yr during the LGM, when ice was within ca. 50 km of the OIS 2 maximum. Retreat rates increased slightly to ca. 50 m/yr after 21.5 k cal yr BP, as ice retreated ca. 110 km from central Indiana to the Union City Moraine (19.3 k cal yr BP) in northeastern Indiana. Needed future work involves investigation of the role of subglacial conditions (frozen vs thawed) on ice margin fluctuations.

P-2455

## Holocene dynamics of Arsine Glacier (Ecrins Massif, French Alps) inferred from cosmogenic $^{10}\text{Be}$ dating

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### Abstract

Due to the sensitivity of mountain glacier dynamics to climate change, reconstruction of Holocene glacier chronologies allows us to better understand the evolution of the natural climate system during the current interglacial. However, records of glacier variations spanning from the Early Holocene to the Little Ice Age (LIA) and based on direct dating of glacial deposits remain scarce. The forefield of Arsine glacier, located in the Ecrins Massif of the Western Alps (France; 45°N), is characterized by the existence of abundant glacio-geomorphologic markers bearing witness of numerous past glacier extents of different size. Cosmogenic  $^{10}\text{Be}$  dating of the most distal moraines in the study area provides evidence for multiple glacier extensions during the Early Holocene, while dating several of the crests on the proximal massive vegetation-free moraine complex yields ages of  $\sim 3$  ka and a few hundred years. These glacier extensions are thus in accordance with the Neoglacial and the LIA, respectively. No moraines are preserved from between  $\sim 10$  ka to  $\sim 3$  ka ago. These results are in very good agreement with Holocene-spanning  $^{10}\text{Be}$  moraine records in the Swiss Western and Central Alps, suggesting that glacier fluctuations during the Holocene were regionally synchronous at least on millennial timescales.

The glacio-geomorphic peculiarity at the study site of Arsine glacier consists in the existence of a 1-km-wide and 0.5-km-long rockglacier-like deposit mostly composed of big sub-concentric blocky lobes and stratigraphically located between the Early Holocene moraines and the Neoglacial/LIA moraine complex. It could testify to a major glacier extent that must have occurred sometime between  $\sim 10$  ka and 3 ka ago, but at present further age constraints are missing.  $^{10}\text{Be}$  dating of boulders from this deposit are currently ongoing to complement the chronology of Arsine glacier's behaviour during the Holocene and to put the origin of the peculiar deposit in the context of the Holocene climate evolution.

P-2456

## Debris-flow cobbles as chronometers of mountain glaciation

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### Abstract

Optically stimulated luminescence (OSL) methods are widely applied for dating Quaternary sediments, and typically utilise the sand or silt-sized grains in clastic sediment as natural radiation dosimeters. The luminescence signal is reset by daylight, so the methods aim to date the last time that grains were exposed to daylight before burial. Daylight may also penetrate rock faces, and recent progress in measurement procedures has allowed OSL dating to be applied to buried cobbles and boulders. This has expanded the range of Quaternary sediments that can feasibly be dated using OSL methods, to potentially include moraine and debris-flow material. Such sediments are difficult to date at present, so an accurate method of doing so would greatly help in reconstructing glacial history and sediment transport in mountainous regions.

Debris flows and other mass movements are usually difficult to date by standard OSL, because resetting of sand grains during transport is unlikely. Cobbles and boulders, however, have a high probability of being exposed on hillslopes and stream beds for prolonged periods, so may have their luminescence signals reset prior to transport. Furthermore, a record of the bleaching history of a clast can be read by measuring the OSL signal with depth, and this provides an internal check on the degree of bleaching.

Here we investigate the debris-flow sediments of the upper Baksan valley in the Caucasus Mountains. The valley contained a major glacier during Pleistocene glaciations, and has evidence of smaller, presumably Holocene glacier advances. The area has steep topography sculpted by ice, prone to debris-flows and avalanches, and many destructive debris flows observed in the last few years. The numerous debris fans in the valley must post-date the last valley glaciation. Dating of these debris fans serves a double purpose: first, to help understand the recurrence intervals and causes of the debris flows; second, to place a chronology on glacier retreat in the Caucasus

P-2457

## Post-Last Glacial Maximum glacier variations in the southern Écrins massif (French Alps) in the light of new $^{10}\text{Be}$ exposure ages

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### Abstract

Only few chronological constraints on Late Glacial and early Holocene glacier fluctuations in the western part of the European Alps (French Alps) have been published. To provide additional chronological benchmarks on glacier variability in the French Alps, moraines of two palaeoglaciers in the southern Écrins massif were mapped and dated. Based on their relative positions in the field, the moraines were correlated and assigned to pre-Little Ice Age (LIA) glacier positions to establish a morphostratigraphy. Thirty-nine  $^{10}\text{Be}$  exposure ages from boulders on selected moraines were obtained to establish a chronology of glacier fluctuations. For suitable comparison with previous studies, 44  $^{10}\text{Be}$  exposure ages from moraines at key sites in the Alps were recalculated according to recent  $^{10}\text{Be}$  production parameters. As a third step, the equilibrium line altitude (ELA) depression relative to the LIA during moraine deposition was reconstructed to enable local stratigraphical correlations, whereby an accumulation area ratio of 0.67 was assumed throughout, as done elsewhere in the Alps.

Regarding the first palaeoglacier, ten pre-LIA positions were identified. According to a  $^{10}\text{Be}$  boulder exposure age from its third outermost mapped moraine, this landform may have stabilised at ca. 17 ka b2k when three confluent glaciers reached the moraine. The ELA of the first palaeoglacier was then depressed by about 220 m with respect to the LIA, whereas the ELA of two tributary glaciers must have been lowered by 490-590 m. The moraine was likely shaped or re-occupied by the first palaeoglacier at around 13 ka b2k when the ELA was about 230 m lower than during the LIA. At least six periods of stable ice margins associated with ELA depressions between 230 and 170 m occurred thereafter. The moraines of the innermost pre-LIA position of the first palaeoglacier stabilised at ca. 12 ka b2k.

Regarding the second palaeoglacier, two distinct groups of four pre-LIA moraines were identified. Their formation was associated with ELA depressions between 130 and 190 m with respect to the LIA. Hence, the moraines can be linked to the same period of glacier variability as the moraines of the first palaeoglacier. This is supported by three  $^{10}\text{Be}$  exposure ages from one moraine of the second palaeoglacier indicating moraine stabilisation at ca. 12 ka b2k.

The  $^{10}\text{Be}$  exposure ages are in agreement with exposure ages obtained from other moraines in the Alps that stabilised during the regional Egesen stadial as well as with data from other types of palaeoclimatic archives. This suggests a common climatic forcing of the glacier variations. Local factors, such as topography, likely explain the exposure age variability. Overall, this study contributes a significant refinement of the chronology of glacier fluctuations in the French Alps.

P-2458

## Ice cap behaviour in the Zackenberg region, East Greenland

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### Abstract

Ice caps and independent glaciers at the periphery of the Greenland Ice Sheet (GIS) cover over 89,000 km<sup>2</sup>. Their small size means that they respond sensitively to climate change, and can provide important insights into Arctic environmental change and GIS margin dynamics. Understanding the Quaternary behaviour of peripheral ice masses is therefore key for predicting the response of Arctic glaciers and the GIS to future climate change. However, detailed reconstructions from Greenland are limited, and many studies focus on south and west Greenland. Here we reconstruct the fluctuations of A.P. Olsen and Clavering Ø ice caps in Zackenberg, High Arctic East Greenland (74°N) using geomorphological mapping of glacial landforms and surface exposure ages (<sup>10</sup>Be) of moraine boulders and glacially scoured bedrock surfaces.

Our new geomorphological mapping and regional chronology indicate that during the Last Glacial Maximum (LGM) it is very likely that the ice caps became confluent with the Greenland Ice Sheet. Trimlines suggest that the highest peaks in the region remained ice free throughout the LGM. Following the LGM, the GIS and A.P. Olsen and Clavering Ø ice caps decoupled. A Younger Dryas readvance (c. 11.7 ka) of A.P. Olsen is marked by clear moraines in Zackenberg valley, and is followed by retreat throughout the Holocene. Extensive areas of hummocky moraine suggest ice marginal stagnation during this retreat phase.

These results provide vital information constraining ice cap behaviour from the Greenlandic High Arctic, a region with very few long-term glacier reconstructions. In comparison to previous regional reconstructions, based on trimline extrapolation, our results demonstrate an earlier deglaciation, and suggest that ice caps in this region responded in phase with climate during deglaciation.

P-2459

## **Pleistocene glaciers reconstruction on the northern valleys of Făgăraș Massif (Romania) from Last Glacial Maximum to Younger Dryas**

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### **Abstract**

Following a long period of major discrepancies in knowledge about glaciation ages between the Carpathians and other European mountain ranges, the Romanian Carpathians finally benefitted in the last decade from several studies presenting numerous absolute age datings of the glacial deposits that improved considerably the knowledge on the last glaciations chronology. Despite the fact that Făgăraș Massif is the highest massif from Southern Carpathians (and of the Romania) and the richest in terms of glacial features with deep glacial valleys and large cirques it remained the least studied and dated in relation with the Pleistocene glaciations.

The concentration, rate of production and rate of decay of terrestrial cosmogenic nuclides (TCN) can be used to determine the exposure ages for a variety of landforms and geomorphological processes associated with deglaciation. Due to the high quartz content of the crystalline schist rocks which are dominant in Făgăraș the exposure ages were determined via <sup>10</sup>Be. Samples were chemically processed and for the first time dated within a Romanian institution, respectively at Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Măgurele – Romania (RoAMS Laboratory - Tandem Accelerators Department and Applied Nuclear Physics Department). The new obtained exposure ages (<sup>10</sup>Be) were compared to the measurements performed at the CEREGE laboratory (France) and the differences were negligible. Based on the measurements carried out on samples taken at different altitudes, using erratic blocks and large blocks of moraines, absolute ages were obtained for 5 valleys with northern exposure (Doamnei, Bâlea, Arpașul Mare, Sâmbăta and Urlea Valleys), which indicate similarities (Younger Dryas advance recorded in most of valleys) in the manifestation of cold phases of glacier advancement, as well as some differences dictated by inherited morphological features of the respective valleys.

P-2460

## Recent data on Pleistocene glaciation history of central part of the North Caucasus

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### Abstract

It is well-known that Central Caucasus region had large glacier systems in the past, that affected the climate of the entire region significantly. Modern landscape of Elbrus highlands is a typical alpine zone with frequent avalanches, debris flows, rockfalls and etc. Geomorphological processes are taking place very intensively and in many places, and because of them it is particularly difficult to study glacial history here.

There were numerous attempts to reconstruct distribution of Pleistocene glaciers. Most of the previous investigations stated, that the Caucasus Mountains have experienced at least three periods of glaciation. Also, there are plenty of unexplored evidences of glacial fluctuations in the valleys. However, paleoclimate reconstructions of the area are fragmentary and incomplete. Moreover, the origin of some particularly large landforms, such as Tubele hill in the Baksan valley, still remains unknown.

Since the dating by standard OSL is difficult in mountain areas, we used rock-surface dating, which allows us to establish the burial date of mostly rock material, since large cobbles are more likely to be exposed to daylight. In the Baksan valley (Central Caucasus), we have investigated cobbles from fans of various genesis. Due to received data, we got the rate of accumulation and ages of different mudflows and avalanches activation phases. These data also can be seen as a good indicator for paleoclimate chronology.

Here we offer recent data on the Pleistocene glaciations stages in the central part of the North Caucasus. The OSL dating of several fans sheds light on the Pleistocene Central Caucasus history.

**P-2461**

## **Late Quaternary Glacial history in the Kali Ganga Valley, Tethyan Himalaya, Uttarakhand, India.**

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### **Abstract**

The Himalaya region has preserved the evidences of various glacial advances. These evidences shows that the glaciers have fluctuated many times throughout the late Quaternary period. Yet, there is a debate whether the glacial advance in the Himalaya occurred as a response to low temperature or it is a result of increased monsoon brought by Indian summer monsoon. We have tried to examine this issue, by observing multiple sets of lateral moraine preserved in four different tributary valley of the Kali Ganga valley, Tethyan Himalaya, India. The glacial chronostratigraphy and history of this region is defined for the first time using Optical Stimulated Luminescence dating. The study also reported the oldest preserved moraine in the valley, which is corresponds to Marine Isotopic Stage-3 (31-56 ka), witnessed by the Optical dating of lateral moraine. The extent of the MIS-3 moraine is only 5-8 km from the present snout , but the ice cover occupied by the glacier valley during this time was (~400-600 m) thick which is now preserved as a highest lateral moraine. The second major glacial advance occurred during Last Glacial maxima (17-23 ka) having less ice thickness (150-200 m) as compared to the MIS-3, with the advance of 1.5 km from the present snout. The third glacial advance took place during the mid-Holocene with the glacial advance of 0.8 km from the present snout. The Hummocky ground moraines were also present below the present snout of the glacier showing the standstill condition of the glacier. The mounds of moraine present proximal to the present glacier depicts the response of glacial during Little Ice Age (LIA). Comparing with the results of other climate proxies, we suggest that in the Kali Ganga Valley, MIS-3 glaciation is triggered by the enhanced monsoon, LGM, Mid-Holocene and Little Ice age glaciation is driven by the low summer temperature having its connection with the Northern Hemisphere cooling events.

P-2462

## Geomorphological and chronological evolution of Karadağ mountain (SW Turkey)

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### Abstract

Karadağ is one of the mountains subjected to the Pleistocene glaciations along with Beydağları, Akdağ and Sandıras in the Teke Peninsula (Teke Region). Within a 30 km straight distance from the northeast of Fethiye Bay to the top of the mountain, the elevation rises 2418 m at the summit surpassing many peaks over 2300 m. The mountain mainly features as a karst terrain having numerous karstic depressions at higher elevations close to the peaks. Glacial landforms also found on the north facing slopes of this area.

There are plenty of quantitative glacial research and dating studies aiming to reveal chronology of the glaciations in Pleistocene in the Teke Peninsula. But most of the studies are on the mountains glaciated in Pleistocene, such as Sandıras and Akdağ. On the other hand, there are only a few glacial studies concerning Beydağları in which the glaciations were mentioned superficially. And lastly, there has not been any studies on Karadağ until this work due to unknown glacial phenomenon. However, Karadağ has distinctive cirques and moraines on the slopes of higher elevation near the peaks. After field works, we carried out in Karadağ, we mapped five cirques which developed in different sizes and aspects and in front of them lie hummocky and frontal moraines descending up to 1800 m.

Here, we present initial results of a TÜBİTAK project aiming to reveal geomorphological, climatic and chronological features of a recently discovered glaciated mountain-Karadağ. <sup>36</sup>Cl surface exposure dating method was used to reveal geochronology and paleoclimatic variations of Karadağ. In addition, an automatic weather monitoring station was set up on the mountain to gather first hand climatic data for better understanding of the climate of Karadağ and the station has started to provide initial data. Spatial data which is obtained by the methods mentioned above was subjected to analyzes using geographic information systems and subsequently, maps and result output were created.

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**Keywords:** Karadağ Mountain, Pleistocene glaciations, Quaternary geochronology, Western Taurus

P-2463

## Groundwater residence times and palaeohydrology in the Köprüören Basin (Kütahya, Turkey)

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### Abstract

In this study, stable isotopes ( $\delta^2\text{H}$ ,  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ), tritium and radiocarbon ( $^{14}\text{C}$ ) have been used to evaluate groundwater residence times and palaeohydrology in the Köprüören Basin which is located in Western Anatolia. 20 groundwater samples were collected in May and September 2012 and analyzed for  $\delta^{18}\text{O}$  and  $\delta\text{D}$  contents. In addition, tritium contents of 11 samples and  $\delta^{13}\text{C}$  and  $^{14}\text{C}$  content of 5 samples were also determined to get information about the residence times. The results indicate that the  $\delta^{18}\text{O}$  and  $\delta\text{D}$  contents of the samples, respectively, ranged from -10.84‰ to -8.55‰ and from -73.6‰ to -61.2‰ in the dry season and ranged from -10.81‰ to -8.28‰ and -73.3‰ to -60.6‰ in the wet season. The majority of the samples plotted along the Global Meteoric Water Line although some of them show deviations from this line. The reason for the deviations is attributed to evaporative enrichment. Tritium concentrations in all samples range from ~0 to 6 TU in the wet season and from ~0 to 7 TU in dry season. Accordingly, some of the groundwater samples recharge from modern precipitation, whereas some samples recharged before tritium from nuclear weapon tests. The  $\delta^{13}\text{C}$  and  $^{14}\text{C}$  contents of five samples range from -5‰ to -14.6‰ and from 8.2 to 78 pmc, respectively. The corrected  $^{14}\text{C}$  ages for these samples are up to 11500 years before present, thereby indicating the presence of paleowaters in the basin. The depletion of  $\delta^{18}\text{O}$  and  $\delta\text{D}$  probably point out that these paleowaters were recharged during a cooler climate.

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**P-2464**

## **Vertical groundwater flux estimation from borehole temperature profiles by a numerical model, RFLUX**

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### **Abstract**

We developed a numerical model, RFLUX, which uses the heat tracer method for vertical groundwater flux estimation, and applied it to the Leizhou Peninsula, South China, to provide information to inform local groundwater resource utilization and management. The temperature–depth (TD) profiles of 24 boreholes, along with the observed ground surface temperature (GST) and surface air temperature (SAT) series in recent decades, were collected in this area. Underground TD data demonstrated the capacity to identify groundwater flow patterns, and local GST and SAT data demonstrated a strong correlation with each other over monthly, seasonal, and annual scales. In the RFLUX model, the average GST and SAT series were applied as an upper boundary condition, and a nonlinear initial condition was set using an analytical solution from the literature. The model results of selected TD profiles demonstrated that the annual vertical groundwater flux was about 0.15 m/a, which tended to be overestimated if a linear initial condition was used. This model can be easily applied with minor modifications, considering its clear purpose and simplicity.

**P-2465**

## **A new framework and application for groundwater modeling in coastal area**

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### **Abstract**

We described the development and application of a new framework to simulate coastal evaporation in groundwater models. Traditionally, the ETS package of MODFLOW are based on a series of linear segments between depth to groundwater and evaporation flux rate. According to the exponential curves from the observed data here, exponential functions can better reflect the relationship in coastal area than linear segments. As a consequence, the errors of simulated processes was introduced, which via coastal climate change, the depth to groundwater and biological process into evaporation simulation.

The framework set the observed data and consider the influence on evaporation simulation, in this way, two methods of topography in evaporation simulation were provided. A traditional method is modeled as an annual source term, treated in linear segments that monotonically closes to maximum evaporation rate. The finer and coarse resolution taken into account the smaller cells response from variations of topography and the depth to groundwater. This paper established the groundwater modeling with 1.5×1.5 km cells in Leizhou Peninsula(LP). The finer resolution 500×500 m were averaged to same cells for convenience of model input, and the coarse resolution 2×2 km were interpolated. Model results indicate that a increased accuracy in predicted flow system between the new framework and traditional approaches. The use of the new framework provided the correlation between the evaporation rates and the resolution of topography. It was showed that using 500×500 m cells for evaporation simulation yielded the best results in groundwater modeling.

**P-2466**

## **An Analysis of Formation Mechanism of Groundwater in the Liuxi River basin: Evidence from Isotopes and PAHs**

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### **Abstract**

Hydrogen and oxygen are basic components of water, and stable isotopes ( $\delta^{18}\text{O}$  and  $\delta\text{D}$ ) are natural tracers in nature; PAHs are derived mainly from anthropogenic inputs and can be used to identify the characteristics of human activities in the process of social development. This study is to analyze formation mechanism of groundwater on PAH composition, sources and stable isotopes ( $\delta^{18}\text{O}$  and  $\delta\text{D}$ ) in the Liuxi River basin. Based on isomer ratios and principal component analysis, coal combustion and vehicle emission were the main PAH sources in groundwater which indicated that groundwater in the study area mainly consisted of surface water of the last 40 years. In the basin, there were some differences of stable isotopes ( $\delta^{18}\text{O}$  and  $\delta\text{D}$ ), PAH composition and isomer ratios between groundwater and surface water, which showed that groundwater was a little replenished by surface water.

**P-2467**

## **Paleoclimatical signals from large aquifers with case studies in China**

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### **Abstract**

Major aquifers worldwide, under favorable conditions, can retain low temporal resolution information on climatic conditions at the time of recharge. Generally, this geochemical information can be used to better constrain reaction of the aquifer to environmental changes or even to assess long term groundwater sustainability. Understanding whether major aquifers at similar latitude world-wide share similar climatic responses and records is one of the objectives of the G@GPS (Groundwater@Global Palaeoclimatic Signals) network. Several flag basins were selected and many activities were carried out since 2011, when G@GPS was accepted as one IFG (International Focus Group) within INQUA and linked closely with the Commission of Groundwater and Climate Change of IAH. The presentation will cover the objectives, major activities and achievements in the past 5 years, with a focus on the case studies in China.  $^{81}\text{Kr}$  and  $^{85}\text{Kr}$  by using ATTA (atom trap trace analysis) to derive paleoclimate signals from deep aquifer was introduced in the workshop and training course in Zhanjiang, Guangdong Province on Dec. 8-13, 2014 and Dec. 1-7, 2018, and some results are to be presented, combined with those from  $^{14}\text{C}$ . Paleoclimatic signal in the last 30-40 ka reconstructed using stable isotopes and dated groundwater indicates environmental changes and several recharge events. The signal was compared and verified by the high resolution data series from two caves in China. The signals from the large aquifers could provide a reasonable regional and global record of environmental change.

**P-2468**

## **Isotopic investigations for the assessment of geochemical processes of the continental intercalaire aquifer in southern Tunisia**

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### **Abstract**

Environmental tracers ( $^2\text{H}$ ,  $^{18}\text{O}$ ,  $^{14}\text{C}$ ,  $^3\text{H}$ , isotopes of Uranium) were applied to study the geochemical processes occurring within groundwaters from the continental intercalaire (CI) in Southern Tunisia.

Hydrochemical investigation shows a spatial variability of chemical facies which is linked to the lithology of the host rock. The mineralization is mainly controlled by the water–rock interaction in particular the dissolution of evaporitic minerals and the cation exchange reactions.

Stable isotopes show an enrichment in  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  contents suggesting the contribution of the Dahar sandstones outcrops in the current recharge of the CI aquifer in an arid context. These results are coherent with those of  $^{14}\text{C}$  and  $^3\text{H}$  that allow the qualitative identification of a current recharge which could probably be supplied by the recent infiltration of waters in Wadis and by the direct infiltration of meteoric water through the local sandstone outcrops of the basin.

However, the most depleted values in heavy isotopes indicate a paleorecharge of the aquifer under wetter conditions revealing a long residence time of groundwaters.

The disequilibrium between  $^{234}\text{U}$  and  $^{238}\text{U}$  is commonly used as a tracer of groundwater flow. Results from water samples using alpha spectrometry method indicate a range in  $^{238}\text{U}$  concentrations and  $^{234}\text{U}/^{238}\text{U}$  activity ratios (AR) of  $0.044 - 1.285\mu\text{g kg}^{-1}$  and 1.2 to 8.84 respectively. The geochemistry of uranium isotopes in groundwater is controlled by many factors, essentially the influence of water rock interactions, the preferential dissolution of  $^{234}\text{U}$  relative to  $^{238}\text{U}$  due to alpha recoil and the mixing processes between different waters with distinct AR as well as  $^{238}\text{U}$  concentrations.

P-2469

## Origin and preservation of methane in Scandinavian Ice Sheet meltwater in the groundwater of the Cambrian-Vendian aquifer system in Estonia

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### Abstract

The groundwater in the northern part of the Cambrian-Vendian aquifer system in Estonia is characterised by the most depleted oxygen isotopic composition known in Europe ( $\delta^{18}\text{O}$  down to  $-23\text{‰}$ ). The water originates from glacial meltwater recharge from the Scandinavian Ice Sheet in the Pleistocene (Vaikmäe et al., 2001). The aquifer system is characterised also by relatively high methane concentrations (up to 50% of the total gas content, about  $1400 \mu\text{mol L}^{-1}$ ), the origin of which has so far remained unclear. In a recent study (Raidla et al., 2019) we focused on the origin of methane, the factors controlling its spatial distribution and its isotope geochemistry in the aquifer system. The data reveal a large spatial variability in methane content and  $\delta^{13}\text{C}_{\text{CH}_4}$  and  $\delta^2\text{H}_{\text{CH}_4}$  values ( $-6$  to  $-105\text{‰}$  and  $-220$  to  $-297 \text{‰}$ , respectively). We argue that local oxidation processes have affected the initial isotope composition of methane rather than different origin of methane. Using the least modified  $\delta^{13}\text{C}_{\text{CH}_4}$  values ( $-85$  to  $-105\text{‰}$ ) we conclude that the methane originates from the organic material overridden by the Scandinavian Ice Sheet that was carried into the aquifer system with infiltrating glacial meltwater. The estimated  $\delta^{18}\text{O}$  values of the water where the methane was formed are in the range of  $-17 \pm 1.5\text{‰}$  that supports the inference that the methane predates the LGM and was formed during the Middle Weichselian interstadial. The study shows that groundwater of glacial origin in the Cambrian-Vendian aquifer system could serve as an alternative palaeoenvironmental archive that can be used to study the variations in climatic and environmental conditions in Northern Europe during the glacial–interglacial cycles in the Pleistocene.

**P-2470**

## **Precession and obliquity controls on South Africa monsoon revealed by fire emission**

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### **Abstract**

Subtropical southern Africa is dominated today by grass-fuelled fires which are controlled by marked rainfall seasonality, with wet austral summers during which fuel accumulates, and dry winters that increase fuel flammability. Microcharcoal (micro-particle produced during vegetation fire), a tracer of fire activity, was analysed from a deep-sea core off Namibia covering the past 170,000 years to study sensitivity of fires to changing climate and therefore to gain insights into fire activity for the near future. We observe clear cycles in fire activity during this period. Spectral analysis of the fire signal shows three distinct periodicities of 12.9, 23 and 54 kyrs. Maxima in fire activity occur during maxima of local summer insolation and maxima of precession (maxima of seasonality). We interpret changes in fire activity as a record of South African monsoon changes (strength and/or intensity) in agreement with results from a set of five simulations from a General Circulation climate model integrated for different key orbital configurations. Although fire activity and South Africa monsoon appear to be paced by orbital forcing through precession, observation of a 54 kyr period suggests a modulation of the response by the obliquity, or a non-linear response of the fire and monsoon to precession and obliquity. We finally propose a simple conceptual model to illustrate such a potential non-linearity, explaining the presence of 12.9, 23 and 54 kyrs periods in the fire record.

**P-2471**

## **Pronounced northward shift of the westerlies during MIS 17 leading to the strong 100-kyr ice age cycles**

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### **Abstract**

The MIS 17 interglacial, ~715 - 675 ka, marks the end of the Mid-Pleistocene Transition as intensified, long and asymmetrical 100-kyr ice age cycles became eminently established. Increasing arrival of moisture to the Northern Hemisphere high latitudes, resulting from the northwestward migration of the Subpolar Front and the intensification of the Norwegian Greenland Seas (NGS) convection, has been put forward to explain the emergence of this quasi-periodic 100-kyr cycle. However, testing this hypothesis is problematic with the available North Atlantic precipitation data. Here we present new pollen-based quantitative seasonal climate reconstructions from the southwestern Iberian margin that track changes in the position and intensity of the westerlies. Our data compared to changes in North Atlantic deep and surface water conditions show that MIS 17 interglacial was marked by three major changes in the direction and strength of the westerlies tightly linked to oceanographic changes. In particular, we report here for the first time a drastic two-steps northward shift of the westerlies centered at ~ 693 ka that ended up with the sustained precipitation over southern European. This atmospheric reorganization was associated with northwestward migration of the Subpolar Front, strengthening of the NGS deep water formation and cooling of the western North Atlantic region. This finding points to the substantial arrival of moisture to the Northern Hemisphere high latitudes at the time of the decrease in summer energy and insolation contributing to the establishment of strong 100-kyr cycles.

P-2472

## An independently dated multiproxy record of environmental change during the Marine Isotope Stage 11 from the Sulmona Basin (Central Italy)

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### Abstract

The study of past interglacial periods is important to understand our present and future climate, because they represent natural reference intervals for evaluating the timing and progression of the present warm stage (Tzedakis et al., 2009). Here we present preliminary results from the Project HELPING\* ("Hydrological Evolution of Past INterGlacial), which aims to reconstruct at high temporal resolution the hydrological and environmental evolution of the period spanning 420 to 370 ka, corresponding to Marine Isotope Stage (MIS) 11, and including the interglacial period of MIS 11c. Our focus is the lacustrine succession in the Sulmona Basin (central Italy). The MIS 11c interglacial took place under an orbital configuration similar to that of the Holocene, so enhancing knowledge about its duration and internal dynamics could be useful in better understanding the present background of natural climate (Tzedakis et al., 2009). Sediment properties in the Sulmona Basin faithfully record regional hydrological and environmental change, which can be linked to Mediterranean and North Atlantic conditions thanks to well-known climate teleconnections (e.g., Giaccio et al., 2015). We obtained a high-resolution, multiproxy sedimentological and biogeochemical record (grain size, mineralogy, stable O and C isotopes on endogenic calcite, elemental composition and organic content). The record is anchored to a preliminary <sup>40</sup>Ar/<sup>39</sup>Ar chronology developed on volcanic-ash layers (tephra) interbedded in the sediment. This allows us to place the observed climate and environmental variability onto an independent time scale. We reconstruct regional environmental evolution with a particular focus on short-term climate changes, then compare our record to the climatic framework apparent from several North Atlantic marine records to unravel potential forcing and mechanisms for intra-interglacial climate variability.

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Giaccio, B., Regattieri, E., Zanchetta, G., Nomade, S., Renne, P. R., Sprain, C. J., ... & Sposato, A. (2015). Duration and dynamics of the best orbital analogue to the present interglacial. *Geology*, 43(7), 603-606.

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**P-2473**

## **Date-driven modeling of Pleistocene global climate variability**

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### **Abstract**

A pronounce change in the glacial-interglacial regime that occurred about 1 million years ago – the so-called Middle Pleistocene transition (MPT) – is widely thought as an apparent manifestation of climate system’s nonlinearity. The MPT is observed in proxy records as a shift in glaciation periodicity (from 41 kyrs to approximately 100 kyrs) accompanied by both increasing of the ice/temperature oscillation amplitude and changing of the characteristic shape of the oscillations. Currently, there are ongoing debates about the roles of different orbital parameters, natural climate variability and other factors in the MPT.

We present here a data-driven dynamical model of global climate variability in the Pleistocene derived from benthic  $d18O$  records (LR04 stack). Such a model is learned from direct data analysis and provides the maximal probability to produce the records we have in hands, or, in other words, is optimal in Bayesian sense. The model is constructed in the form of a stochastic nonlinear evolution operator parameterized by a universal approximator (artificial neural network) and forced by the insolation signals at different latitudes. The model also contains adjusting explicit dependence on time reflecting the slow cooling (and decreasing  $CO_2$ ) trend that was permanent during the Pleistocene. The stochastic state-dependent term in the model is representative of shorter-scale (millennial and centennial) processes which are under temporal resolution of data we use.

The model shows that the MPT could not appear without both the gradual cooling trend and the intense millennial climate variability represented by a stochastic term (“internal forcing”) in the model. Substantially nonlinear response of the model to these factors determines the gradual transition to sawtooth relaxation oscillations in the middle Pleistocene. Regarding the insolation forcing, we have found that the only meridional gradient of the insolation, driven primary by the obliquity oscillations, is important for the Pleistocene dynamics both before and after the MPT. In particular, after the MPT the obliquity oscillations ensure through phase locking the occurrence of the climate cycles with periods in the range of approximately 80 to 120 years. The dynamical mechanisms underlying the detected model responses are presented in the companion presentation of Dmitry Mukhin.

P-2474

## Freshwater inflow to the East Sea, Korea during the last glacial period

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### Abstract

Freshwater inflow into the ocean is the important factor controlling the ocean circulation. To clarify variations of the freshwater inflow to the East Sea, Korea over the last glacial period, we conducted pollen analysis of 3.6m long core taken from the northern Ulleung Basin in the East Sea. We interpreted the signal of herbaceous pollen as a proxy of freshwater inflow to the East Sea, because the amounts of herbaceous pollen in the marine sediments tend to be mainly controlled by the intensity of freshwater inflow. High abundance peaks of the herbaceous pollen, recorded during the periods of 12-18 ka, 25-57 ka, and 95 ka, are highly correlated with the high C/N ratio that represents enhanced input of terrestrial organic matters. This interpretation is also supported by the fact that the fungal spore *Glomus* indicating intensified soil erosion is increased during this period. The freshwater inflow to the East Sea is mainly supplied from the Nakdong River and the Seomjin River along the southern coast of Korea, and the East China Sea coastal water (ECSCW). Comparison with precipitation from the Chinese Loess Plateau suggests that the ECSCW likely played an important role in controlling the freshwater inflow of the East Sea during the last glacial period.

P-2475

## A dynamical mechanism of the Middle Pleistocene transition revealed from data-driven models

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### Abstract

Many conceptual models of the Pleistocene dynamics have been proposed to date suggesting a variety of relevant dynamical mechanisms leading to the Middle Pleistocene transition (MPT), but so far there is no consensus about the most preferred one. Here we use a data-driven modeling approach for inferring the MPT mechanisms from proxy time series. We use Bayesian data analysis for revealing the dynamical model that is minimal but enough for describing data (see the companion presentation of Alexander Feigin). Mathematically, such a model provides the highest probability to produce the proxy records we have, and hence, yields statistically justified inferences. Thus, a model so obtained is fully independent of any physical conception and can be used for testing different climatological theories. In this work we restrict our consideration by the analysis of widely used LR04 stack based on benthic  $d^{18}O$  records and show what MPT mechanisms are evident from this single time series. Other possible applications of the proposed methodology to different proxy records over the globe, e.g. emphasizing regional distinctions in climate dynamics, are discussed.

We find from the model phase space exploration that, from a dynamical point of view, the MPT was generated due to a long-term trend in climate leading to a noise-induced strongly nonlinear oscillation build-up. The obtained trend makes steady states of the system less stable allowing the phase trajectory to push forward to substantially nonlinear area of the phase space corresponding to colder states. As a result, the slow-fast (sawtooth) climate oscillations of large amplitude become approachable in the late Pleistocene; this gives indication that the large glaciations become possible to be initiated at higher temperatures than in the pre-MPT epoch. It is very important that such post-MPT sawtooth oscillations cannot arise in our model without shorter-scale (millennial and centennial) forcing treated as stochastic process in the model: due to such a noise the system is able to go far away from the attractor of the deterministic (noise-free) system. Also, the model detects the increasing power of such noise processes in colder climate. Finally, we detect and explain the mechanism of post-MPT climate response to insolation forcing: the obliquity oscillations both amplify the glacial-interglacial cycles and phase-lock the major deglaciations via the meridional gradient of insolation.

P-2476

## The difference of hemispheric climates under the influence of astronomical forcing

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### Abstract

The response of climate system to astronomical parameters is a very important scientific issue, but the internal processes and feedbacks are still not very clear. In order to discuss the difference of hemispheric climates under the influence of astronomical forcing solely, a more than 90,000-year long transient simulation starting from 511 ka BP is performed with only varying insolation forcing. The results of surface air temperature (SAT), sea surface temperature (SST) and sea ice are analyzed. Our results show that the most interesting difference between the Northern (NH) and Southern (SH) Hemispheres is in the sea ice variability. Precession plays a dominant role on sea ice in the NH mainly due to its response to the local summer insolation. The Arctic sea ice is also influenced, but to a less degree, by the northward oceanic heat transport (mainly via the Atlantic meridional overturning circulation). However, obliquity plays a dominant role on sea ice in the SH. First, a smaller obliquity leads to lower insolation in high latitudes and finally to a cooling and more sea ice formation. Second, a smaller obliquity leads to larger latitudinal temperature and pressure gradients, and then to stronger westerly winds, which cool the sea surface and leads to more sea ice formation in the Southern Ocean. For the SAT and SST, precession plays a dominant role at low latitude in the NH and SH, because both of them involves vegetation feedbacks and meridional oceanic heat transport. Compared to low latitudes, middle and high latitudes are more influenced by obliquity. This is partly due to the increased role of obliquity on the daily insolation towards the high latitudes, and is also due to the increased role of the atmospheric heat transport on the SAT at high latitudes. Precession is more important in the NH middle and high latitudes than SH due to the vegetation and sea ice feedbacks. More details on the atmospheric and oceanic processes and feedbacks will be presented.

P-2477

## Lake Ohrid: the history of forest biodiversity and hydrological variations from Europe's oldest lake

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### Abstract

The vegetation record of the Quaternary in Europe is characterized by successive loss of tree species during glacial-interglacial (G-IG) cycles. Relative to central Europe, tree diversity in refugia in the Mediterranean remained high for much of the Quaternary, although the precise relation between (regional) extinctions, climate variability and local landscape factors is not known. Lake Ohrid, located at the Albanian / FYROM (Macedonian) border at 693 m asl, is the one of the deepest and largest lakes in Europe, and formed between 1.2 and 1.9 Ma ago. Lake Ohrid is a biodiversity hotspot and a glacial forest refugium, containing a continuous sediment infill of glacial-interglacial vegetation cycles since its establishment.

Within the International Continental Scientific Drilling Program (ICDP), the lake was drilled in 2013 and a 569-m long sediment core was collected. The palynological record of the DEEP site has now been analyzed at millennial-scale resolution down to the base of the continuous lake phase at nearly 1.4 Ma, and is supported by a well-constrained independent age model based on tephrostratigraphy, magnetostratigraphy, and complementary tuning of biogeochemical proxy data to orbital parameters. Here we report on the relation between the tree cover, glacial-interglacial climate variability and local palynological richness. There is an excellent correspondence between forested / non-forested periods at Ohrid and interglacial / glacial cycles of the Mediterranean marine isotope stratigraphy, suggesting a regionally relevant vegetation and climate record. Prior to 1.2 Ma, the Ohrid catchment had a clearly different configuration with shallower water, less pronounced vertical vegetation zonation, and high amounts of relict taxa, including occurrences of typical 'Tertiary elements' that currently occur in warm temperate and subtropical parts of the American and Asian continents.

Palynological richness of tree taxa, based on a moving window of species accumulation curves, shows relatively low variability in line with the refuge character of the site where, in glacial conditions, vegetation belts were compressed but tree diversity remained largely intact. After 1.2 Ma, lake levels increase and maximum tree richness is recorded. The reorganization of G-IG cycles during the Middle Pleistocene Transition is mirrored by several tree richness declines. Starting from 0.94 Ma, most relict tree taxa develop a discontinuous distribution and gradually disappear. Variations in richness vary on the same timescale as G-IG cycles, although the amplitude of these variations is generally not proportional to the intensity of glaciations as recorded in the global  $\delta^{18}\text{O}$  benthic stack. A striking exception is the tree richness recovery at Lake Ohrid shows during MIS 9-7, coinciding with a reduction in G-IG amplitude. Precession-scale variability is significant in the record and is characterized by rapid alternations between mesophilous and lower montane vegetation that point to significant humidity variations.

**P-2478**

## **Relative effects of precession, obliquity and eccentricity on the interglacial climate over Eastern and Southern Asia**

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### **Abstract**

The long-term orbital changes have been proved to produce changes in global and regional climate, which are reflected in the geological records. *However, how astronomical parameters influence climate is not yet fully understood at regional scale.* Here, based on climate model simulations, we study the climate response of several sub-regions over Eastern and Southern Asia to continuously changing astronomical parameters under interglacial conditions (MIS-1, MIS-5, MIS-9, MIS-11 and MIS-19). The outputs are obtained with two methods. The first one is based on the transient simulations using the model LOVECLIM driven by varying insolation forcing (Yin and Berger, 2015). The second one is a Gaussian process emulator (Araya-Melo et al., 2015) calibrated on an ensemble of well-chosen snapshot simulations by the model HadCM3. *In order to assess the individual effects of each parameter, data are also obtained when obliquity and precession vary respectively. The results obtained by the two models are generally consistent.* Among the three orbital parameters, precession is the main factor regulating temperature and precipitation. In general, the relative effects of the three astronomical parameters are quite similar over the selected sub-regions over Eastern and Southern Asia although differences exist. In the next stage, more sensitivity experiments and regression analysis will be carried out.

P-2479

## **Abrupt hydrographic changes in the northwestern Pacific response to the ice melting during MIS 19 from the Chiba composite section**

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### **Abstract**

Marine isotope stage (MIS) 19 has been suggested as one of the best orbital analogs for present interglacial, because of the similarity of the orbital configurations between both interglacial periods. Therefore, paleoenvironmental reconstructions of MIS 19 will provide valuable knowledge to evaluate the anthropogenic impacts for present and future climate changes. Additionally, the abrupt climate changes associated with the ice melting in the North Atlantic are globally documented in the paleoceanographic and paleoclimatic records during the MIS 20–19 transition and late MIS 19, suggesting global climatic teleconnection during the periods. The Kuroshio Current, the largest western boundary current of the North Pacific ocean, transports a large amount of heat and water poleward, and strongly influences the East Asian climate, however, responses of the Kuroshio Current to the ice melting in the North Atlantic remains unknown. Here, we provide new ultra-high-resolution oxygen isotope ( $\delta^{18}\text{O}$ ) records using benthic, and surface and subsurface planktonic foraminifers throughout MIS 19 from the Chiba composite section in east-central Japanese island. Vertical water temperature structure and their gradient ( $\Delta T$ ) based on the  $\delta^{18}\text{O}$  profiles exhibit two and four southward displacement events of the Kuroshio Extension Front (KEF) on millennial-scale during MIS 20–19 transition and late MIS 19, respectively. Consistencies of the timing, amplitude, and periodicity with those of periodic disruption/reactivation of the Atlantic meridional overturning circulation (AMOC) due to iceberg discharges in the North Atlantic indicate that the freshwater forcing induce the abrupt latitudinal displacements of the KEF via atmospheric dynamics. Additionally, during MIS 19a two-phase warmings in the millennial-scale variations of the surface  $\delta^{18}\text{O}$  and  $\Delta T$  imply that the northward remigrations of the KEF and surface water temperature warming driven by reactivations of the AMOC were amplified by relatively strong boreal winter insolation associated with the low eccentricity-precession forcing.

P-2480

## Radiometrically dated speleothem records of Terminations IV and V and linkages to the North Atlantic

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### Abstract

Paleoclimate archives tied to accurate and precise chronologies are crucial for developing a dynamical understanding of the causes and nature of Quaternary glacial terminations [1]. While numerous well-dated archives provide good chronological control through Terminations I and II, there is presently a lack of well-dated records spanning earlier terminations. A notable exception to this is a suite of remarkably well-dated Chinese speleothems that have been used to date the commencement of each termination over the past 640 kyr [2,3]. This has been achieved by correlating weak Asian Monsoon anomalies as captured by speleothem oxygen isotope signals with terminal Heinrich events in the North Atlantic. While this approach is well-suited to testing orbital hypothesis by comparing the timing of termination commencement with insolation metrics, it only provides precise age control at the beginning of each termination. This precludes assessment of the progression of climatic changes over the full course of the termination, and the timing at which full interglacial conditions are reached.

Here we present a composite speleothem record spanning glacial terminations IV and V from the Antro del Corchia cave system located on the western coast of central Italy. This record is anchored to a uranium-thorium based chronology and contains numerous proxies representing both local and regional climate, including  $\Delta_{47}$ -based temperature data derived from a pool carbonate formed under very slow degassing conditions. By taking advantage of established links between speleothem proxies from this cave site and marine proxies from the North Atlantic, we fix the marine sediment data to a radiometric age scale. This allows us to constrain the timing of ocean circulation and SST changes occurring in the North Atlantic throughout the duration of Terminations IV and V, and compare these with terrestrial temperatures in central Italy.

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P-2481

## How far modeling of sapropel S1 (Early Holocene) allow the understanding of sapropels occurrence since mid-Miocene?

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### Abstract

In a first part, we will revisit the classical causal link invoked for the first time by Rossignol-Strick et al (1982) with a new modeling approach using coupled OARCM (Ocean-Atmosphere Regional Circulation model) with high spatial resolution ( $1/8^\circ$ ) enable to capture correctly the convection all over the Mediterranean basin both in location and intensity. Using this tool, through sensitivity experiments to Nile freshwater input, we investigate in details its impact on Mediterranean ocean dynamics and demonstrate the intensity of the stratification. We pinpoint the crucial role of Nile freshwater on stratification of eastern basin water masses. Moreover, using the recent modeling development of the  $\epsilon\text{Nd}$  (tracer of the paleo-circulation) in the Mediterranean Sea (Ayache et al., 2016), we compared our results obtained in simulating the changes of  $\epsilon\text{Nd}$  and compare to those depicted by the data (Vadsaria et al., 2019, Paleoceanography).

To better describe the climatic context of the sapropel S1, we developed a numerical platform able to downscale existing OAGCM simulations for the Early Holocene. That platform involves an Atmospheric Regional Circulation Model providing the dynamical downscaling in order to drive the Mediterranean Sea at  $1/8^\circ$ . Accounting for the simulated changes in hydrology, we quantified the respective impact of the different components of this budget in terms of runoff of the main rivers and changes of precipitation pattern. We demonstrate that the freshwater input from the Nile plays the major role in producing stratification of the eastern basin.

This numerical platform may be use for any past OAGCM simulation and therefore could be applied for other sapropel occurrences. Indeed, it has been shown recently that the triggering of sapropel S1 is a long lasting process associated with deglaciation (Grimm et al., 2015). Therefore, the hydrologic perturbation is not restricted to the Early Holocene and Nile River but is also due to the Fennoscandia ice sheet (FIS) melting. We show, using ICE-6G (Peltier et al., 2015) melting scenarios, but also the recent high-temporal resolving reconstruction of Patton et al (2017), that the freshwater coming from the melting of the FIS contributes to precondition the Mediterranean basin. In this new scenario, monsoon and Nile River freshwater act as an ultimate trigger to produce the sapropel S1. It would be necessary to study sapropels occurring in other contexts such as the sapropel S5 occurring in a warmer climate than the S1.

P-2482

## Caribbean hydroclimate and vegetation history across the last glacial period

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### Abstract

We present a new speleothem trace element and stable isotope record, which extends previous paleoclimate evidence from Cuban speleothems to the last 96 ka. This is one of the few records from the climatically sensitive transition zone between Central and North America, the Caribbean and the western tropical Atlantic. Our multiple proxies provide geochemical evidence for pronounced environmental changes over the last glacial cycle in the American low latitudes and allow the comprehensive reconstruction of past precipitation and vegetation changes on orbital to millennial timescales.

Our results confirm the close link of Caribbean precipitation to North Atlantic (NA) climate variability, insolation and the strength of the Atlantic Meridional Overturning Circulation. The associated variations in Caribbean sea surface temperatures and the shift of the Intertropical Convergence Zone (ITCZ) led to substantial changes of the hydrological cycle. During Heinrich stadials and the Younger Dryas, climatic conditions on Cuba were comparably cool and/or dry. This is in agreement with previous evidence for the Holocene, when NA cold events coincided with drier conditions on Cuba. In contrast, warm Dansgaard/Oeschger cycles were accompanied by more humid conditions. However, our record suggests that this teleconnection was less dominant during MIS 4 to 2, displayed by a weaker response of Cuban precipitation proxies to NA climatic shifts than during MIS 5 in particular. We hypothesize, that this observation indicates a weakening of the northern branch of the Caribbean Low Level Jet when the ITCZ is in a generally more southern position. This is strikingly evident during the deglacial, when driest and/or coolest conditions prevailed in western Cuba from HS 1 into the Younger Dryas, including the Bolling/Allerod interstadial.

In addition, our proxies indicate a shift in the abundance of C4 vegetation and a decline of soil activity during colder and drier periods, in particular the Last Glacial Maximum and MIS 4, but also during Heinrich stadials.

In summary, our record provides a valuable climate reconstruction for the Caribbean realm for the last Glacial period and gives new insight into past variability of the Caribbean hydrological cycle.

**P-2483**

## **A multi-proxy approach to assessing multiscale monsoon variability over the past six glacial cycles**

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### **Abstract**

High-resolution proxies from Chinese loess deposits can document the East Asian monsoon changes at glacial-interglacial to millennial time scales. Unlike the absolutely dated speleothem  $\delta^{18}\text{O}$  records that exhibit persistent millennial changes over the past 640 kyr, well resolved loess proxies can only reflect abrupt monsoon changes over the last two glacial cycles. Here we present grain-size and elemental records from a 180-m loess core retrieved from the western Chinese Loess Plateau, extending high-frequency variations of Asia monsoon back to the last six glacial-interglacial cycles. The mean grain-size records display significant glacial-interglacial timescales and match well with the marine  $\delta^{18}\text{O}$  record in terms of amplitude and periodicities. Because of varied sensitivity of grain-size and elemental ratios to grain-size sorting (winter monsoon) and chemical weathering (summer monsoon), precessional cyclicity are distinctive but with different intensities in these physical-chemical indicators. Moreover, large-amplitude and high-frequency oscillations were persistent during past glacial and interglacial intervals. Compared them with Chinese speleothem  $\delta^{18}\text{O}$  and North Atlantic ice-rafted debris (IRD) records, loess proxies display similar magnitudes of abrupt climate changes, however the timing and amplitude of these abrupt climatic events are not easily correlated. Our results indicate that integration of speleothem, loess, ice and marine record permits better understanding of the origin and dynamics of abrupt climatic changes, particularly regarding its links with glacial and astronomical forcings.

P-2484

## Rising atmospheric CO<sub>2</sub> concentrations: the overlooked factor promoting forest development in southwestern Europe across Termination I?

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### Abstract

Climate models indicate that transient CO<sub>2</sub> forcing superimposed on Atlantic Meridional Overturning Circulation (AMOC) changes caused the dramatic climate changes of the last deglaciation (including Termination I). Across the last deglaciation, global atmospheric concentrations of CO<sub>2</sub> (pCO<sub>2</sub>) increased from ~190 to ~280 ppm, with significant step-wise increases around 16.3, 14.8 and 11.7 kyr (Marcott et al., 2014). However, little is known about the impact of pCO<sub>2</sub> changes on vegetation across Termination I. It is well known that under full glacial low pCO<sub>2</sub>, plants experienced strong constraints on photosynthesis, especially woody C<sub>3</sub> plants. At very low pCO<sub>2</sub>, stomatal opening must adjust to maintain an adequate atmosphere-leaf CO<sub>2</sub> gradient resulting in a trade-off between carbon assimilation and water loss. As such, physiological drought under glacial conditions will have been reinforced by low pCO<sub>2</sub>. Therefore, although rarely considered, a major reduction in CO<sub>2</sub> limitation must have occurred, modifying the impact of local and regional climate changes across Termination I.

The analysis of terrestrial (pollen) and marine (alkenone-derived Sea Surface Temperature, SST) indicators in the Iberian margin marine core IODP U1385A ("Shackleton site") throughout the last deglaciation, at high resolution (165 yr and 114 yr, respectively), allows us to track and compare changes in vegetation and SSTs with the shifts in global pCO<sub>2</sub>. We observe that a major development of forest (corresponding to a biome shift) in SW Iberia, occurred at ~15.0 cal kyr BP, corresponding to a pCO<sub>2</sub> of 240 ppm. Furthermore, major jumps (of 10 to 20% increase) in temperate and Mediterranean forest are synchronous, within age model uncertainties, with abrupt pCO<sub>2</sub> increases observed at ~16.2, 14.6 and 11.8 cal kyr BP. We hypothesise that the increase in pCO<sub>2</sub> represents a gradual reduction of the physiological constraint on arboreal development that promoted forest response to episodic warmer and wetter conditions during the deglaciation. This overlooked role of pCO<sub>2</sub> could explain an intriguing feature observed in the U1385A and other Iberian margin records, namely the near absence of forest during HS1 but high forest cover during the YD, despite quite similar cold SSTs. Across these cold periods and the intervening warm and humid interstadial (Bölling-Alleröd), neither AMOC strength nor regional SSTs can account for the pattern of forest development. Our ongoing work aims to shed light on the potential impact of pCO<sub>2</sub> on forest response to deglacial climate changes across the Iberian Peninsula. This hypothesis, which is well grounded in plant physiology, should be explored through model simulations to establish the amplitude and critical thresholds of pCO<sub>2</sub> impacts on regional vegetation.

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**P-2485**

## **How the orbital forcing influences vegetation from high latitudes to low latitudes?**

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### **Abstract**

It is noted that certain recurring vegetation patterns appear to be a result of climate changes linked to specific astronomical parameters. Proxy reconstructions show that the response of vegetation phases to orbital configurations is complex and varies with regions. There is limited knowledge of the links between terrestrial vegetation changes and orbital forcing. It is therefore instructive to explore systematically how the astronomical forcing controls vegetation development from high latitudes to low latitudes. By analyzing the components of vegetation in different latitudinal zones and annual precipitation and temperature, which are associated with specific orbital parameters, including obliquity, precession and eccentricity, we find that: (1) Vegetation were mainly influenced by obliquity and precession. But eccentricity also had a non-negligible effect. (2) Mostly the responses of tree and grass in a specific area to the same astronomical parameter were opposite. (3) At low latitudes, precession generally played greater important role on tree fraction than in northern high latitude area, whereas in northern high latitude area, obliquity showed greater importance on tree fraction than at low latitudes.

P-2486

## What can past interglacials climate and oceanographic variability teach us about the ongoing climate warming?

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### Abstract

Anthropogenic CO<sub>2</sub> release into the atmosphere leads to temperature projections for 2100 not experienced on earth since many million years. Those periods are poorly known due to low temporal and spatial data and ill-defined climate forcing. But, past warm periods (interglacials), occurring during the Quaternary, under variable boundary conditions (e.g. greenhouse gases concentration, sea level and ice sheets size, insolation and orbital forcing), can provide invaluable information on the dynamics and processes behind natural warm climates. In order to gain information on the possible dynamics of the ongoing/future climate, we are studying the warmest intervals from Marine Isotope Stage from 31 to 5e, in particular MIS31, MIS19 and MIS11, which in terms of orbital configuration, are the closest analogues to the present interglacial. This study is based on the SW Iberian margin sedimentary sequences from Sites U1385 and U1391, recovered during IODP Expedition 339. In this study we present records for the past sea surface temperature based in U<sup>K</sup><sub>37</sub>-SST, paleo-productivity derivate from total alkenone and continental input reconstructions at orbital, millennial and sub-millennial scale for the past tree interglacials and its comparition with the present Interglacial, the Holocene. The results show that the older Interglacials are warmer and shorter. Interglacials before MIS 19 show maximal warmth at the onset of the interglacial period following obliquity forcing. Furthermore, the fact that these very warm periods co-occur with low pCO<sub>2</sub> concentrations, makes it crucial to understand climate dynamics on those times to better foresee antropogenic-forced climate change.

**P-2487**

## **A case of astronomical forcing – evidence from the south east Baltics**

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### **Abstract**

The climatic variability and its effects on the biota operate on several characteristic time scales. On the time scale of millions to tens of thousands of years Milankovitch forcing prevails in the Quaternary. Shorter term or sub-orbital climatic variability is much less understood and explored in the fossil record. The multivariate analysis of the latest Pleistocene and Holocene pollen assemblages from the south western part of the Lithuania (Čepkeliai section) reveals persistent long-term trends in the plant composition as best explained by the centennial to millennial climatic oscillations. Besides the presence of the distinct climatic events, such as Holocene thermal maximum, Roman Climatic Optimum and Medieval Warm Period, spectral analyses of the data show the presence of common periodicities in the NMDS (non-metric multidimensional scaling) scores as well as the Tsallis entropy scaling exponents  $1/q^*$  (which represents the diversity of the assemblages). At the centennial time scales statistically significant periodicities range from 176 up to 240 years in the period length which corresponds to the so called de Vries solar activity cycles. On the millennial time scales  $\sim 1,900$  and  $\sim 3,800$  year cyclicities appear. The duration of these cyclicities suggests their possible harmonic relations to the precession term of the orbital climatic variability.

### **Acknowledgements**

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P-2488

## Climate change and vegetation dynamics during the lukewarm interglacial MIS 13 in SW Europe

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### Abstract

The study of past interglacials, periods of reduced ice volume like our present interglacial (the Holocene) is crucial for understanding the future climate. Marine Isotope Stage (MIS) 13 (478–533 ka) represents a Quaternary interglacial of primary interest and in recent years it has become the focus of much attention. One of the main reasons of this interest stems from the fact that MIS 13 is among the most glaciated and cooler interglacials of the past 800,000 years, and unexpectedly it is associated with an unusual strong summer monsoon, even though CO<sub>2</sub> and CH<sub>4</sub> levels are not particularly high. Conversely, a growing body of evidence indicates that the conditions during MIS 13 vary geographically, and several continental records document a rather warm interglacial coupled with relatively low global ice volume. In the Mediterranean region, the study of MIS 13 climate is, however, strongly hampered by the paucity of available records, particularly in the terrestrial realm as only two vegetation sequences contain a complete record of MIS 13.

Here we present the first high-resolution (centennial-scale) pollen record from IODP Site U1385 covering MIS 13, that allows the reconstruction of vegetation and atmospheric changes on orbital and suborbital timescales, in a direct comparison to alkenone-based sea surface temperature (SST). This site, also known as the “Shackleton Site”, was collected on the SW Iberian margin, a region highly sensitive to global warming that is considered a prime location for tracing past climate changes. Western Mediterranean atmospherically-driven vegetation changes and surface oceanic conditions are discussed in the light of a larger European and North Atlantic context to assess the influence of global and remote controlling factors throughout MIS 13.

P-2489

## Feedback analyses of the seasonality of arctic climate changes driven by orbital parameter changes

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### Abstract

A quantitative study of the climate feedback processes for determining summer temperature in the northern high latitudes is needed for our understanding of climate system, including glacial-interglacial cycles. In this study, we focus on the differences of (1) dependence of the seasonal, especially summer, temperature change at northern high latitudes upon orbital parameters and of (2) climate feedback processes operating under different seasons.

In order to investigate the seasonal temperature changes, we use a coupled atmosphere-vegetation GCM with slab ocean of MIROC GCM (O'ishi and Abe-Ouchi, 2011) and performed numerous experiments by systematically changing the combinations of orbital parameters (maximum, minimum and present values for each parameter). We also focus on the role of vegetation feedback effect by comparing experiments with and without the vegetation model (LPJ), since several recent studies indicate its importance. A seasonal feedback analysis method (Lu and Cai, 2009) is also applied to understand the relative importance of surface albedo feedback, changes in cloud radiative forcing, changes in surface sensible and latent heat fluxes, changes in heat storage, and changes in the clear-sky downward infrared radiation in causing the seasonality of arctic surface amplification.

Results show that the efficiency of summer temperature change over land in the northern high latitude is about 50% larger by obliquity changes than by precession-eccentricity changes. This is mainly because obliquity changes promote a larger seasonal climate feedback, especially vegetation-snow-albedo feedback in the spring, than the precession-eccentricity changes.

P-2490

## A review of Atlantic Subpolar Gyre variability based on investigations of Holocene marine sediment cores

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### Abstract

The subpolar gyre (SPG) is a major feature controlling climate and ocean circulation of North Atlantic region, with significant variability of cold and warm ocean currents feeding into the gyre. The western sector of the SPG, the Labrador Sea, is a major deep water formation site, thus also directly influencing the Atlantic Meridional Overturning Circulation (AMOC). Here we compare records of SPG circulation from selected sites off south Iceland, west and southeast Greenland and Newfoundland in order to establish a combined record of SPG circulation through the Holocene. Our records combine multi-proxy studies (foraminifera, diatoms, dinoflagellate cysts, sediment properties, biomarkers, elemental composition and environmental magnetics) from a range of marine sediment cores to test for large-scale changes in ocean circulation in the Holocene. The SPG region has experienced several major changes in ocean circulation, with a major reorganisation occurring during the deglaciation and again at approximately 7.5 kyr BP and 3-4 kyr BP. Especially during the late Holocene, climatic conditions were largely antiphase in the Labrador Sea to the general North Atlantic region climate due to influence of the Northern Annular Mode affecting the strength of the Atlantic component of the West Greenland Current as well as the flow of the Labrador Current. This again influenced the strength and expansion of the SPG and exemplifies that the SPG has undergone significant variability at multi-decadal to millennial time scales during the Holocene.

P-2491

## New multiproxy evidences of the postglacial marine transgression recorded in the sedimentary infill of Ría de Ferrol (NW Iberia)

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### Abstract

The Ría de Ferrol is a confined tide-dominated incised valley located in the mesotidal passive Atlantic margin of Galicia (NW Iberia). The sedimentary evolution of the ria from the Last Glacial Maximum to the present was reconstructed using a multidisciplinary approach, combining seismic and sedimentary facies and supported by radiocarbon data, geochemical proxies and pollen and dinoflagellate cysts analyses.

Late Pleistocene and Holocene high-frequency sea-level variations were one of the main factors that modulated the type of depositional environments established within the incised valley, as well as their evolution. This evolution was modulated by the antecedent morphology, with a rock-incised narrow channel in the middle of the basin (the Ferrol Strait), which influenced the evolution of the ria as it became flooded during Holocene transgression.

During the lowstand of the Last Glacial Maximum (*ca* 20 kyr BP), the ria was a fluvial valley drained by a braided river system, whose sediments are mainly preserved in the inner sector. Sediments from ponds and stagnant areas were recovered in the sediment cores, dated to be older than 10790-11170 cal yr BP.

Facies from a tide-dominated estuary have been dominant within the incised valley during most of the Holocene, with sedimentary environments shifting toward the east at the time when sea level rose. Tide influence was enhanced by the structural straight. Extensive tidal flats dissected by estuarine channels of variable dimensions occupied most of the basin. Radiocarbon data showed ages from 8610-8910 to 5760-5940 cal yr BP. Slow sea-level rise after *ca* 4 ka BP finally forced rivers to retreat to the present position, causing the dispersion of their energy and leading to the final evolution of the area into a fully marine system.

Several erosive events and changes affecting the local development of biomes found in the sedimentary infill correlate with relevant changes observed in pollen sequences obtained at different mountain areas from NW Iberia. Thus they can be interpreted as local signals of the climatic variability affecting most of the North Atlantic during the Lateglacial and the Holocene.

P-2492

## Rapid sea-level rise and climate change: lessons from the early Holocene

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### Abstract

The '8.2 ka cold event' is recognised as the largest magnitude Holocene cooling event in the North Atlantic region. Freshwater input from the retreating Laurentide Ice Sheet drove a slowdown of the Atlantic Meridional Overturning Circulation (AMOC) which subsequently caused the observed climatic shift. A 160 year period of temperature cooling of  $3.3 \pm 1.1$  °C and reduced precipitation are observed in Greenland, with contemporaneous climate shifts recognised in many other records around the North Atlantic region and further afield. In this presentation two new high-resolution sea-level reconstructions from both hemispheres will be presented with the aim of resolving the history of North Atlantic melt-water input prior to the 8.2 ka event.

Litho- and bio-stratigraphic data alongside high-precision radiocarbon dates have been collected from the Ythan Estuary (NE Scotland) and Swan Inlet (Falkland Islands) for the centuries prior to the 8.2 ka event. In the Ythan Estuary, two complimentary single core analyses utilise a foraminifera based transfer function and multiple high-precision radiocarbon dates to produce a robust high-resolution reconstruction. Swan Inlet is the first southern hemisphere location where a rapid flooding event preceding the 8.2 ka event has been discovered. Optically Stimulated Luminescence analysis shows that the observed sea-level rise, in the order of 2-4 m, occurred in Swan Inlet within a few centuries. This is further constrained by radiocarbon dating and a diatom-based transfer function to resolve the phase(s) and magnitude of this rise.

The combination of sea-level reconstructions from both hemispheres allows confirmation of a Laurentide melt-water source as the trigger of the 8.2 ka event by comparing the magnitudes in conjunction with sea-level fingerprint models. Identifying the freshwater source(s) and quantifying melt-water input allow climate models to be tested in order to apply them more confidently to future AMOC responses to scenarios of warming and ice melt. Thus, this work ultimately will help to improve understanding of the impacts of Arctic ice melt on oceanic changes and future climate, especially in the North Atlantic region.

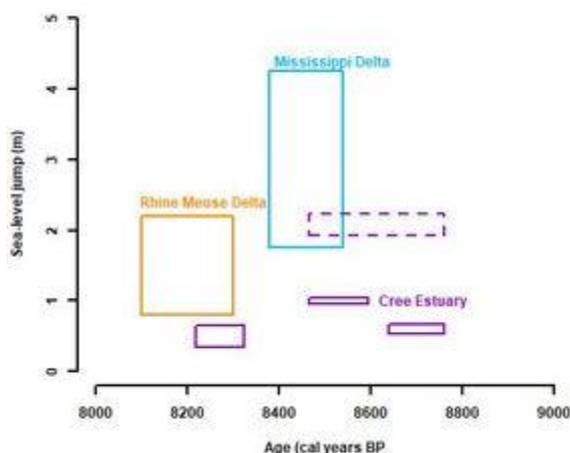


Figure 1. The timing and magnitude of previously observed sea level jumps from sites shown in figure 2, highlighting the current disagreement.

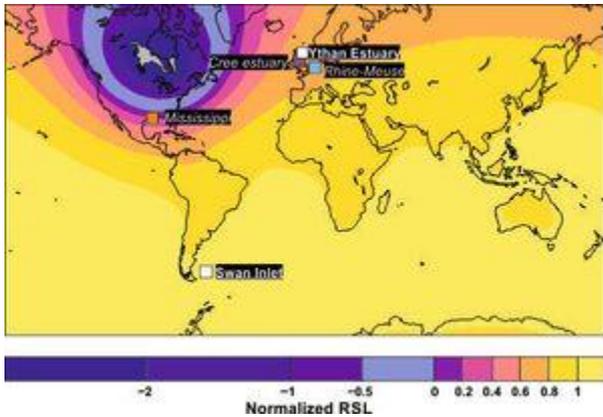


Figure 2. Numerically predicted sea-level fingerprint due to the melt-water input from the retreating Laurentide Ice Sheet at 8.4 ka, normalized by a eustatic rise (0.4 m). The coloured squares represent sites of previous sea-level measurements shown in figure 1 and the white squares are sites from this study. (Adapted from: (Kendall *et al.* 2008)

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P-2493

## Ocean and climate conditions in SW Greenland during the last 2 000 years

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### Abstract

This study presents multi-proxy data from a high-resolution marine sediment core from the SW Greenland shelf. This climatically sensitive region is influenced by warm water inflows from the Atlantic Ocean and cold water inflows from the Arctic Ocean, as well as meltwater release and ice discharge from the Greenland Ice Sheet. Variations in ocean surface temperatures and sea ice conditions in this region have a significant implications to the North Atlantic Deep Water Formation and Atlantic Meridional Overturning Circulation. The aim of this study is to reconstruct ocean surface conditions (sea surface temperatures; SST and sea ice conditions; SIC) and identify iceberg and meltwater discharge from the Greenland ice sheet during the last 2 000 years using microfossil assemblages (diatoms, dinocysts and benthic foraminiferas) and sedimentological proxies (XRF-scan, sediment grain size and IRD). The results of this study are compared with other temperature reconstructions from the Southeast Greenland, subpolar North Atlantic and the Norwegian Sea to identify possible temperature seesaw-pattern linked to the atmospheric forcing of the North Atlantic Oscillation (NAO) and to investigate variations in the strength of Atlantic-sourced warm water inflows.

The results reveal fluctuations in sea surface temperatures on a centennial and decadal timescales. The temperature record shows that cooler oceanic conditions prevailed over the Medieval Climate Anomaly (from ca. 1000 CE to 1500 CE), whereas warmer conditions prevailed over the Little Ice Age (from ca. 1500 CE to 1800 CE). Similar temperature trend was discovered in the subpolar North Atlantic while the opposite temperature trend prevailed in the Norwegian Sea region. This seesaw pattern is likely to be linked to the atmospheric forcing of the NAO, which regulates the strength of the Irminger Current carrying warm Atlantic waters to northwest North Atlantic. The relative percentage of the coarse grain material in the sediment ( $>63 \mu\text{m}$ ) indicates decreasing amount of iceberg rafting during the last 2000 years, whereas sea ice proxies imply increasing sea conditions towards the present day.

P-2494

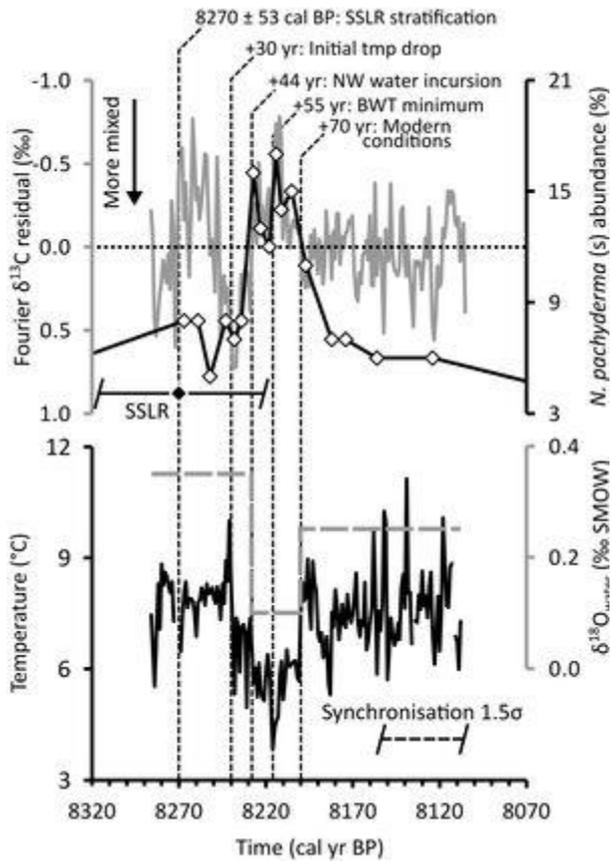
## 8.2 ka event North Sea hydrography determined by bivalve shell stable isotope geochemistry

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### Abstract

The abrupt 8.2 ka cold event has been widely described from Greenland and North Atlantic records. However, its expression in shelf seas is poorly documented, and the temporal resolution of most marine records is inadequate to precisely determine the chronology of major events. Here we present an annually-resolved temperature and water column stratification reconstruction based on stable isotope geochemistry of *Arctica islandica* shells from the Fladen Ground (northern North Sea) temporally coherent with Greenland ice core records. Our age model is based on a growth increment chronology obtained from four radiometrically-dated shells synchronised to estuarine and saltmarsh deposits in SW Scotland which suggests that our reconstruction covers the 8290-8100 cal BP interval. Our results indicate that a sudden sea level rise (SSLR) caused the North Sea water column to stratify between ages 8320-8220 cal BP. Thirty years later, cold and stormy conditions inhibited water column stratification but an eventual incursion of sub-Arctic waters into the North Sea re-established density-driven stratification. The water temperatures reached their minimum of ~3.8 °C 55 years after the SSLR. Intermittently-mixed conditions were later established when the sub-Arctic waters receded. This work is currently the only high or mid-latitude marine records with such a high temporal resolution. These reconstructions provide an insight on climatic reaction times to perturbations to the Atlantic Meridional Overturning Circulation.



P-2495

## Reconstruction of Holocene oceanography and climate in the eastern Baffin Bay: Evidence of fluctuations in the advection of Atlantic water

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### Abstract

The Baffin Bay is a semi-enclosed basin connecting the Arctic Ocean and the western North Atlantic. This study aims to reconstruct the fluctuations in the advection of relatively warmer and saline Atlantic waters and the incursion of colder deep Arctic water masses flowing into the Baffin Bay through the multiple gateways in the Canadian Archipelago and the Nares Strait. A multiproxy study of a 738 cm long marine sediment core retrieved from the eastern Baffin Bay near Upernavik (core AMD14-204C; 73°15.663' N/57°53.987' W; 987 m water depth), allows the reconstruction of the paleoceanography and paleoclimate of the area. Results of benthic foraminiferal assemblage analyses, XRF data, CT-scans and radiocarbon datings of the core reveals that several fluctuations in the entrainment of Atlantic subsurface water into the West Greenland Current occurred during the Holocene, inferred by periods of high abundance of Atlantic water species. The two periods with strongest advection of Atlantic waters occurred around 8000-7500 cal BP and 6500-6000 cal BP coinciding with a decrease in the abundance of benthic sea ice species further implicating an increase in air temperature and thus a reduction of the sea ice cover. At ~3200 cal BP, possibly coinciding with the onset of the 'Neoglaciation', an abrupt transition to a benthic fauna dominated by agglutinated species indicate that enhanced carbonate dissolution influenced the area. This was likely in part caused by a reduction of the influx of Atlantic water, allowing increased influx of the cold, corrosive Baffin Bay Deep Water originating from the Arctic Ocean, entering the Baffin Bay through the Nares Strait. These cold subsurface water conditions persisted throughout the late Holocene, only interrupted by short-lived climate fluctuations superimposed on this cooling trend.

P-2496

## The contribution of the glacial lakes of northeastern Quebec and Labrador (Canada) to the meltwater discharges of the early Holocene

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### Abstract

The climate variability of the early Holocene is intrinsically linked to the drainage of large ice-dammed lakes that formed during the deglaciation of North America. The meltwater outbursts that resulted from the drainage of these lakes are believed to have altered the Atlantic Meridional Ocean Circulation, which likely triggered climatic events such as the 8.2 ka Event. The number and magnitude of the meltwater forcings that occurred during this interval of the deglaciation are now under focus due to a growing number of studies showing that the present-day increase in freshwater releases from the melting of Greenland may also potentially lead to a slowdown of the ocean thermohaline circulation and cause important climate feedbacks. Furthermore, recent studies suggest that the meltwater discharge from Lake Agassiz-Ojibway that presumably triggered the 8.2 ka cooling may have been smaller, while others point to a contribution from a series of glacial lakes surrounding Ungava Bay in northern Quebec-Labrador. These uncertainties arise from an inadequate understanding of the patterns of retreat of the Laurentide Ice Sheet (LIS), notably those related to the Ungava glacial lakes, which are limited by a lack of chronological constraints.

Here, we assess the potential impact of the drainage of the Ungava lakes on ocean surface conditions and climate through a reconstruction of the demise of the LIS over northeastern Quebec-Labrador using a global isostatic adjustment model combined with remote sensing mapping and new cosmogenic ages of deglacial landforms. Our reconstruction provides a 2500 years-window (10.1 – 7.7 cal. ka BP) on the retreat pattern extending from the Torngat Mountains to the Shefferville area and to the western Ungava Bay region. Using 100 years isochrones as ice margins, the reconstruction reproduces major lake levels and outlets that were documented in the field while respecting deglacial (continental) chronologies. Our findings suggest that 50% of the meltwater released (0.513 Sv; 10 days drainage) is related to the drainage of glacial Lake Naskaupi, which occurred between 8.3 and 8.2 cal. ka BP. While Ungava lakes were probably too small to trigger a major climatic event, the new chronological constraints on Lake Naskaupi suggest the drainage contributed to the meltwater forcing of the 8.2 ka Event.

Our methodology based on a multi-proxy model of deglaciation thus shows a strong potential to accurately scale the magnitude of the drainages of Ungava lakes during the early Holocene, an important step in assessing the impact of smaller freshwater forcing on the ocean and climate. This approach should be applied to other large proglacial lakes that formed during the last deglaciation, which would benefit from a re-evaluation of their volume and drainage chronology using reconstructions that incorporate the latest global isostatic adjustment models, absolute ages and field-based constraints.

P-2497

## Palaeoenvironmental evolution of Galway Bay, Western Ireland, since the last glacial maximum.

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### Abstract

Quaternary environmental studies are essential to understand the speed and scale of modern day climatic and environmental change. During the late Quaternary significant environmental and relative sea-level variations have contributed to shaping present day coastal areas. This is particularly evident along formerly glaciated continental margins. A dynamic ice sheet extended off the western continental shelf of Ireland during the last glacial maximum (LGM), and its retreat left a strong signature in the form of submarine and terrestrial landforms. The period following the LGM was likely characterized by rapid and abrupt changes in relative sea-level along the western Irish coastline due to the former ice sheet presence. However, knowledge of the effects of these drastic changes along the coast is limited.

This research is a multi-disciplinary investigation into the elements that have shaped Galway Bay since the LGM. Seismic and multibeam data, sedimentological, micropaleontological, geochemical analysis and 17 radiocarbon dates of sediment cores from the bay provide the first post-LGM sea level and environmental reconstructions for the region. Analysis on the microfossil content and geochemistry of the cores in the bay show a continuous progression from shallow water, intertidal deposits to estuarine and open marine conditions. There is evidence of sea-level 70m lower than present day following deglaciation, submerged coastlines and paleo-fluvial channels. Throughout the post-glacial period to the present, the evidence from Galway Bay suggests constant transgression, with the seismic, geochemical, microfossil and sedimentary data all supporting sea-level rise across the bay. The data also show prolonged sea-level slow stand and that the bay was affected by global events such as meltwater pulses 1A and 1C, but not by others. The geochemical signal in the cores seem to provide a good record of local changes in environmental conditions, such as rainfall, changes in vegetation, and land use. The mapping of seafloor landforms coupled with hydrodynamic modelling reveals that the bay is lastly shaped by the strong tidal currents and storm events, which currently characterize the western Irish coastline. The overall picture of palaeoenvironmental change since the LGM will be compared with global signals to identify the specific drivers of change in this region.

P-2498

## Environmental controls on the carbon and oxygen stable isotope ratios of modern land snail shells in Australia.

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### Abstract

Land snails are present across Australia, and their shells have been found in sedimentary accumulations, including important archaeological and palaeontological sites. The carbon and oxygen stable isotope compositions ( $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of these shells should preserve information about past climates, but to date have not been used in Australian palaeoclimate studies. The relationship between the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of modern land snail shells in Australia and contemporary climate variables had also never been tested.

We measured the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of land snail shells collected from Australian sites covering a wide climatic gradient. We compared these measurements with local climate variables, derived from gridded observational data. The strongest relationship observed is a negative correlation between shell  $\delta^{13}\text{C}$  and annual precipitation amount. Where a collection site yielded more than one species, shells from different species preserve distinct  $\delta^{13}\text{C}$ . Shell  $\delta^{18}\text{O}$  is also negatively correlated with precipitation amount, and the species offset is less pronounced.

We suggest that the negative correlation of shell  $\delta^{13}\text{C}$  and precipitation reflects the vegetation  $\delta^{13}\text{C}$  response to moisture availability. Absolute values indicate that in this case, the response manifests through changes in stomatal conductance of  $\text{C}_3$  plants in response to moisture stress, rather than changes in vegetation composition (plants using the  $\text{C}_3$  versus  $\text{C}_4$  metabolic pathway). We test this supposition using a snail flux balance model in conjunction with the predicted distribution of vegetation  $\delta^{13}\text{C}$  across Australia.

The negative correlation of shell  $\delta^{18}\text{O}$  with precipitation follows a similar trend to the distribution of oxygen isotopes in precipitation in Australia, which in turn is largely driven by precipitation amount. Snail shell  $\delta^{18}\text{O}$  is therefore probably a reflection of the effect of precipitation amount on the  $\delta^{18}\text{O}$  of rainwater. To extricate source water (snail body fluid)  $\delta^{18}\text{O}$  from the influence temperature in the shell  $\delta^{18}\text{O}$ , we measured the clumped isotope composition (ratio of  $^{13}\text{C}^{18}\text{O}^{16}\text{O}$  to  $^{12}\text{C}^{16}\text{O}^{16}\text{O}$ ;  $\Delta_{47}$ ) of a subset of shells. We used shell  $\Delta_{47}$  to calculate the temperature at the time of snail shell growth. In controlled tests, snail shell  $\Delta_{47}$  has been demonstrated to accurately record temperature. However, shell  $\Delta_{47}$  values from these snails in their natural habitats do not have a straightforward relationship with annual or seasonal average temperatures. Snail shell  $\Delta_{47}$  is therefore especially useful as a means to estimate snail body fluid  $\delta^{18}\text{O}$ .

Snail shells hence track precipitation amount via two mechanisms i.e. its influence on  $\delta^{18}\text{O}$  of precipitation (seasonal precipitation amount), and its effect on vegetation  $\delta^{13}\text{C}$  (annual precipitation amount). Our results indicate that the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of ancient land snail shells may provide insight into past rainfall in Australia, particularly if the dietary preferences and active season of the snails are known.

P-2499

## U-Th concentration and isotope ratio of seawater from the East China Sea using MC-ICPMS

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### Abstract

Precise measurements of U-Th concentration and isotope ratios in seawater play an important role in ocean study in both space and time, e.g., in dating corals and other marine carbonates in the Quaternary period. Here, we have investigated the U-Th concentrations and isotope ratios in East China Sea and Okinawa Trough. The precision and accuracy of U and Th is determined by NBS-CRM-112A and IRMM Th-035. IRMM Th-035 was measured for five times, giving an average  $^{232}\text{Th}/^{230}\text{Th}_{\text{atom}}$  ratio of  $87317 \pm 1627$  ( $2\sigma$ ,  $n = 5$ ). Nine surface seawater samples were collected from East China Sea, and five surface samples were collected from Okinawa Trough. Results showed that the U contents (salinity = 35‰) of surface seawater were from 3.122 to 3.401 ppb, with an average value of  $3.211 \pm 0.137$  ppb ( $2\sigma$ ,  $n = 14$ ), and  $\delta^{234}\text{U}$  was from 145.2 to 150.0 ‰, with a mean value of  $147.1 \pm 2.8$  ‰ ( $2\sigma$ ,  $n = 14$ ).  $^{232}\text{Th}$  concentrations were with a marked difference from East China Sea and Okinawa Trough, giving value from 0.171 to 1.155 pg/kg with an average of  $0.516 \pm 0.732$  ( $2\sigma$ ,  $n = 9$ ) pg/kg for East China Sea, and from 0.306 to 0.388 pg/kg with a mean value of  $0.335 \pm 0.073$  pg/kg ( $2\sigma$ ,  $n = 4$ ) for Okinawa Trough. The purpose of this study was providing accurate U-Th data for related environmental change research in the East China Sea and adjacent sea areas.

P-2500

## Stable and clumped isotope composition of land snail shells and their climatic implications

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### Abstract

The widely-distributed land snails are excellent material for reconstructing terrestrial climatic changes using the carbonate clumped isotope ( $\Delta_{47}$ ). Here we studied the  $\Delta_{47}$  of modern snail shells cultured under controlled temperatures or collected in the field and the fossils sampled on the Chinese Loess Plateau (CLP). Three species were raised at controlled temperatures and the *Achatina fulica* was sampled monthly for  $\Delta_{47}$  analysis. On the whole, the  $\Delta_{47}$  value of snail shells decreases with increased cultivation temperature. However, the  $\Delta_{47}$  values decreased when snails grown larger and almost all of the  $\Delta_{47}$  values fall below the calibration line of Bonifacie et al (2017) and it is  $\sim 0.016\text{‰}$  smaller on average.

We further analyzed the snail shells collected in the field from two strikingly different climatic regions-Monsoonal and Mediterranean climatic areas. The  $\Delta_{47}$  temperature ( $T_{47}$ ) are consistent with the rainy season temperature when the snails are active, irrespective what climatic conditions they live in. This suggests that snail shells record their growing season temperature. Moreover, our results show that the mean  $T_{47}$  of modern snails is  $\sim 12^\circ\text{C}$  higher than the glacial fossils and the average  $\delta^{13}\text{C}_{\text{shell}}$  is  $2.7\text{‰}$  more negative. We argue that the  $\delta^{13}\text{C}_{\text{shell}}$  couldn't record the  $\text{C}_3/\text{C}_4$  changes on the CLP and it may mainly reflect the condition of aridity with negative value reflecting reduced aridity. Additionally, the mean  $\delta^{18}\text{O}_{\text{shell}}$  and the reconstructed body water  $\delta^{18}\text{O}$  of modern snail are  $2.8\text{‰}$  and  $5.3\text{‰}$  more positive, respectively, and the body water  $\delta^{18}\text{O}$  is also positive than the precipitation  $\delta^{18}\text{O}$  during the growing season. This may be related to high degree of evaporation enrichment of environmental water  $\delta^{18}\text{O}$  in the body/ingested by modern snails under warm condition. Thus, it is difficult to use the  $\delta^{18}\text{O}_{\text{shell}}$  to directly reconstruct precipitation  $\delta^{18}\text{O}$  on the CLP.

P-2501

## $\delta^{18}\text{O}$ of modern land snail from sub-humid to arid climate zones in China and their relation to environment

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### Abstract

Many studies have investigated the stable isotopes of land snail shells from diverse geographical and climatic units. Generally, shell  $\delta^{18}\text{O}$  is related to the isotopic composition of environmental water ingested by snails (e.g. precipitations), relative humidity (e.g. Yapp, 1979; Balakrishnan and Yapp, 2004) and the temperature of carbonate precipitation. Here, we studied modern land snails from 15 localities, from Dalian (121.62°E, 38.93°N) on the east coast to Jiayuguan (98.30°E, 39.77°N) in the west inland in China. The longitudinal span exceeds 2000 km, covering from sub-humid to arid climate zones. Our results show that mean  $\delta^{18}\text{O}$  from the western localities are more positive than those from the east, in another words, the mean  $\delta^{18}\text{O}$  values decreased from arid (-0.9‰) to sub-humid conditions (-4‰). Noticeably, the amplitude of  $\delta^{18}\text{O}$  is up to ~10‰ in Xi'an city. This allows us to speculate that temperature change alone cannot induce such large variations in  $\delta^{18}\text{O}$ , because this would require extremely large changes in ambient temperature. Furthermore, the calculated  $\delta^{18}\text{O}$  of snail body water are more positive than the local precipitation  $\delta^{18}\text{O}$  values during snail growing season. Thus, contrary to previous studies (e.g. Lécalle, 1985), we conclude that shell  $\delta^{18}\text{O}$  values may not reflect the  $\delta^{18}\text{O}$  of meteoric waters, and we infer that it may reflect the evaporation enrichment of environmental water/snail body water and the relevant relative humidity.

P-2502

## Quantitative evaluation for driving factors of carbonate oxygen isotope composition in lake sediments

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### Abstract

The isotope composition of authigenic carbonates is one of the commonly used paleoclimate proxies for lake sediments. However, the  $\delta^{18}\text{O}$  variations in carbonate sediments are often characterized by high uncertainty in the paleoenvironmental interpretation due to the multiplicity of material sources and complication of sedimentation processes. Here we selected the Xiaohushan section (XHS), which formed during the Late Pleistocene by AMS  $^{14}\text{C}$  ages, from the Gaxun Nur paleolake to quantitatively evaluate the processes driving the change of carbonate  $\delta^{18}\text{O}$ . XHS section is located in Ejina Basin with an altitude of 908 m a.s.l.. The meteorological data (1951-1980) from Guaizihu meteorological station shows that the average annual rainfall is about 37.9 mm, with an annual temperature of about 8.4°C, with an annual extreme maximum rainfall of about 103.0 mm and a minimum rainfall of about 7.0 mm. Roughly 60% ~ 70% of the annual precipitation occurs between July and September, with potential evaporation of around 3769.6 mm, and relative humidity of about 35%.

The sediments of XHS section were rich in authigenic carbonates. The result of XRD analysis showed that calcite, dolomite and aragonite in sediment were mainly carbonate minerals. On the layer from 590cm to 500cm, calcite disappeared with relative content increasing of dolomite. The  $\delta^{18}\text{O}$  of carbonate showed abnormal increasing with positive amplitude of about 6.1‰, which can't be interpreted by environmental processes. Here we try to quantitatively evaluate the processes driving  $\delta^{18}\text{O}$  change of XHS section. The mineral typology, grain size, TOC and carbon isotopes of organic matters were also analysed. Our results showed that both the concentrating effect due to lake water evaporation and phase change of carbonate minerals could lead to a change in carbonate  $\delta^{18}\text{O}$ , the later of which can cause the isotopic fractionation and serve as one significant factor in changing the carbonate  $\delta^{18}\text{O}$  values. In the XHS samples, the  $\delta^{18}\text{O}$  signal in the dolomite was enriched by 7.65‰~11.02‰ than that in the calcite. Therefore, it was estimated that the isotope fractionation could account for 70% of the variance in the  $\delta^{18}\text{O}$  values between both minerals. All these suggest that there exist isotopic fractionation in the  $\delta^{18}\text{O}$  values among different forms of carbonate minerals and this phenomenon should be taken into account in the sediment-based paleoclimate reconstruction.

P-2503

## A high-resolution climate proxy record of the terminal Pleistocene to early Holocene from lacustrine carbonates, southern Ontario, Canada.

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### Abstract

Understanding how environments responded to climate warming from the terminal Pleistocene to Holocene is crucial for improving our ability to predict the impacts of future climate change. While climate changes throughout this period have been well characterized on a global scale, there is still a lack of high-resolution climate records, particularly those that identify how climate has changed on a local scale. High-resolution climate records are especially needed in southern Ontario, which hosts the southern Great Lakes. Identifying the climatic variations associated with the terminal Pleistocene-Holocene transition in this region should offer critical insights into how the Great Lakes responded to past change. Such information is crucial for assessing how the Great Lakes will respond to ongoing, anthropogenically induced warming. Proxy records obtained from the lacustrine sediments of the Great Lakes have at best a century-scale resolution due to low sedimentation rates. The water column conditions recorded by the proxies also have been averaged over the very large watersheds in which the Great Lakes are situated. To overcome these limitations, we have generated a high-resolution (decadal-scale) record of environmental change using oxygen ( $\delta^{18}\text{O}$ ) and carbon ( $\delta^{13}\text{C}$ ) isotope compositions of endogenic carbonate (marl) and coeval biogenic carbonate (shelly fauna) from an ancient kettle lake deposit at St. Agatha, Ontario, Canada. We have generated a well-constrained age-depth model using shelly fauna and organic macrofossils for the thick St. Agatha marl deposits (~4m; ~0.75mm/yr). Our records capture the end of the Bølling-Allerød, the Intra Allerød Cold Period (IACP), and the Younger Dryas cold period (YD). We observed a synchronous decrease of ~4‰ in  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  of both marl and coexisting shelly fauna during the end of the Bølling-Allerød interstadial with the most dramatic decrease in isotopic compositions occurring in the IACP. The  $\delta^{18}\text{O}_{\text{marl}}$  increased by ~2.5‰ directly following the YD, suggesting that this time period was characterized by increasing warming over a relatively short time period. Our results also show that southwestern Ontario did not experience noticeable Pre-Boreal Oscillation (PBO) cooling before the start of the Holocene, contrary to what is reported in the literature for larger spatial scales. Our data yet again demonstrate that climate anomalies pertinent to global scale investigations are not always an accurate representation of environmental change at the local scale. Our future work will focus on multiply-substituted clumped isotopes ( $\Delta_{47}$ ) of the marl and biogenic carbonate. Such data will help us to better distinguish between hydrologic (net flux) and temperature effects on endogenic and biogenic carbonate  $\delta^{18}\text{O}$  at St. Agatha, and thus further quantify climate change over this critical period of time (~13,500 to 8200 cal BP).

P-2504

## Ugandan crater lakes, past and present: Identifying drivers of hydroclimatic change using isotope mass balance modelling

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### Abstract

Water resources play an important role in providing domestic supplies for remote communities in western Uganda, as well as sustaining local agriculture, aquaculture, and tourism. Current and projected climate change and population growth in the region is putting water bodies under unprecedented pressure. Through reconstructing the response of lakes to historic climate variability and human impacts, we can further understand the potential impact of future changes on lake water balance and therefore on water availability.

Uganda has over 80 crater lakes, associated with the western branch of the East African Rift System, that are a natural laboratory for investigating the response of tropical lacustrine environments to climate and human driven change. The lack of long-term environmental monitoring in the region requires the use of proxies recorded in lake sediments to infer past lake conditions. Previous studies of the crater lakes have utilised multi-proxy approaches including diatoms, pollen, charcoal, and pigments to reconstruct a history of environmental change in the lakes extending back over 2,000 years.

While some environmental parameters related to water quality are relatively well constrained for the Ugandan crater lakes, past lake water balance and local hydroclimatic conditions, i.e. water quantity, remain poorly understood. This project aims to interpret records of lake carbonate  $\delta^{18}\text{O}$  and quantitatively infer changes in water flux over time, by developing isotope mass balance models for the crater lake systems.

Here we test this approach with the previously published record from Lake Kasenda (Ryves et al., 2011). Through the last 1,300 years the  $\delta^{18}\text{O}$  values in the Kasenda sediments are relatively positive, but a number of large negative isotope excursions are also seen in the isotope record. These could be the result of a number of interacting drivers including flooding, intense precipitation, and/or influx of groundwater into the system. By conducting sensitivity tests on an isotope mass balance model based on the present day Kasenda system, we are able to identify the most likely driver(s) of water balance change at Lake Kasenda, and better interpret these distinct negative isotopic excursions.

When compared to other palaeolimnological work from a number of other crater lakes in the region it appears that Lake Kasenda experienced relatively persistent freshwater conditions during regionally climatically arid phases (e.g. the late 18<sup>th</sup> Century drought); it is suggested that this could be a result of groundwater connectivity. Furthering our understanding of the possible 'buffering' of the impacts of hydroclimatic change at Lake Kasenda by groundwater is of interest for predicting individual lake response to future change. The ability to identify lake systems, and therefore communities and ecosystems, most vulnerable to future change will help inform sustainable management of these water resources.

P-2505

## Death on the Nile – volcanoes on trial

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### Abstract

Climate change and water availability is a major concern in subtropical Asia and Africa, with summer monsoon precipitation being one of the main sources of precipitation. Yet, summer monsoon rainfall has been found to be strongly tied to large volcanic eruptions through asymmetric forcing (Oman et al. 2006) caused by the stratospheric injection of sulfate aerosols (Figure 1). Here we use polar ice cores to identify the locations, magnitudes and timing of large volcanic eruptions in the past 2,500 years. We further identify the eruptions' imprint on hydroclimate variability in the monsoon regions that are now home to more than 60% of Earth's population. More specifically, we integrated written and natural archives to show that volcanic eruptions repeatedly suppressed the agriculturally-critical Nile flood. Previous work linking eruptions to Nile flow noted coincidences in timing between Nile "failure" and a handful of eruptions (Eldgjá, 939 CE, Laki, 1783 CE (Iceland), Katmai, 1912 (Alaska)). Using a state-of-the-art ice-core volcanic reconstruction (Sigl et al. 2015) with Nilometer data (the world's longest-known documentary hydrological record; Kondrashov et al. (2005)) we show a persistent suppression of the Nile through time, with modelling used to characterize the underlying mechanism as the radiative and dynamical impacts of eruptions on the Monsoon (Manning et al. 2017). Egypt's monsoon-mediated vulnerability to remote volcanic eruptions is a salient lesson for all monsoon-dependent agricultural regions, presently including many of the world's most populous states.

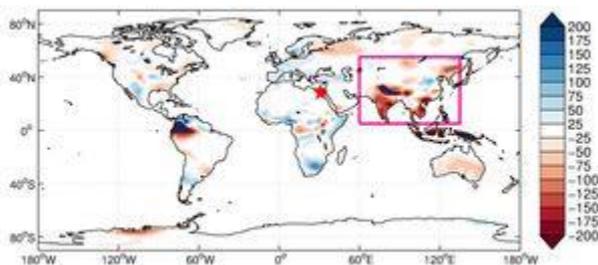


Figure 1 | Boreal summer precipitation response to Mt. Pinatubo eruption. Ensemble mean difference for 1992 May-September averaged precipitation over land, computed from the output of 60 historical NorESM simulations with and without Mt Pinatubo forcing. Units are in mm/yr. The box (5-55°N, 60-135°E) marks the region Feng et al.(2013) used for defining their warm season Asian precipitation index. The red star marks the location of the Nilometer on Roda Island, Cairo, used to reconstruct monsoon-driven streamflow variability since 622 AD.

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P-2506

## Late Pleistocene precipitation changes using stable isotope analysis of a speleothem from the Majuanas Cave System, Cuba

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### Abstract

A stalagmite was collected in the Salón de la Permenencia-01 of the Majaguas Cave, which is a part of the Majaguas-Cantera Cave System in western Cuba. The use of this stalagmite as a natural climate archive is advantageous not only because stalagmites can record continuous episodes of growth that are thousands of years in duration but also because they are easily and reliably dated using U/Th dating methods. With this method, the stalagmite (which is currently active) was dated and shown to have undergone three periods of growth: from 100 ka to 68 ka; from 11 ka to 10 ka; and during the late Holocene to the present. The stable isotopes of oxygen and carbon from this stalagmite show considerable variability during the period from 100 ka to 68 ka and provide information on the factors influencing Caribbean region precipitation and other climatic events during the late Pleistocene. Due to the lack of high-resolution paleoclimatic records from western Cuba, this study will add to our knowledge of past climate variability for Cuba and the Caribbean as a whole for the time periods from 100 ka to 68 ka, the late glacial period, as well as the last few thousands years.

P-2507

## Global distribution and controls on cave drip water oxygen isotope composition

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### Abstract

The oxygen isotope composition of speleothems is a widely utilised paleoclimate proxy that is responsible for the current state-of-knowledge of past Asian monsoon dynamics, the timing of glacial-interglacial cycles, and the insolation control on inter-tropical convergence zone position, among other climate processes.

Because speleothems are deposited by cave drip water, and this is derived from meteoric precipitation, it is critical to understand the empirical relationship between precipitation and cave drip water  $\delta^{18}\text{O}$ .

Here, we present the first global analysis, based on data from 148 drip sites, 38 caves, and five continents. Globally, drip water  $\delta^{18}\text{O}$  is most similar to the amount-weighted precipitation  $\delta^{18}\text{O}$  where mean annual temperature (MAT) is  $< 10\text{ }^\circ\text{C}$ . For seasonal climates with  $\text{MAT} > 10\text{ }^\circ\text{C}$  and  $< 16\text{ }^\circ\text{C}$ , we demonstrate that drip water  $\delta^{18}\text{O}$  records the recharge-weighted  $\delta^{18}\text{O}$ .

Our analysis implies that speleothems (formed in near isotopic equilibrium) are most likely to have  $\delta^{18}\text{O}$  that directly reflect meteoric precipitation only in cool climates. In warmer and drier environments, speleothems will have a seasonal bias toward the precipitation  $\delta^{18}\text{O}$  of recharge periods and, in some cases, the extent of evaporative fractionation of stored karst water.

**P-2508**

## **Moisture variations since the last deglaciation revealed by the loess sediments over the core area of arid central Asia**

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### **Abstract**

Climatologically, humid east Asia and arid central Asia (ACA) constitute the mid-latitude Asian continent. ACA is located in the hinterland of the Eurasian continent, and the special geographical position far from any ocean brings typical continental temperate climate. The arid environment, sparse vegetation cover and fragile ecosystems make the ACA very sensitive to climate change. Thus, understanding of climate changes in ACA and possible mechanisms on multiple timescales is indispensable for the assessment of present and future climatic dynamics in the region, especially under ongoing global warming.

The water resources are extremely valuable due to scarce precipitation and high evaporation in ACA. As yet it has been well established that the Westerlies play an important role in driving hydrologic climate feature in ACA. However, Holocene moisture evolution in ACA remain controversial possibly due to differences in study sites, disputed implications of paleoclimatic proxies and, in particular, obscure seasonality of precipitation. The eastern sector of ACA receives most of its annual precipitation during summer, and the west does during winter. Here, we investigate moisture variabilities since the last deglaciation in the different sectors of ACA, with moisture proxies from loess sediments, on the multi-millennial time scale. The results show that:

- Summer-dominated precipitation showed a gradual wetting trend since the last deglaciation, while winter-dominated precipitation distinctly increased in the initiation of Holocene and late-Holocene.
- Summer-dominated precipitation is forced by the greenhouse gases (GHG). Increased GHGs lead to the higher humidity over the Eurasian high-latitudes and thus the more water vapors carried by the Westerlies, which yields more precipitations in the water vapor supply-limited eastern sector.
- Changed atmospheric circulations and increased water vapors in sources are responsible for the present picture of winter-dominated precipitation during the last deglaciation. Holocene winter-dominated precipitation are mainly related to the capacity of the Westerlies to transport water vapors, which is controlled by the insolation gradient between mid-and high-latitudes and winter insolation at mid-latitudes.
- Comparison of the stacked Indian monsoon records with the precipitation proxies indicates the Asian monsoon didn't penetrate our study area even if when the monsoon is stronger.

Our study provides more comprehensive information about the precipitation variabilities in the ACA and explores the driving mechanisms of moisture evolution since the last deglaciation. This contribution would facilitate prediction of the future climate in the ACA.

P-2509

## Observations and implications of high level spatial variability found in instrumental regional hydroclimate records for subtropical Southeast Queensland, Australia

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### Abstract

Subtropical Australia is a region with a short and sparsely documented hydroclimate history. What is abundantly clear is the strong nature of extreme events in this region as evidenced by recent devastating flood (1974, 2011, 2013) and drought (1939-1945, 1996-2010) events. As such the long-term hydroclimate of this region needs to be better understood so that adaptation and management of future events can be implicated. However, instrumental records only begin in the mid-1800s and much of the data collected prior to 1900 is considered unreliable. Proxy sources to extend these instrumental records are also lacking due to few lake, coral, or caves systems in the region to provide paleoclimate data. Yet there are several forest environments across the subtropics that can be used to develop long-term tree-ring hydroclimate reconstructions. This process has recently been applied in several studies in Southeast Queensland (SEQ) with rainfall and drought reconstructions presented. However, as these are individual site based studies and not networks of tree-ring records it is important to understand the spatial extent which they can be considered representative of.

Here we look at 140 instrumental rainfall stations across SEQ to identify trends in both temporal and spatial variability from 1908-2007. Pearson correlation analysis between each station has categorised them into 80%, 85%, and 90% correlation groupings with annual deviations from the mean developed for each group. Analysis of above and below average rainfall phases for each of the correlated groups indicates that rainfall is not uniform across SEQ and can in fact be categorised into several well correlated instrumental groups. Additional assessment of all instrumental streamflow gauges of longer than 50 years duration within SEQ indicates that the spatial groupings also apply to the river networks as rainfall is the main contributor to regional hydroclimate inputs. Strong connections between the regional hydroclimate records and the El Niño Southern Oscillation as well as the Interdecadal Pacific Oscillation are observed.

Assessment of the currently available tree-ring reconstructions from SEQ to the hydroclimate groups developed indicates that single site tree-ring records are best considered representative of the spatial groups they are contained within. It is clear that they cannot represent all of SEQ let alone larger areas which are lacking in both rainfall and streamflow data. The implications this has on long-term hydroclimate understanding for this and other similar regions is discussed.

P-2510

## A Two-Core chironomid-based Mid- to Late Holocene ecosystem reconstruction of the Tibetan lake Taro Co

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### Abstract

The Tibetan Plateau stores Earth's third largest amount of ice and supplies water for a major part of Asia, home to almost two thirds of the world's population. To better predict water availability under ongoing and future global warming, lake level reconstructions for periods with different past climatic conditions are important. The Tibetan lake Taro Co (4,567 m a.s.l., maximum depth 132 m) is a large (483.2 km<sup>2</sup>) endorheic freshwater lake located in the western part of the Central Tibetan Plateau (31°03'–31°13' N, 83°55'–84°20' E).

Here we present chironomid based reconstructions of changes in lake ecosystem conditions using two sediment cores from the central basin (TOC 11-04, 68 m water depth) and from a prodelta close to the southern shoreline (TRGC 14-06, 29.4 m water depth), respectively. The two-core setting depends less on local signals like chironomid community thresholds at certain water depths or head capsule transportation and therefore presents the unique opportunity to separate local from lake-wide ecosystem signals.

Preliminary results for both cores show very low chironomid concentrations with less than ten head capsules per gram dry weight in the oldest part of the cores (7350 and 10500 cal. yr BP, respectively). Chironomid concentration increases rapidly at about 5200 cal. yr BP in the central core, whereas in core TRGC 14-06 they remained low until a hiatus in sedimentation between about 10500 and 5000 cal. yr BP. In both cores the oldest zone differs greatly from the rest of the core and shows the lowest percentages of the otherwise dominating *Micropsectra radialis*-type. Further changes in the chironomid abundances and assemblages are observed at about 2400 cal. yr BP in both cores and at about 3600 cal. yr BP as well as 250 cal. yr BP in core TRGC 14-06. Both cores show similar concentrations of chironomid head capsules except for the time window between 5000 and 3600 cal. yr BP, when concentrations are two to four times higher in core TRGC 14-06.

This phase as well as the zone boundary connected to the concentration decline at approximately 3600 cal. yr BP most likely show a local signal potentially connected to changes in the inflow of the closest tributary river and therefore sedimentation of head capsules. The second change in the chironomid assemblages only observed in core TRGC 14-06 at about 250 cal. yr BP may have resulted from anthropogenic influence that is better visible in this core because of the proximity to the shore. Contrastingly, the other two boundaries at 5200 and 2400 cal. yr BP most likely represent lake-wide ecosystem changes and match changes in the intensity of Monsoon- and Westerlies visible in multiple archives of Central Asia.

**P-2511**

## **Foraminiferal assemblages and Stable Isotope analysis as indicators of Past Climate Change in Bays and Estuaries**

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### **Abstract**

Both Nueces and Baffin Bay are secondary bays located in Southeastern Texas. Nueces Bay is very anthropogenically disturbed due to deposition of dredging spoil from Corpus Christi Bay and also diversions (from the Nueces River) of fresh water in flows. Baffin Bay is also disturbed, but to a lesser extent. Salt water inflows come through Corpus Christi Bay which has a direct connection to the Gulf of Mexico. Baffin Bay also has fresh water inflow which are minimal as only ephemeral creeks provide fresh water inflows. There is no direct connection to the Gulf of Mexico as this bay exists behind a barrier island and only has access to a legume system (Laguna Madre), and is there for hypersaline. Both bays provide a stable environment for uncovering the effects of anthropogenic climatological and ecological influence in the region.

Physical/Chemical measurements, along with microfossil assemblage and oxygen and carbon isotope have helped provide a better understanding of the climatic history of the region. These and other measurements (dendrochronology, etc.) help elicit a greater understanding of regional airmass and climatic teleconnections.

P-2512

## Late-Pleistocene climate and vegetation of north-central India: Clues from sedimentology, molecular distribution of n-alkane and stable isotopes

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### Abstract

Indian Summer Monsoon (ISM), an important component of the global climatic system, played a vital role in shaping the food budget of the agro-based economy like India. High-resolution proxy based climatic records of ISM is limited. Moreover, the time period Late-Pleistocene is characterized by the dramatic oscillation of climatic condition which severely disturbed the Pleistocene biotic evolution. Hence, it is important to improve our understanding of Late-Pleistocene climate variability and its response to vegetational shifts. However, paleoclimatic reconstruction from fluvial sediments of Yamuna river dominated, Yamuna-Betwa interfluvium is rather limited (Sinha et al., 2005). Hence, to improve our understanding of paleoclimate variability from the central part of the Indo-Gangetic plain, we provide a continuous reconstructed multi-proxy record of precipitation and terrestrial vegetation changes during the last ~25 ka. The chronology of the sedimentary core (8 m) is established using Optically Stimulated Luminescence (OSL) dating of quartz grains. For the first time, we have coupled micro-morphological features of paleosols and soil carbonate (SC), molecular distribution pattern of n-alkanes with stable isotope study such as  $\delta^{13}\text{C}_{\text{OM}}$  of bulk soil organic matter,  $\delta^{18}\text{O}_{\text{SC}}$  and  $\delta^{13}\text{C}_{\text{SC}}$  of SC and  $\delta\text{D}_{n\text{-alkane}}$  and  $\delta^{13}\text{C}_{n\text{-alkane}}$  of n-alkanes from the paleosols of a sedimentary core of Betwa river bank to understand the climate-vegetation relationship.

The stable isotope values suggest that low rainfall condition with a higher abundance of C<sub>4</sub> plants at ~20 to 23 ka which corresponds to Large Glacial Maximum (LGM). Micro-morphological study of paleosol bearing horizon contain b-fabric, clay coating, pedorelicts suggest arid condition prevailed before the Holocene (~10 ka). The early Holocene intensification at ~10 ka is clearly observed in  $\delta^{18}\text{O}_{\text{SC}}$  and  $\delta^{13}\text{C}_{\text{SC}}$  values and  $\delta\text{D}_{n\text{-alkane}}$  and  $\delta^{13}\text{C}_{n\text{-alkane}}$  value which was supported by the presence of high terrestrial organic matter input. The highest increase in C<sub>3</sub> plants observed during last ~1.4 ka. However, the overall weak relationship of rainfall amount and pCO<sub>2</sub> concentration with vegetational shift suggests an important role of other factors for such as substrate control and plant functional type.

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P-2513

## Linking long-term CO<sub>2</sub> induced leaf stomatal conductance decrease to vegetation greening through $g_{smax}$ - NDVI comparison in Scandinavia

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### Abstract

The inherent CO<sub>2</sub> regulated link between climate and vegetation affects the hydrological cycle. Reduced water loss through leaf stomata under current CO<sub>2</sub> increases has the potential to induce a wide range of changes in the global hydrological cycle such as H<sub>2</sub>O fluxes, run-off rates, cloud formation and precipitation. Especially in the northern latitudes, photosynthetically active, and thus transpiring leaf area is maintained for an increasingly longer period throughout the year due to the lengthening of the growing season under ongoing warming.

The increasing CO<sub>2</sub> availability moreover allows plants to optimize carbon uptake versus water loss through adjustment of their leaf stomatal conductance. The resulting increases in water use efficiency, defined as the ratio of carbon uptake to actual water loss, regulates the canopy transpiration and therewith the evapotranspiration of the vegetated areas.

On plant leaf level, the structural maximum stomatal conductance ( $g_{smax}$ ) adaptation can be quantified by microscopic analysis of the epidermal cell morphology in modern and fossil plant leaf material, providing an important tool to determine the long-term trends in plant hydrological properties under anthropogenic CO<sub>2</sub> increase.

The  $g_{smax}$  records produced for the past 150 years spanning the anthropogenic CO<sub>2</sub> increase reveal a substantial decrease in  $g_{smax}$ . The hydrological properties of plant foliage are thus indicating a downregulation of the vegetation transpiration with the potential to act on the hydrological cycle. This pattern however is not clearly visible in the instrumental records and increasing leaf area through CO<sub>2</sub> fertilization has been offered as a buffering mechanism.

We here test this hypothesis by directly comparing  $g_{smax}$  records from Scandinavia with satellite imagery based NDVI data of the regions covered by the proxy data. Our results show that  $g_{smax}$  rate of change is by far exceeding NDVI increments leaving a large part of the vegetation induced changes unexplained.

**P-2514**

## **Diagnosing the controls of Holocene drought in North America: P, E, or surface water- and energy-balance feedback?**

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### **Abstract**

The Holocene paleoenvironmental record of the mid-continent of North America clearly shows the impact of the mid-Holocene (8.2 to 4.0 ka) “gigadrought” that killed trees, drained lakes, and otherwise affected water resources in way that, if repeated today, would have devastating effects. Although well-documented for over 40 years now through Tom Webb’s mapping of the dynamics of the Prairie-forest border, the specific climatic mechanisms responsible for the drought are still not understood, and subsequent work by Webb’s students and colleagues has shown that while the gigadrought generally had an abrupt onset and ending, some aspects of the paleohydrological record were time-transgressive or diachronous, suggesting multiple factors may have been acting in concert.

Drought has multiple controls. Moisture availability (as indexed by moisture-flux divergence or precipitable water vapor) and precipitation-producing (or suppressing) mechanisms (generated by the mid-tropospheric atmospheric circulation), together govern the precipitation component of P - E. The evaporation component also has multiple controls: supply, related to soil-moisture availability and surface-water storage, and demand, as indexed by vapor-pressure deficit and the difference between actual and potential evapotranspiration, are each related to atmospheric and surface conditions. There is also the possibility of feedback through the surface water and energy balances, as expressed by Bouchet’s (1963) “complimentary relationship”: as the surface dries, net radiation is partitioned into decreasing latent and increasing sensible heating, which steepens the vapor-pressure gradient which further dries the surface. All of these controls operate simultaneously.

One approach toward diagnosing the specific controls of (paleo) hydroclimatic variation is to exploit the thousands of individual cases provided by transient (e.g. TraCE-21k), and multi-model (PMIP) simulations using the standard tools of modern climate diagnostics (as applied to reanalysis data sets) such as the construction of composite anomalies, as well as area-average time series of long-term mean differences.

Month-length adjusted TraCE data (supplemented by offline simulations of surface water-balance variables using SPLASH v1.0), reveal the changing nature of drought throughout the Holocene. In the early Holocene, simulated precipitation was greater than present, supported by atmospheric circulation and moisture flux into the interior of the continent, but evaporation, in particular evaporative demand, was much greater than present. The trends in net radiation (driven by insolation) and latent and sensible heating are suggestive of significant reinforcement of evaporation through feedback, despite the greater-than-present precipitation. The middle Holocene was characterized by little change in precipitation, and a general reduction in evaporative demand, likely related to the attenuation of the summer insolation anomaly, and the late Holocene was characterized by a general relaxation of all of the components of the surface water- and energy-balance toward the present.

**P-2515**

## **Late Pliocene-Earliest Pleistocene eolian sequence on the NE margin of the Tibetan Plateau and its record on Asian monsoon evolution**

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### **Abstract**

Eolian loess and red clay sediments from the Chinese Loess Plateau (CLP) contain a wealth of information about variations in the Asian monsoon and the aridification history of the Asian interior. To date, however, late Pliocene-early Pleistocene loess-red clay deposits have only rarely been reported from the western CLP, which significantly hinders our understanding of the distribution of eolian deposits and the palaeoenvironmental evolution of the region. Here, we present magnetostratigraphic, lithologic and rock magnetic results for two recently-drilled boreholes from the central Linxia Basin. Our results demonstrate that the loess-red clay sequences from the lower boreholes have an age range of ~3.7–2.4 Ma, and they represent the first direct evidence of upper Pliocene-lower Pleistocene eolian deposition in the western CLP. This sequence underlies basin-widely distributive late Quaternary loess sequences. The major trends of the magnetic susceptibility and grain size records from the lower parts of the two boreholes are highly correlative with those of contemporaneous loess-red clay sequences in the eastern CLP, suggesting that these parameters can be used both for stratigraphic and palaeoclimatic correlation and as powerful tools for identifying late Pliocene-early Pleistocene aeolian deposits in the western CLP. Spatially, a clear decrease and increase in magnetic susceptibility and grain size is observed between the central and western CLP, indicating that the modern spatial pattern of the East Asian monsoon regime in the western CLP has been maintained since at least the late Pliocene.

**P-2516**

## **A review of Marine Isotope Stage 4 mountain glacier moraine chronologies**

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### **Abstract**

Mountain glaciers waxed and waned over the last glacial cycle in response to changes in climate. While most glacial geologists have focused on reconstructing the paleoclimate conditions for the Last Glacial Maximum (LGM; ~21,000 years ago; Marine Isotope Stage (MIS) 2), a few have unveiled MIS 4 (~60-70,000 years ago) as a time when mountain glaciers were close to or larger than their MIS 2 extents. Moraines that predate the LGM are relatively rare due to preservation issues but a growing number of publications are finding and dating MIS 4 moraines. This presentation is a review of all published MIS 4 moraine chronologies, their site locations, and possible mechanisms for explaining extensive mountain glaciers during MIS 4.

P-2517

## **$^{10}\text{Be}$ and $^{26}\text{Al}$ exposure history of the highest mountains in Wales: evidence from Snowdon and the Glyders**

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### **Abstract**

Cosmogenic  $^{10}\text{Be}$  and  $^{26}\text{Al}$  exposure ages from samples collected from the mountains of Glyders (1001 m) and from Snowdon (1085 m) in Wales provide new insights into the glacial history of the highest mountains in the British Isles outside of Scotland. Sample elevations range from 598 to 1013 m and taken from centimetre-thick quartz veins on bedrock and also one boulder. The summits of the Glyders are characterised by intensely modified frost-shattered surfaces and have long been recognised as exemplars of mountain summit periglacial activity in the British Isles. However, numerous glacially-transported boulders on the highest ground indicate that ice overran the summits. Bedrock samples at c. 960 m yielded  $^{10}\text{Be}$  exposure ages of 72 ka and 153 ka. In addition, a glacially-transported boulder at 985 m gave a  $^{10}\text{Be}$  age of 57 ka. This boulder sample is important because it negates issues of inheritance that are possible with bedrock samples and it provides the closest estimate of the timing of ice thinning and the true exposure age of the Glyders summits. All  $^{26}\text{Al}$  ages were consistent indicating non-complex histories. These results clearly confirm the Glyder summits were overtopped by the Welsh Ice Cap during marine isotope stage (MIS) 4, when ice in this area was thicker than at the global last glacial maximum (LGM) in MIS 2. The summits were revealed as ice thinned during the transition from MIS 4 to 3. Both the geomorphological evidence and our new cosmogenic ages support recent ice cap modelling predictions that the summits then stood as nunataks above the LGM ice sheet surface in MIS 2. The oldest  $^{10}\text{Be}$  (and  $^{26}\text{Al}$ ) age of ~150 ka from the frost-shattered summit tor displays significant nuclide inheritance and previous work has demonstrated evidence of gibbsite in the summit soils. The wide range in  $^{10}\text{Be}$  apparent exposure ages and the evidence of glacially-transported boulders on intensely frost-shattered bedrock suggests erosion of the Glyder summit surfaces largely proceeded by plucking/quarrying rather than abrasion. This would have occurred under cold-based conditions with ice flow dominated by internal deformation rather than sliding. In contrast, at altitudes below 900 m ice-scoured rock surfaces on both the Glyders and neighbouring Snowdon yield exposure ages consistent with deglaciation after the global LGM in MIS 2. Based on these ages and similar results from other summits in North Wales the Welsh Ice Cap rapidly thinned after c. 20 ka leading to a phase of alpine-style glaciation. However, on Snowdon, arête crests yielded very young apparent ages of ~5 ka. These young ages reflect continual stripping of the arête rock surfaces through the current interglacial.

**P-2518**

## **Glacier-climate reconstructions of a Big MIS 4 in southernmost South America**

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### **Abstract**

While globally integrated records such as the LR04 stacked benthic  $d^{18}O$  record suggest that the global climate was less extreme during MIS 4 than it was during MIS 2, local and regional-scale paleo records have recently put that assumption into question. At the Strait of Magellan in southernmost South America we map and date an MIS 4 moraine that was assumed to be an older advance of the last glacial maximum. We now know that the lobe extended all the way out to the Atlantic during MIS 4, beyond Primera Angostura and the MIS 2 limit, meaning that the Strait of Magellan lobe would have coalesced with the Otway lobe and at least some deposits in the area are younger than previously thought. We apply the University of Maine Ice Sheet Model to reconstruct the climate conditions needed to allow the lobe to grow to our mapped extents and compare the climate of MIS 4 to that of MIS 2. We also compare our Strait of Magellan record with that of the similarly timed MIS 4 in the Southern Alps of New Zealand (Schaefer et al., 2015) and place it into the larger Southern Hemisphere context by looking at the Antarctic and offshore climate records that extend into MIS 4.

P-2519

## A rapid, deterministic age-depth modelling routine for geological sequences with inherent depth uncertainty

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### Abstract

Traditional approaches to age-depth modelling typically assume no uncertainty for the depth value of dated intervals. However, such an assumption may not be fully valid in the case of poor coring recovery or significant sediment deformation, as well as in the case of a large subsampling interval. In consideration of these issues, we present a new age-depth modelling routine, *Undatable*, which includes uncertainty in both age and depth. *Undatable* uses Bayesian radiocarbon (<sup>14</sup>C) calibration software (*MatCal*) and a deterministic approach with a positive sediment accumulation rate (SAR) assumed *a priori* which, combined with efficient programming practices, allows for the rapid production (in a matter of seconds in many cases) of age-depth models for multiple types of geological archives. *Undatable* has so far been successfully applied to coral archives, as well as sediment archives from estuarine, lacustrine and deep-sea environments. Through the inclusion of a bootstrapping option, the software performs particularly well in the case of a large scatter in age-depth constraints by expanding the uncertainty envelope of the age-depth model. Unlike other deterministic models, increasing the density of age-depth constraints results in increased precision in *Undatable*, even at centennial scale, thus emulating the results of probabilistic models. In addition to the code itself, we also provide an interactive graphical user interface (GUI) that allows users to experiment with multiple age-depth model settings to investigate the sensitivity of a given dataset to multiple parameters.

P-2520

## CLIMCOR: a 7 year project to develop new generation of drilling/coring tools for the French and international scientific communities

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### Abstract

Fundamental paleoclimatic data, geochemical or geophysical, cannot be recovered without sophisticated technological equipments to retrieve top quality records. After the initial revolution of the 80s-90s in paleoclimate science and technology, it is now time to launch a new generation of technical equipments & approaches on various paleoclimate archives. The increasing complexity of the mechanisms to decipher in climate models render mandatory to improve not only the quality, but also the temporal & spatial coverage as well as the range of proxies acquired in paleoclimate archives. One key objective is notably to access very high quality data and high-resolution records that could extend their temporal coverage further back in time, in more contrasted climate conditions than the last two millennia or the Last Glacial Maximum, so that the calibration of the Earth system models could encompass a larger range of boundary conditions.

The available drilling/coring equipments in France did not allow such important jump in the quality of the data, and therefore in the knowledge of past climate variations at extremely high resolution.

A preliminary initiative named C2FN (Centre de Carottage et de Forage National, supported by the CNRS, at the National Institute of Earth Sciences and Universe, gathered the present coring equipments, at the technical division of INSU or on oceanographic vessels, under an official umbrella, aiming at coordinating the different efforts conducted in marine, ice & continental drillings.

The CLIMCOR project (<http://climcor-equipex.dt.insu.cnrs.fr/> 17.68 M€) intended to support this effort by providing the French scientific community with top-notch technological support for the new generation of drilling/coring tools & for an upgrade of the Marion-Dufresne vessel capacity to collect oceanographical data as crucial complements of paleoclimatic data. Beside paleoclimatic reconstructions based of both ice and marine sediment coring, there is an urgent need to improve our understanding of the role of oceans in the current climatic machinery at the global level. With its oceanographical fleet & the skill of its marine researchers, France is a major actor in this scientific field, providing for example other international bodies involved in climate change issues. Besides CLIMCOR developed a new cyber-database, to properly archive the upcoming data obtained from the cores.

CLIMCOR will increase the competitiveness of the French paleoclimate and marine science community at the international level. It will contribute to bring key constraints on the possible range of future climatic evolutions. The technological developments aimed by CLIMCOR have resulted in new patents. While the C2FN infrastructure gathers renowned engineers in their respective fields, strong interactions with French companies are a daily routine for them. Our presentation is showing the completion of the different developments achieved in the ice, marine & terrestrial coring activities for the benefit of the French and international communities.

P-2521

## Temporal Variability of Planktic and Benthic Reservoir Ages of Surface, Deep, and Intermediate Waters in the LGM-to-Deglacial Southern South Pacific

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### Abstract

To meet the challenge of an accurate and precise timing and correlation of glacial and deglacial events in Southern Ocean circulation and to uncover their links to other ocean basins and global climate change we employ the absolute chronology presented in the varve-counted atmospheric <sup>14</sup>C record of Lake Suigetsu (Bronk Ramsey et al. 2012, Schlolaut et al. 2018). This record shows a suite of narrow-standing age-calibrated <sup>14</sup>C plateau boundaries that, in turn, provide a series of robust age tie points with semi-millennial resolution to which likewise highly resolved marine <sup>14</sup>C records from any site with high sedimentation rates in the global ocean can be tuned (<sup>14</sup>C Plateau Tuning Technique; Sarnthein et al. 2007, 2013, 2015). We apply this technique to two sediment records from the eastern and western continental margins each in the Pacific sector of the Southern Ocean to derive accurate and precise estimates of the differences between (coeval) atmospheric and surface, intermediate, and deep-water <sup>14</sup>C ages and their trends and short-term variability over peak glacial and deglacial times. For the LGM, our results show surface water reservoir ages of 1000 to 1800 <sup>14</sup>C yr, intermediate water ages of 2300 to 2900 yr, and apparent deep-water ages ranging from 3900 to 4600 yr in the Southwest Pacific. In total these ages provide important new insights into the role and strength of overturning processes both in the North Atlantic and North Pacific and the speed of changes in ocean stratification and the ocean release of dissolved inorganic carbon as compared to glacial-to-deglacial changes in atmospheric pCO<sub>2</sub> and <sup>14</sup>C concentration.

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P-2601

## Quaternary dune evolution on Fraser Island, Australia; environmental and archaeological implications.

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### Abstract

Fraser Island (K'gari) in South-East Queensland, Australia is the world's largest sand island and contains an exceptional record of coastal dune field development. The island lies at the northern end of the world's largest down drift system with the bulk of sands feeding the dune field originating 1000 km to the south, between the Hawkesbury and Hunter Rivers. The dune field is remarkable because of the well-developed vegetation cover, including the largest area of true rainforest on dunes. It also shares some of the world's largest soils (megapodzols) with the Cooloola Sand Mass to the south. Remarkably, there has been very little research into the geochronology of the dunes and the environmental implications of the dune field. A provisional OSL chronology for the dunefields will be presented.

The island can be divided into three separate dune fields. The largest (southern) section is a parabolic dune field that is a continuation of the adjacent Cooloola Sand Mass. There is a narrow band of Holocene dunes along the eastern section of this coast but based on correlations with Cooloola, most of the dune field is Middle-Pleistocene in age with dune units ranging up to over 700 ka in the far west. North of the parabolic dune field, there is a broad area of transverse sand dunes, nested inside a large dune activation phase that started as a series of large parabolic dunes. Based on soil characteristics these dunes are likely to be early Holocene or very Late Pleistocene in age. The very far north of the island has a mix of deeply eroded dunes on the western side and very young (late Holocene to modern) dunes in the east. This northern part of the island is likely the remnant of an older, largely eroded dune field, and has only recently been connected to the rest of the island.

In the southern part of the Island, dunes of likely MIS 5e age blocked previously eastward draining valleys creating very extensive lakes. These lakes have gradually contracted over the last glacial cycle but large lakes still persist (e.g. Lakes Birrabeen, Boomanjin, Mackenzie). We conclude that large persistent lakes are a feature of Fraser Island during the last glacial cycle. This makes the island one of the few places in eastern Australia with truly permanent freshwater and has likely implications for human occupation and biodiversity.

P-2602

## Late Quaternary deposition-deflation cycles preserved within playa-lunette systems on the High Plains, Kansas, USA

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### Abstract

Playas are upland-embedded depressional wetlands occupying the lowest position within closed watersheds, and lunettes are isolated dunes that form along the margins of some playas. Collectively referred to as playa-lunette systems (PLSs), they are important landscape elements of semi-arid and arid regions around the world. During wet phases, runoff delivers sediment and organic matter to playas, where it accumulates, while lunettes are stabilized by vegetation and pedogenesis dominates. During dry phases, regional dust inputs combined with accumulation of sediment deflated from playas outpaces pedogenesis and existing surface soils are buried as lunettes aggrade. Thus, the combined stratigraphic records of PLSs are potential archives of high-resolution paleoenvironmental data, with an abundance of carbon and luminescence dateable material, to reconstruct past geomorphic processes. Due to a relatively high surface area-to-depth ratio, playas are particularly sensitive to changes in climate, and PLSs may represent the most complete paleoenvironmental records for semi-arid and arid landscapes. Research on the High Plains of Kansas, in the central United States, indicates that playa morphology is a strong control on lunette distribution and morphology. Lunettes are only associated with playas with a surface area >5 ha, and ~10% of these playas have a lunette. Nearly 90,000 playas have been mapped on the High Plains, with ~12,200 playas with a surface area >5 ha, suggesting 1,200 or more PLSs are distributed throughout the High Plains.

To reconstruct past environments and geomorphic processes affecting High Plains PLSs, soil cores were extracted from seven PLSs in Kansas to maximum depth possible using a hydraulic coring rig. Cores were imaged and analyzed for bulk density, magnetic susceptibility, and spectral color. Detailed core descriptions consisted of horizonation, Munsell color, structure, redoximorphic features, and carbonate occurrence. Soil-sediment samples were collected and analyzed for stable carbon isotopes, and twenty-five samples collected from buried soils were numerically dated via AMS <sup>14</sup>C to provide stratigraphic age control. Age data indicate that lunettes preserve lengthy records of environmental change, with most extending to at least 40,000 cal yr BP (MIS 3). Lunettes are dominated by several-meter-thick stratigraphic sequences of 2 to 10 cm thick dark-light intercalated zones interpreted as incipient soil (A/C)-sediment layers. Playas are composed of thick, cumulic soils frequently welded to pedocomplexes dating to the Pleistocene-Holocene transition underlain by several meters of gleyed clays. Stable carbon isotope and magnetic susceptibility data indicate repeated small-scale shifts in climate throughout much of the late Pleistocene and into the early Holocene, with increased aridity throughout much of the Holocene. Geomorphic processes in the late Pleistocene regularly alternated between alluvial-lacustrine in playas and pedogenesis on lunettes to aeolian deflation from playas and deposition on lunettes, while the early-to-middle Holocene was dominated by aeolian processes.

P-2603

## A paleodust database for the last glacial-interglacial cycle: state of the art

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### Abstract

Natural archives show that the dust cycle experienced variability in the past in response to global and local climate change. The growing number of paleodust archives and the inclusion of the dust cycle in climate models has promoted synthesis efforts in the compilation of global dust data sets, based on dust mass accumulation rates as a quantitative metric that allows inter-comparison among different sites, among different kind of natural archives, and between models and paleodust observations.

We review our most recent efforts in reconstructing the past global dust cycle with model simulations and the compilation of a paleodust database based on dust mass accumulation rates and particle size distributions for the Holocene. We also give a perspective on ongoing work aimed at providing adequate tools for paleoclimate model validation over the full last glacial-interglacial cycle, considering that the representation of the dust cycle will be an option in the upcoming PMIP4-CMIP6 experiments.

**P-2604**

**Reconstructing the late Pleistocene climate sequence at Alexandra Cave, Naracoorte, South Australia, using Optically Stimulated Luminescence dating and palaeoenvironmental proxies**

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**Abstract**

The drivers of the Australia-wide megafaunal extinction during the late Pleistocene remains poorly resolved. Hypotheses include individual or synergistic combinations of climate fluctuations, human impacts through hunting or habitat alteration by landscape burning. Moreover, the relationship between extinction dynamics and long term glacial - interglacial timescales is not yet understood. Using a series of complementary geochronology, palaeoecological and geochemical techniques on a sedimentary sequence in Alexandra Cave, Naracoorte, this study provides improved reconstructions of past climates in south-east South Australia around the time of megafaunal extinction. Ten luminescence dating samples constrain the age of the sedimentary sequence to 17.7 – 106.3 ka. Palaeoenvironmental reconstructions undertaken using charcoal, carbon isotopes and geochemical analysis reveal high fire frequency and precipitation during Marine Isotope Stage (MIS) 5, while MIS 4 and the Last Glacial Maximum were arid, with low fire frequency. MIS 3 was wet, with little fluctuation in the environment, with the exception of a change in biomass burning at 36 – 50 ka. These findings suggest that climate change likely played a minor role in the demise of megafauna locally, whereas changes in fire regime could have acted as a more significant driver or consequence of megafauna extinction.

P-2605

## Dust from the Sahara and Sahel to the Atlantic: Evidence from the mineralogy and geochemistry of paleosols, Canary Islands, Spain

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### Abstract

It is well known that African dust is transported seasonally to the Atlantic Ocean at present. Less certain is how long this process has been ongoing and where dust sources in Africa are found. On the basaltic Canary Islands off the west coast of Africa, we studied sections of carbonate-rich dune sand (carbonate sand=70-95%; basaltic sand=5-30%) on the islands of Lanzarote (14 meters; 11 paleosols) and Fuerteventura (8 meters; 5 paleosols). On nearby Gran Canaria, we also studied a paleosol developed on basalt and overlain by marine deposits. On Lanzarote and Fuerteventura, paleosols are distinguished from unaltered carbonate dune sand by their pedogenic structure and color and higher silicate clay and fine silt contents. On these two islands, radiocarbon ages of land snails indicate that all but the youngest paleosols (of Holocene age) are older than ~40-50 ka, minimum-limiting ages. <sup>87</sup>Sr/<sup>86</sup>Sr values of the marine carbonate skeletal grains indicate the host sands are ~600 ka to ~800 ka, maximum-limiting ages. On Gran Canaria, basalt underlying the paleosol studied and marine deposits overlying the paleosol are both ~400 ka. On all three islands, the presence of quartz (absent in local basalt) in paleosols indicates that the soils are derived, at least in part, from an external source, likely long-range-transported dust. The clay mineralogy of the paleosols is dominated by smectite, mica, and kaolinite. Mica, absent in basalt, is also likely derived from an external dust source because true cases of pedogenic mica are extremely rare. In principle, kaolinite could be derived from in situ chemical weathering of basalt, but this seems improbable in the arid climate of the Canary Islands. Such an interpretation is also supported by the presence of unaltered marine skeletal aragonite at all depths in the sections on Lanzarote and Fuerteventura. Thus, chemical weathering in these paleosols has been minimal and a pedogenic origin for kaolinite is unlikely. Geochemical signatures, using immobile trace elements (Sc-Hf-Th; Cr-Hf-Th; La<sub>N</sub>/Yb<sub>N</sub>-Eu/Eu\*; Gd<sub>N</sub>/Yb<sub>N</sub>-Eu/Eu\*), also show that the paleosols are derived from a mix of African dust and detrital basaltic sand. Thus, we interpret mica to be derived from eroded Aridisols and sediments in the Sahara and kaolinite to be derived from kaolinite-rich Alfisols in the Sahel. Quartz could be derived from either region of Africa. These interpretations are consistent with the mineralogy of modern dust collected at various points along the western African coast. Results indicate, therefore, that dust transport from Africa to the Atlantic Ocean has been ongoing for much of the Quaternary. Furthermore, dust sources in both the Sahara and Sahel have existed for much of the Quaternary, whenever conditions were dry enough for a vegetation-free Sahara and when extended droughts brought about a dry Sahel region.

P-2606

## A quantitative method for analysing Quaternary aeolian dune accumulation records

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### Abstract

Luminescence dating has, since Singhvi *et al.* (1982), become the primary method for dating aeolian deposits, to the point where it is regarded as a standard method in both Quaternary palaeoenvironmental studies and investigations of long-term dunefield dynamics. By 2018, over 4000 luminescence ages from desert dunefields worldwide had been published, as recorded in the INQUA Dune Atlas database (Lancaster *et al.*, 2016; <https://www.dri.edu/inquadunesatlas>). Environmental and climatic interpretations of these dated dune sediment records have however proved problematic (Hesse, 2016) and sometimes controversial (Thomas and Burrough, 2012), and it has remained challenging to test hypotheses of the systematic response of dunefields to changes in external forcing in the past (Chase, 2009) and to make predictions of the future.

A numerical method for handling and modelling age data at the dunefield scale, provides an approach that addresses many of the issues associated with past age interpretations (Bailey and Thomas, 2014). This takes account of key factors including sediment preservation, sampling bias, and dating errors that can complicate the interpretation of past accumulation records<sup>7</sup> (Fig. 1). The *Accumulation Intensity* method quantifies dune sediment accumulation from age datasets, rather than simply using the ages themselves as proxies of change. This allows periods of dune accumulation, over  $10^2$ - $10^5$  years, to be identified from compilations of dated sand sea stratigraphic sequences.

This approach is applied to dunefield age datasets from southern Africa, Asia (China, India, Israel and UAE) and Australia (examples given in the poster) providing model outputs that allow dunefield accumulation histories to be directly compared and analysed against local, regional and global records of Quaternary environmental and climatic dynamics (Thomas and Bailey, 2017). This generates the potential to test hypotheses of long term controls on dunefield development, as well as identifying significant gaps and limitations in some existing dune age archives.

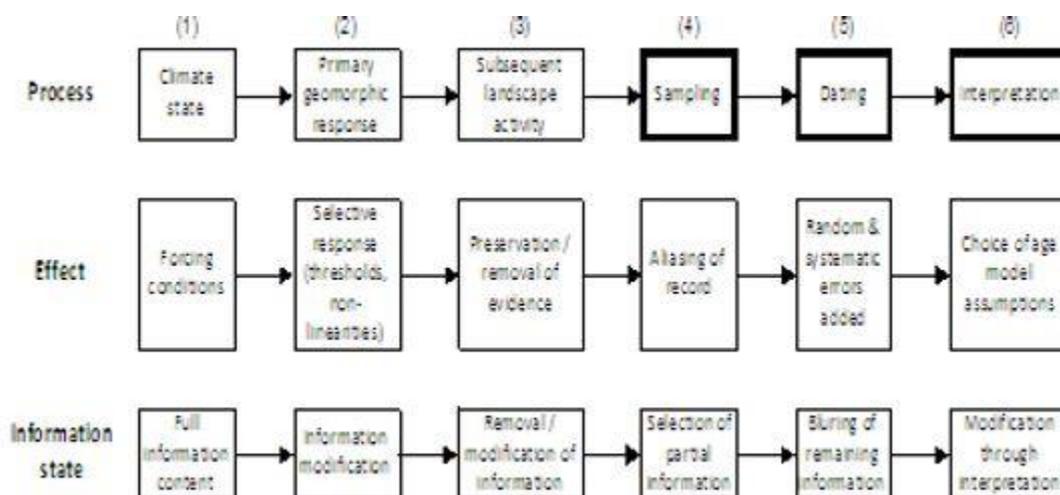


Figure 1. Factors that impact the integrity of ages derived from dune sediments (Bailey and Thomas, 2014)

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P-2607

## Subsurface expression of the Cooloola Sand Mass dune morphosequences, southeastern Queensland, Australia

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### Abstract

The Great Sandy Coast of southeast Queensland is home to the world's largest sand islands which are fed by the world's longest down drift sand transport system. The sand islands, coupled with onshore sand masses represent one of the world's oldest continually active coastal dune fields. The long period of activity has resulted in the development of very deep (over 30 m) podzol soil sequences. The Cooloola Sand Mass is one of the onshore sand masses and has recently been studied to understand the evolution of the system and how changes to the dune field relate to variations in climate and sea level as well as the influence of fire and other destabilization events.

Over the period of four years, approximately 250 km of high-resolution ground penetrating radar were collected in the Cooloola Sand Mass and adjacent Fraser Island. On Cooloola, a simultaneous surficial geomorphic mapping effort was undertaken to remap the dune sequences identified by Ward (2006). This effort included hand coring, OSL dating and GIS mapping. The surficial mapping (see Patton et al., submitted; Ellerton et al., submitted) resulted in the identification of eight (8) dune morphosequences. GPR data were acquired across morphosequence boundaries and within morphosequences to characterize the subsurface relationships between morphosequences. In most locations, the GPR was able to image the subsurface architecture to 28 m and resolve primary and secondary sedimentary structures as well as horizons related to present and formerly truncated or buried soil sequences.

This presentation highlights a composite GPR transect that crosses the entire Cooloola Sand Mass from the high coastal bluffs in the east, over the highest portions of the dunefield, to the low elevation hummocky plains in the west near Tin Can Bay. A GPR facies interpretation based on the radar characteristics was developed. Each of the facies were plotted spatially and compared to the surficial mapping effort of Ellerton et al. (submitted). While the GPR data were able to identify boundaries between the major surficial units, the boundaries were often not collocated with those from the surficial mapping efforts. We attribute this to the post depositional reworking that has occurred and mantles the original boundaries. The team is currently attempting to reconcile several aspects of the subsurface and how it spatially and temporally relates to the surface expression of the morphosequences, soil sequences, geophysical stratigraphy and chronology to better understand the Quaternary evolution of the Great Sandy Coast.

Patton, et al. Submitted. Remapping the coastal dunefields of South-east Queensland, Australia: a morphometric approach. *Journal of Maps*.

Ellerton, et al. Submitted. Sea level forcing and dune emplacement at the world's oldest coastal dune field: 800 kyr record of the Cooloola Sand Mass, Queensland, Australia. *Geomorphology*

**P-2608**

## **Sedimentological observations of aeolian sand deposits in permafrost regions**

Julian Murton

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### **Abstract**

The circumpolar permafrost zones contain widespread deposits of aeolian sand and silt. Some of these deposits are currently accumulating, especially in polar deserts, in regions of sandy tundra and adjacent to floodplains, but most of them predate the Holocene, and provide a rich archive of environmental change in periglacial regions beyond the limits of Pleistocene glaciation. Many of them accumulated during cold stages of the Pleistocene, when the permafrost and periglacial zones extended equatorwards and the climate of the mid and high latitudes was generally drier, windier and dustier than at present. This permafrost aeolian archive, however, remains to be systematically investigated because the aeolian deposits have commonly been mis-identified, for example as deltaic or fluvial in origin.

This poster summarises the aeolian sand facies and sedimentary structures that characterise present and past permafrost regions. The main types of facies relate to dune and sand-sheet deposits. Distinctive sedimentary structures commonly associated with them and formed under cold-climate conditions include vertical cracks (unfilled thermal contraction cracks), sand veins and wedges (infilled thermal contraction cracks) and various sand-ice composite veins and wedges. Additionally, palaeosols and peaty layers within frozen aeolian sands are commonly involuted, and in situ roots from grasses and sedges are often well preserved and suitable for radiocarbon dating. Examples of facies and sedimentary structures are presented from the Tuktoyaktuk Coastlands of western Arctic Canada and the Yana River basin of northern Siberia, and compared with those from the lowlands of northwest and central Europe. The aeolian sedimentary environment that characterised much of the unglaciated subcontinent of Beringia and its extension into central and western Eurasia during Marine Isotope Stage (MIS) 2 is discussed.

P-2609

## How reliable are granulometric proxies in paleoenvironmental studies?

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### Abstract

Grain size data of loess-paleosol samples provides valuable information on the physicochemical environment of sedimentary mechanisms from particle entrainment and transport to deposition. As post-depositional alterations can also be reconstructed from grain size parameters, particles sizing is also a valuable component of multi-proxy paleoclimatic investigations. However, diverse aspects of aeolian sedimentation (wind strength, distance to source area or possible further source regions and modes of sedimentation and transport), provenance of dust material as well as post-depositional weathering and various aspects of paleosol formation (weathering intensity, syn-sedimentary soil-forming material addition) can only be reconstructed from precise and appropriate grain size data via a correct sedimentary and paleoclimatic interpretation.

In this study, particle size data of terrestrial aeolian dust deposits (primarily paleosols in loess sequences) were determined by laser scattering instruments (Fritsch Analysette 22 Microtec Plus, Horiba Partica La-950 v2 and Malvern Mastersizer 3000 with a Hydro LV unit), while particle size and shape distributions were gathered from Malvern Morphologi G3-ID automated static image analysis measurements. This paper systematically reviews the grain size data obtained from different laser diffraction measurements, and it is aimed at to (1) provide new data on dependence of laser scattering particle sizing on optical setting of devices; (2) present new results of comprehensive comparison of widely used laser scattering devices; and (3) demonstrate the importance of accurate description of applied measurements methods and settings for a more practicable repeatability and comparability of grain size data of research groups using different devices.

Our results showed a clear dependence of laser diffraction results on several factors frequently ignored in previous studies. In the course of our investigations, grain size distributions of 10 selected samples were measured by using 3 state-of-the-art laser diffraction instruments. The applied 68 different optical settings of the instruments have resulted 2040 grain size data-series.

Major findings include that measurements using the Mie theory provide more accurate data on the grain size distribution of aeolian dust deposits. However, different applied complex refractive index settings have had significant effects on the measured volumetric amount of fine-grained fraction of the investigated sedimentary samples. Significant differences between the Mie and Fraunhofer approaches have also been found for the finest grain size fractions, while only slight discrepancies were observed for the medium to coarse silt fractions.

Support of the National Research, Development and Innovation Office NKFIH K120620 (for G. Varga) is gratefully acknowledged.

P-2610

## Dune-field pattern of blowouts and sinuous ridges for a vegetated aeolian system, western Pampas, South America

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### Abstract

The role of vegetation in active and non-active dune fields has been a matter of attention in aeolian research, particularly in regards of landscape reactivation, stabilization and related dune mobility. It is well known the existence of vegetated dunes with simultaneous sand accumulation, such as parabolic dunes coastal foredunes and sand sheets. Stabilized dune fields are common in semi-arid to semi-temperate environments and reflect a shift from the dominance of aeolian processes to ecologic succession resulting in landscape stabilization in response to climate change and/or anthropic impacts. In the western Pampas of southern South America ( $\sim 34^{\circ}\text{S}$ ), the San Luis paleo-dune field is a vegetated savannah-like environment (grassland with scattered woodlands) of a stabilized aeolian system with a rich sedimentary record spanning the last  $\sim 50$  ka. This aeolian system shows dunes of different morphology, size and orientation, with cross-cutting relationships, indicating dune formation at different times, consistent with the stratigraphic record. Uncertainty remains on driving forces for the evolution of this landscape, particularly with recent landscape stability ca. 1000 years ago and partial reactivation in the 1930s. Specifically, the relation between dune depositional/erosional events and the formation of compound aeolian bedforms often defies known process-based reasoning. Here we present observations on compound and complex blowout dunes (variable mean length of 835-1700 m and mean width of 500-1130 m) and unusual, multiple-sets of sinuous ridges (mean length, amplitude and slopes of  $\sim 620$  m,  $\sim 2.5$  m and  $\sim 3^{\circ}$ , respectively) (Fig.1). Our aim is to contribute to the understanding of aeolian geomorphology and to improve the use of dunes and aeolian sand sheets as a geoproxy of landscape response to past environmental and climate changes. The working hypotheses is that the compound and complex blowout dunes were inherent emergent elements of this aeolian landscape, and the two different orientations (NW and SW transport directions) correspond to distinct and successive aeolian phases during the late Pleistocene. Three possible explanations are evaluated and discussed for formation of sinuous ridges: 1) The forms were initially linear dunes, later modified to the present morphology, with stabilization by grassland succession, 2) Sinuous ridges were originally a primary dune form, such as barchanoid-ridges and stoss and lee slopes were extensively modified with stabilization and changes in wind direction and, 3) These sinuous ridges are some type of zibar form that originally grows in conflict with vegetation and reflect long wavelength and low amplitude aeolian transport.

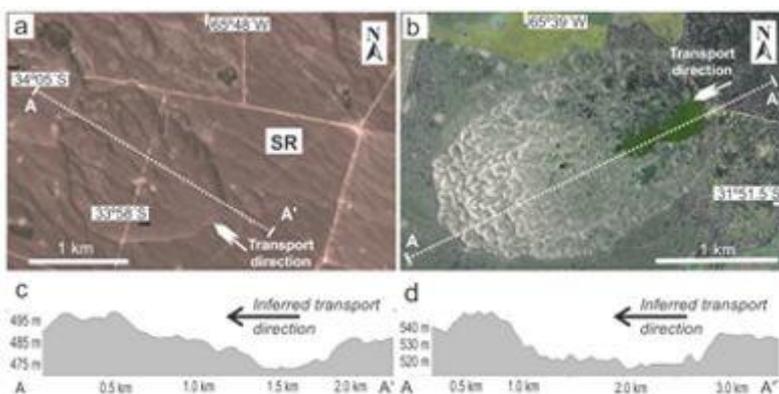




Figure 1: Google Earth<sup>a</sup> satellite images of a) blowout dune with NW transport direction, and b) blowout dune with SW transport direction and sinuous ridges (SR); c,d) topographic profiles in m asl (data from SRTM-C).

**P-2611**

## **Terrestrial mollusk records from Chinese loess sequences and changes in the East Asian monsoonal environment**

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### **Abstract**

The terrestrial mollusk fossils found in Chinese loess strata have been studied for over one hundred years. However, the greatest progress in these studies has been made only in the last two decades. In this work, we review the advancements, advantages and limitations of terrestrial mollusk studies in Chinese loess deposits. Improvements in research methods and approaches have allowed the extraction of more detailed paleoenvironmental and paleoclimatic information from mollusk assemblages. The broadened research scope and content have yielded many new findings and results. The mollusk record has thus become one of the most important proxies in the paleoenvironmental and paleoclimatic reconstruction of loess-paleosol sequences in China. The greatest progress in the studies of terrestrial mollusks in Chinese loess sequences can be summarized as follows: (1) modern mollusk assemblages can be classified into four ecotypes, based on their temperature and humidity requirements, including eurytopic, semi-aridiphilous and sub-humidiphilous, cold-aridiphilous, and thermohumidiphilous types; (2) Quaternary mollusk assemblages can be modified into the following three ecological types: glacial loess, interglacial paleosol, and interstadial weakly-developed paleosol assemblages; (3) mollusk records successfully reveal long-term climatic and environmental changes reflective of the history of East Asian monsoonal variations since the Late Cenozoic, and the succession of mollusk species also indicate short-term environmental changes such as millennial climate variability during Last Glacial Maximum and unstable climatic fluctuations during glacial and interglacial periods; and (4) more recently, new analytical approaches have offered increased research potential in areas such as paleotemperature reconstruction using the isotopic compositions of modern and fossil mollusk shells, combined with higher accuracy  $^{14}\text{C}$  dating of Quaternary loess deposits, which will greatly improve future loess paleoenvironmental research.

**P-2612**

## **Beyond the determination of paleowind direction - perspectives in the magnetic fabric study of loess**

Balazs Bradak

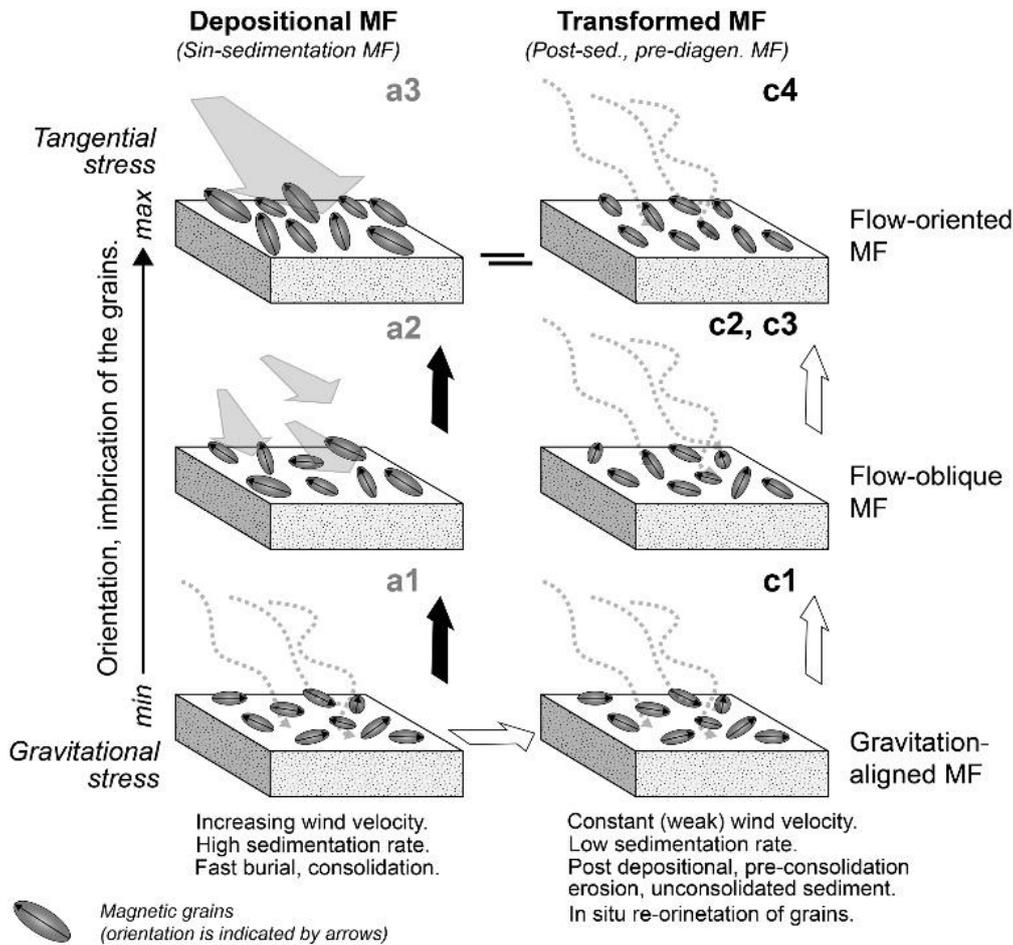
Department of Physical Geography, ELTE Eotvos Lorand University, Budapest, Hungary. Research Center for Inland Seas, Kobe University, Kobe, Japan

### **Abstract**

#### **Abstract**

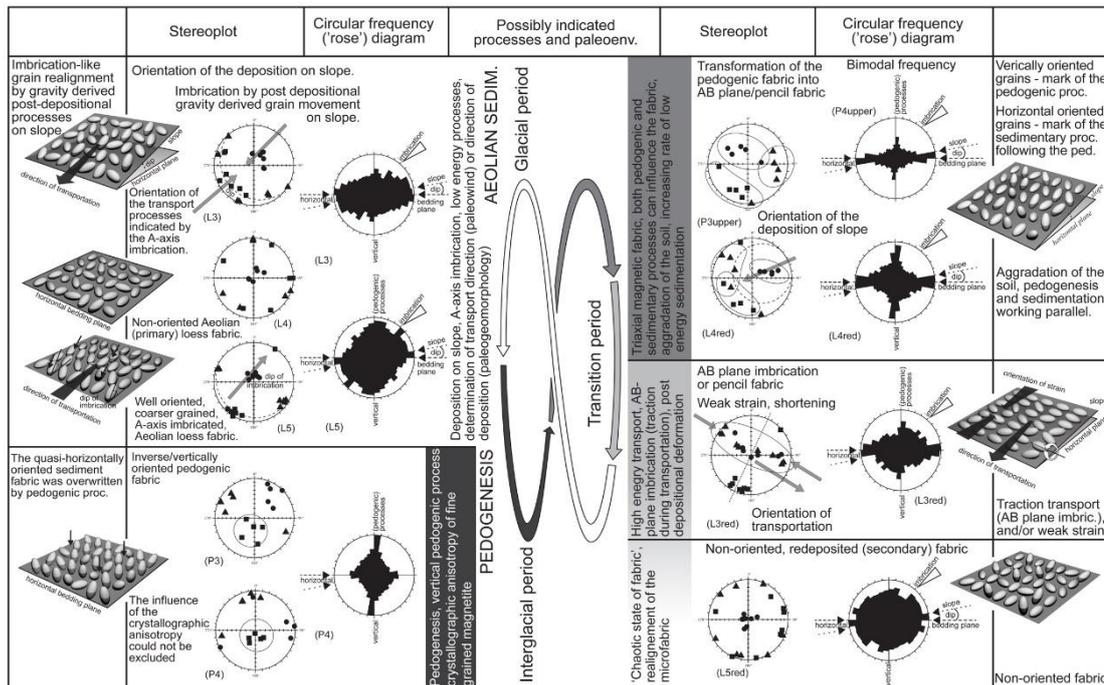
Although there are many doubts about the application of magnetic fabric methods in the determination of paleowind direction, magnetic fabric studies have been applied on loess since the early studies in the 1980<sup>th</sup>.

In the ideal (?) magnetic fabric (MF) of aeolian loess, formed of elongated magnetic minerals, the orientation of the long axis is determined by the maximum principal susceptibility, and that of the shortest axis by the minimum principal susceptibility. Theoretically, if the dust was deposited on a nearly horizontal surface the bedding-dominated fabric will be defined by minimum susceptibility, its orientation being the bedding pole. The maximum and intermediate susceptibility axes will lie in the bedding plane, with the orientation of maximum susceptibility indicating the paleo-wind direction (Fig. 1).



**Figure 1. The steps of the flow-oriented loess magnetic fabric development in various sedimentary environments (Paks, Hungary).** Depositional MF was developed by sin-sedimentary processes, and transformed MF was developed by the realignment of the magnetic grains from gravitational MF before diagenesis, but after the deposition of the grain (Bradák et al. 2018)

There are numerous phenomena which can bias the goal of magnetic anisotropy research into loess, among them, the determination of paleo-wind direction, such as redeposition, pedogenesis and seismic activity (Fig. 1 and 2).



**Figure 2. Various magnetic fabric and paleoenvironment in the Cérna Valley loess succession (Hungary).**

Characteristic differences between sedimentary, post sedimentary (redeposition by water lain processes) and pedogenic environment can be characterized by various magnetic fabric of the studied (Bradák-Hayashi et al. 2016)

The goal of the poster is to summarize the recent developments and future perspectives in the study of magnetic fabric of loess, especially, but not limited to some key section from Hungary (e.g. Paks profile) and its significance in the reconstruction of palaeoenvironment and processes.

## Acknowledgement

Research was funded by the Hungarian NRDIO K119366 project.

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**P-2613**

## **Intermittent aeolian deposits in Tasmania indicate rapid climate oscillations over the last glacial cycle.**

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### **Abstract**

Tasmania lies at c. 42°S and has experienced multiple glaciations. In contrast to areas like New Zealand where large braided rivers carried glacial erosion products including large amounts of silt from uplifted mountains to the sea, providing a source of loess, loess is not present in Tasmania, but local near-source aeolian deposits are widespread. These deposits have accumulated as lunettes downwind (west) of seasonally-dry lakes, as longitudinal dunes in the drier parts of the semi-arid Tasmanian glacial landscapes, as near-source dunes downwind of river floodplains and as lenses of white quartzose sands and silts in gravelly colluvial and alluvial deposits. These lenses of aeolian origin are interpreted to have accumulated in dry and windy conditions when little erosion and runoff was occurring on hillslopes. Intervening colluvium is interpreted as indicating milder and wetter conditions.

Aeolian deposits have been dated at over 40 locations in Tasmania, with the oldest being over 200 ka. The Maynes Junction section near Maydena in southern Tasmania is particularly valuable for climatic interpretation: TL and radiocarbon ages for three pale quartz-rich silty and fine sandy layers (separated by weathered colluvium) indicate dry windy conditions at c. 20 ka, 30 ka and 90 ka. A strongly developed clayey palaeosol in colluvium c. 21 ka at Maynes Junction indicates an interval of mild conditions (and possibly forest vegetation) immediately before the LGM. This 23-21 ka interval is provisionally named the Tasmanian Mild Interval (TMI). Stratigraphy at Dunlin Dune in northern Tasmania also indicates a wet period producing soil podzolisation at about 21 ka, possibly a result of periodic high rainfall in eastern Tasmania during the Last Glacial as a result of moist easterly winds associated with southward-tracking depressions in the western Tasman Sea. This climatic inference is supported by pollen analysis of a peat core from the Freycinet Peninsula (Mackenzie 2010) showing an increase of wet-favouring taxa between 22 and 17 ca ka.

When all dated erosion products in Tasmania are plotted, aeolian deposits (and inferred cool windy conditions) occur mostly in four age ranges: 90-74 ka, 59-48 ka, 38-23 ka and 21-17 ka and colluvial and alluvial deposits and soil development (inferred to have occurred in moist and cool conditions) during the intervening periods: 74-59 ka, 48-38 ka, 23-21 ka, and from 17 ka to the present (the Holocene).

McKenzie, L. 2010. Late Quaternary environments of Freycinet Peninsula, eastern Tasmania. Thesis, University of Queensland.

P-2614

## The role of DRS measurements and cluster analysis in loess research

József Szeberényi<sup>1</sup>, József Kovács<sup>2</sup>, Balázs Bradák<sup>3,4</sup>, Gabriella Barta<sup>3</sup>, Diána Csonka<sup>3</sup>, Erzsébet Horváth<sup>3</sup>, Ágnes Novothny<sup>3</sup>, Tamás Végh<sup>3</sup>, György Varga<sup>1</sup>

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### Abstract

Diffuse reflectance spectroscopy (DRS) parameters, such as redness index and hematite/goethite ratios are popular in the study of loess-paleosol sequences. The suggested parameters, however, have their limitations: only some parts of the whole reflectance spectrum have been used, and the spectra of some important components may have been excluded from the analysis.

A mathematical statistical method, hierarchical cluster analysis, was applied to the loess-paleosol succession at Malá nad Hronom (Slovak Republic) to characterize the entire reflectance spectrum and classify sediment groups. The sedimentary units were classified into seven different cluster groups such as sediments, weak and well-developed paleosols. The distribution of the spectral features in the reflectance spectra was located using the key-wavelength, given by the Wilk's lambda analysis. The key-minerals, which play an important role in the classification, were determined by characteristic extrema in the second derivative of reflectance spectra of the seven reference minerals (hematite, goethite, muscovite, illite, montmorillonite, kaolinite and calcite).

Mineral groups influence together certain curve sections within the measured range, therefore curve sections modified by individual minerals were to differentiate only in a few cases. The mentioned mineral groups refer to characteristics of the formation environment and to climate change during the Pleistocene.

Acknowledgement: The research was supported by NKFI K119366, NKFI K120620 and OTKA 100180. The paper was also supported by Balázs Bradák's fellowship at the Research Center for Inland Seas, Kobe University, Japan was supported by the Japan Society for the Promotion of Science (JSPS). Agnes Novothny was funded by a post doctoral project of the Hungarian Scientific Research Fund (OTKA PD-100315).

P-2615

## Loess sedimentation in the Debed valley, northern Armenia; stratigraphic and archaeological significance

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<sup>2</sup>Department of Anthropology, University of Connecticut, Storrs, CT, USA. <sup>3</sup>Institute of Geological Sciences, National Academy of Sciences, Yerevan, Armenia. <sup>4</sup>Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany. <sup>5</sup>Institute of Archaeology and Ethnography, National Academy of Sciences, Yerevan, Armenia

### Abstract

Loess sequences provide valuable archives for understanding landscape development and environmental change during the Quaternary. The association of these deposits with Palaeolithic archaeological remains helps establish the relationships between the timing of early human occupation and environments through the production of high-resolution chronologies and intra/inter-regional correlation of these sequences. In Eurasia, many loess-filled basins have been extensively studied, however, until recently, there was a paucity of investigations in the Southern Caucasus (Wolf et al., 2016). This region, however, has great significance for improving our understanding of hominin dispersal and behaviours during the Palaeolithic, as attested by the presence of several archaeological sites of global importance (Dmanisi, Gabunia et al., 2000; Nor Geghi 1, Adler et al., 2014).

Here, we present preliminary results from ongoing investigations at several newly discovered loess sequences in the Debed valley, northern Armenia. These sequences are characterised by alternations of loessic layers and soil formation, reflecting at least four phases of aeolian sedimentation and landscape stability. Three of these sequences have yielded stratified archaeological remains, comprising principally Middle Palaeolithic stone tools. Through the integration of detailed sedimentological analysis, micromorphology and luminescence dating we have further investigated these sequences and have developed a chronostratigraphic record for landscape change and Middle Palaeolithic occupation in the region.

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P-2616

## Investigation of quaternary sand movement and soil forming periods with different dating methods in the Nyírség blown sand area, Hungary

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### Abstract

In the Carpathian Basin the Nyírség is the second largest sand dune area (ca. 4600 km<sup>2</sup>), formed on the alluvial deposits of the Tisza River and its tributaries. When the weather was dry, wind-blown sand was blown out and the wind started to develop the aeolian landforms. The first significant sand movements in the Nyírség was in the Upper pleniglacial and the Late glacial. The main landforms of the Nyírség were developed at this time. The aeolic transformation of the land was not completed in the Nyírség at the end of the Pleistocene. In the Holocene moved the sand on the small area, mainly anthropogenic impact.

Our aim is clarify the age of the wind-blown sand movement and soil forming periods, with different absolute (Radiocarbon dating methods, OSL), and relative (Archaeological finds, Pollen analysis) dating methods.

We have collected charcoal samples for the radiocarbon age determination from many sand quarry (Gyüre, Gégény, Kántorjánosi, Nyíradony, Nagyvarsány, Máriapócs, Lövőpetri and Petneháza, Kótaj, Vásárosnamény) which contain fossil soil layer. For the OSL measuring the samples were collected from Baktalórántháza, Gégény and Kántorjánosi, Gyüre, Lövőpetri, Kótaj and Vásárosnamény. We collected samples from 5 places for the pollen analysis (Nyírtanya, Máriapócs, Nyírbéltek-Nyírlúgos, Nyírábrány, Vámospércs), and visited an archeological excavation (Nyíregyháza–Oros).

The results of our investigation confirmed the previous thesis. In the Nyírség the first significant sand movements were in the cold and drier period of the Upper pleniglacial and Late glacial (Baktalórántháza, Nyírtanya, Vámospércs, Gyüre, Lövőpetri, Máriapócs, etc.). At the end of the Pleistocene the sand movements not completed in the Nyírség (Gégény, Kántorjánosi, Nyírábrány). Sand movement in the first half of the Holocene, in the Preboreal and in the Atlantic Phase took place due to climatic and anthropogenic effects also (Gégény, Kántorjánosi, Kótaj).

In the Subatlantic Phase, there were many little sand movement periods, mainly caused by anthropogenic impacts (Nyíradony, Nyíregyháza-Oros, Nyírlugos).

The C-14 datas show us, paleosols in the Nyírség developed Bölling-Allerød/Younger dryas, Preboreal, Boreal and Atlanti phases.

According to radiocarbon ages, the first paleosols development period might happened in the Bölling-Allerød Interstadial and continued in the Younger Dryas. Also during the Holocene (Preboreal, Boreal, Atlantic, Sub-Atlantic) soil layers were formed several times in the Nyírség. The soil layer formation were interrupted by several sand movement periods in this area.



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P-2617

## Postglacial landscape adjustment driven by relative sea level changes and climatic variation, Savary Island, British Columbia

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### Abstract

The coastline of British Columbia (BC) has experienced relative sea level (RSL) changes of more than 200 m since the end of the last (Fraser) glaciation. The timing of sea level change is relatively well-known in this region, although the landscape's response to sea level change and postglacial climatic variation is less understood. Savary Island, off the southern coast of BC contains a geomorphic and stratigraphic history of relative sea level change and climate-driven postglacial landscape adjustment. This island is comprised mainly of glacial advance outwash sand and gravel (Quadra Sand), and is distinctly different from the surrounding islands which are chiefly bedrock. Throughout the central part of Savary Island, large parabolic sand dunes lie under a mature Douglas-fir forest.

This study sought to constrain the timing of relative sea level retreat, dune initiation, and dune stabilization on Savary Island. To this end, two well-established optical dating protocols were applied: the single-aliquot regenerative dose (SAR) protocol, and the multiple-aliquot additive-dose with thermal transfer correction (ADTT) protocol. SAR and ADTT optical ages were then compared with independent <sup>14</sup>C ages from the same sediments, and with local well-defined relative sea level curves. Multiple variations of the SAR technique yielded optical ages that underestimate both the <sup>14</sup>C ages and the sea level curve, whereas optical ages calculated using the ADTT method were within the expected age range, although their analytical uncertainties are larger. As such, we suggest that the ADTT method is more reliable for Savary Island sediments, but the reason for this is presently unknown.

Using the ADTT optical ages, the postglacial landscape adjustment chronology of Savary Island is as follows: RSL was at ~8 m above present sea level (apsl) at  $11.5 \pm 1.1$  ka BP, resulting in littoral reworking and sorting of Quadra Sand. This age agrees with nearby RSL curves which indicate that RSL was at ~8 m apsl at ~12.5 ka BP. Aeolian deposition began to dominate no later than  $9.1 \pm 0.8$  ka BP and persisted as recently as  $5.9 \pm 0.5$  ka before vegetation stabilized the dunes and aeolian deposition largely ceased. During the phase of aeolian activity, weak palaeosols found within the sedimentary record suggest that short periods of landform stabilization occurred during the aeolian phase, lasting for perhaps hundreds of years. Charcoal <sup>14</sup>C ages indicate aeolian activity was occurring between 9.5-9.6 ka ago and 8.2-8.3 ka ago. Dune initiation occurred near the end of the established Holocene xerothermic interval, a warm and dry period, and the stabilization of dunes occurred as climate became cooler and wetter. These findings suggest that in warmer and dryer climatic periods, dune development may dominate in BC coastal environments.

P-2618

## MIS6-MIS3a Fluvio-Aeolian sequence from the Qaidam basin margin, northeastern Tibetan Plateau, China

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### Abstract

Middle to Late Pleistocene (MIS's 6-3a) dune-damming of a small second order basin, at an elevation of 3437 m a.s.l, at the northeastern margin of the Qaidam basin caused an accumulation of a >12.5m fluvio-aeolian sedimentary sequence. This continuous fluvial sequence (9 meters) dated to 119-38.6 ka (MIS5e-MIS3a), includes >30 sedimentary units composed of fine gravel units at the base and fining-upward sedimentary units from fine angular gravels and granules to fine sand and silt at the middle and upper parts of the section. These units, unconformably overlap flanks of a dune, characterized by steeply-dipping sand units, OSL dated to ~143-134 ka (MIS6) which is one of the oldest Quaternary records of dune-damming. The contacts between the fluvial units are erosional, but other - mainly at the middle and upper part of the section, are composed of reddish silty-clay layers that contains carbonates and other pedogenic indicators indicating unconformities, representing significant time gaps.

A massive sand-dominated unit dated to ~15 ka that marks an horizontal breaching of the dune dam truncating the top of the dune, while the natural reservoir at the back of the dune, was probably almost full with fluvial sediments. This breaching unit together with another overlying sedimentary units dating until ~ 12 ka, represent the last deglaciation period during which a second dune-damming phase blocked the basin. These Aeolian-fluvial phases completely changed the morphology and drainage of the Qaidam basin. The fluvial units are associated with specific deglaciation periods, whereas periods of enhanced wind power led to significant eastward dune mobilization up the slopes of the Qaidam basin margins resulting in damming of local streams.

The upper part of the section (3.5 m) is aeolian and composed of massive, fine sandy-silty loess separated by pedogenic unconformities into two paleosols underlying the current soil, with calcic B horizons. Dated to the Holocene (10.1 ka-present) this part of the section suggests a period of loess accumulation with changing rates of deposition and a wind power relax since the last deglaciation.

The sediments of the margins of the Qaidam basin accumulated by: (a) intense dune mobilization, (b) consequent long-term dune damming, (c) filling of backdune reservoirs which was followed by dune breaching by major floods. These processes, were probably controlled by the paleoclimate of glacial-interglacial cycles.

**P-2619**

## **Distribution, chronostratigraphy and palaeoenvironments of the Quaternary aeolian deposits of West Siberia**

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### **Abstract**

The Quaternary aeolian deposits widespread in West Siberia and consist of loess and dune sands.

West Siberian loess province is located in the central part of the mid-latitude Eurasian loess belt extending from Western Europe to China. Loess deposited during upper part Lower and Middle Pleistocene occupy weakly uplift territories - the CisAltai plain, low and middle Altai mountains, western slopes of Salair and the Kuznetsk depression. During the Late Pleistocene loess distribution expanded abruptly, it developed widely in West Siberian plain and Kazakhstan. The loess-soil sequence of West Siberia consists of rhythmically alternated thick layers of loess and complexes of fossil soils interbedded by 1-2 more thin loess horizons. The complete loess-soil sequence in Brunhes Chron of West Siberia includes ten soil complexes alternated with thick loess layers. The structure of pedocomplexes in the West Siberian loess-soil sequence well reflect the structure of global odd warm stages consisting of closely spaced warm events interfered with brief cold intervals. Pleistocene warm and wet periods corresponded to soil formation in conditions of weak air circulation. In mountain areas loess horizons and paleosoils keep the main structure and morphological features, specific for them in the West Siberian Plain. Paleosoils of low Altai mountain and south West Siberian plain in Middle Pleistocene were formed for a long time under warmer and wetter climate than the modern climate. Climate in low Altai mountain during Late and Middle Pleistocene area was warmer and wetter than in plain territories. The presence in microstructure of loess indications of cryogenic processes and traces of aeolian treatment on quartz grains evidence that loess layers were formed by wind in cold conditions. Cold times were associated with climate drying and more intense air transport of dust. The loess deposition in the Siberia was accompanied by the formation of large deflation surfaces and closed deflation basins in an environment of cold deserts. On the bottom of deflation basin of Lake Aksor with deep more 70 m was formed carbonate crust, desert pavement with ventifacts and splitting pebbles and boulders with desert varnish. In the Last Glaciation (MIS 2) aeolian sands covered vast territory of West Siberian plain and formed aeolian relief. West Siberian plain was an area of vast cold desert. The aeolian topography consists of ridges (large dunes - grives) oriented along the wind direction and deflation basins. The distribution and orientation of the aeolian landforms produced during glacials suggest their origin by transport with mostly western winds. The western transport was largely responsible for erosion and deposition in middle latitudes during glacial stages. Its increase during glaciations coincided with intense winter monsoons in eastern Asia.

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P-2620

## Luminescence chronology of environmental evolution of the Ob Plateau loess-paleosol sequence in the Late Quaternary

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### Abstract

Loess deposits cover wide areas in the south of the West Siberia. It forms uneven-age covers overlying each other and divided by palaeosols. More than 150 sections are known there. They have a clear stratigraphy, based on palaeopedology and on C14 dating (Zykina, Zykina, 2012).

To establish the age of the horizons and to get detailed geochronology for this region OSL dating was used as it is the most widely accepted technique for accurate dating of such deposits. Despite the fact, that south of West Siberia is a huge loess area, there is a lack of detailed dating and dating older than the limit of C14 method. Only in the Middle Siberia there is reference well-dated section Kurtak (Zander et al., 2003).

Lozhok section was chosen since it is the key profile of the Late Pleistocene loess formation of Ob Loess Plateau in Novosibirsk region. Ob Plateau is presented by a series of steep ridges presented by up to 100 m thickness Pleistocene loess-palaeosol sequence. The whole sequence of the Lozhok section consists of Middle-Late Pleistocene loess-palaeosol deposits (Zykina, Zykina, 2012), in this study we consider its Late Pleistocene part. A 8,5 m depth section exposes the Bagan and Eltsovka loesses (both correlate to MIS-2), the Iskitim pedocomplex (MIS-3), Tulino loess (MIS-4) and Berdsk pedocomplex (MIS 5 c, e). This profile contains an unique record of dust dynamics over the last 130000 years. Using modern multidisciplinary methods allowed to reveal several palaeoenvironmental changes expressed by increasing of humidity (Sizikova, Zykina, 2015). Accurate OSL dating helped to identify the nature of these changes and its connection with some global events. It allowed to estimate more precisely average rates of loess accumulations during three cold periods and to define the time of hiatuses in the section. Obtained OSL dating were put in the base of geochronological scheme of studied region. It allows to make detailed age correlations with adjacent areas and to compare periods of loess and palaeosol formation in different regions.

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P-2621

## High-resolution luminescence chronology for the coastal loess-paleosol sequences in the Jiaodong Peninsula and Miaodao Archipelago, Eastern China

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### Abstract

During Pleistocene glaciation, the shallow continental shelf exposed and formed the desert-loess depositional system due to lowered sea level and strengthened East Asian Winter Monsoon (EAWM) in the marginal sea of Eastern China. As a consequence, the loess-paleosol sequence in the Jiaodong Peninsula and Miaodao Archipelago is a special type of eolian sediment related to the dynamic changes of coastal zone environment, and an important archive for paleoclimate and sea level changes of the coastal zone of Eastern China. However, this loess-paleosol sequence is still poorly understood due to the lack of independent age control, which have limited the interpretation of their palaeoclimatic and palaeoenvironmental information. In this study, high-resolution luminescence dating which based on quartz SAR OSL and K-feldspar post-IR IRSL (pIRIR<sub>290</sub>) measurements, are employed to the two loess-palaeosol sequences located in the Jiaodong Peninsula and Miaodao Archipelago, respectively. Our results show that quartz SAR OSL and K-feldspar pIRIR<sub>290</sub> ages are more or less indistinguishable from one another up to ~70 ka. Beyond this age, the K-feldspar pIRIR ages increased systematically with deposition depth, agreeing well with the expected ages as far as ~130 ka. On the basis of our fully independently-dated timescale, we are therefore able to propose, for the first time, a new age model for the loess deposits in Jiaodong Peninsula and Miaodao Archipelago accumulated since the last interglaciation (corresponding to S1 palaeosol in CLP). Using our newly obtained luminescence dating ages, it appears that there is a marked loess accumulation variability since the last interglaciation, which possibly indicates the desertification process of this coastal zone in the late Pleistocene.

P-2622

## New map of Quaternary deposits of the Russian territory and adjacent offshore areas, scale 1:2 500 000

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### Abstract

The new Quaternary Map of the Russian Federation, scale 1:2500000, has been produced in the department of Quaternary Geology and Geomorphology in VSEGEI in co-operation with VNIIOkeangeologia. The map covers all Russian territory with internal seas and adjacent offshore areas. This is a result of cartographic generalization of geologic data obtained since the publication of an analogue map of the same scale in 1973.

The legend is built on the traditional for Russia stratigraphic-genetic principle. The legend is in the matrix form: genetic types of deposits proceed along the horizontal axis whereas geological age of the units increases vertically downwards. The mappable unit called stratogen is a depositional body of a certain genetic type with defined geological age. The alphabet consists of 24 pure genetic types to whom specific colours are assigned (alluvial, glacial, marine etc.). The addition of geological age make the number of stratogens ca 340. The size of genetically individual polygons are limited by the scale of the map. Therefore in many cases the mapped unit is presented as a paragenetic association of several adjacent depositional bodies with disparate genetic labels. Such an association is designated by a colour of the dominant genetic type and by a series of genetic indices separated by commas. For the uniformity of their display on the map we used a special digital database of symbols developed in VSEGEI. This database is also employed for geomorphic and palaeogeographic elements: karst, landslides, mud volcanoes, ice limits, sea transgressions, permafrost boundaries, recent faults, thin cover sediments, etc.

For the global and regional correlations the map legend incorporates the following charts: International Chronostratigraphic Chart, the scale of marine isotope stages, International and Russian Magnetostratigraphic scales and General Stratigraphic Scale of Russia. The latter has the lower boundary at 2.6 ma and is divided into the Holocene, Upper, Middle, Lower Neopleistocene, Eopleistocene and the Gelasian stages. The Holocene and Neopleistocene are subdivided into climatostratigraphic steps roughly corresponding to MIS. They are the source of special indices used in the map for designating the age of the mapped units. E.g. all<sub>1</sub> means alluvium of the first thermochron step of the Upper Pleistocene corresponding to MIS 5.

The map layout is accompanied by small-scale inset maps of structure-formation zonation, permafrost and seasonal frozen rocks distribution, glaciations and marine transgressions and by the Glaciomorphological Map. The map database also includes Correlation Table of Regional Stratigraphic Units, Catalogues of Key Sections and Explanatory Note.

Our map reflects the present understanding of the structure of Quaternary deposits within the Russian Federation and adjacent offshore areas and brings a solid basis for interregional correlations. The map is designed in a digital form and can be downloaded via VSEGEI website (<http://vsegei.ru/ru/info/quaternary-2500/>).

P-2623

## Complementary data of the Quaternary Map of Spain: active faults, extent of glaciations and key sites

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### Abstract

The basic information of geological maps about formations sometimes needs other kind of complementary data that helps to inform about significant subjects such as the relationship between the formations and the internal and external geodynamic, to indicate geological materials that cannot be represented with their real dimension at the map scale, but singular, or to highlight remarkable sites of special science interest. As a general rule, the usefulness of complementary data will increase as the scale of the map decreases and as the geological complexity and diversity of the territory rises.

Adding information about active faults to the Quaternary Map of Spain is not a simple cosmetic exercise. In the SE of Spain there is a set of small intermountain sedimentary basins originated during the upper Miocene (Tortonian) with continuous deposition until the Pleistocene (basins of Granada, Guadix - Baza, etc.) and related to sets of faults of the Betic orogen (Iberian – Africa plate boundary). Therefore, the Quaternary-Active Fault Database of Iberia or QAFI is an important source of complementary data for the Quaternary Map of Spain and helps to understand these tectonic relations (Figure 1). The QAFI is an inventory of faults showing evidence of activity during the Quaternary. The QAFI is a project created, supported and periodically updated on the basis of the available scientific literature by the Instituto Geológico y Minero de España (IGME, Spain) and the Laboratório Nacional de Energia e Geologia (LNEG, Portugal).

To catalogue geosites of interest has been a usual task of the IGME in recent decades. The IGME, in collaboration with experts from other scientific institutions, has also developed the "Global Geosite Project" (IUGS - UNESCO) in Spain, result of which was the selection of 20 geological frameworks of international significance for conservation. One of these frameworks is named "Vertebrate deposits of the Spanish Pliocene and Pleistocene" and it includes 20 selected paleontological sites, most of them in karstic environments, spread out from the north (Cantabrian Mountains and Pyrenees) to the south (Betic range), with a great faunal diversity and an almost a continuous record of the Quaternary (Figure 2). These deposits are the minimum of key sites that should be indicated in the maps of the Quaternary of Spain and in the European one.

Quaternary glaciers of the Spanish mountains were small and scattered, except in Piryenees. and their moraines are impossible to represent at the map scale. Therefore, the limits of the last glacial maximum is an important dataset for the Quaternary Map of Spain and the only way to show these glaciated areas.



Figure 1. Screenshot of

the QAFI v.3 database (<http://info.igme.es/qafi/About.aspx>)



Figure 2. Paleontological

site Fonelas P1 in the Guadi-Baza Basin (2 Ma).

P-2624

## Geological mapping of end-moraine systems in Northern Italy: a long-lasting story of survey, stratigraphy and age-assessment

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### Abstract

The end-moraine systems in the Alpine piedmont plain in Northern Italy have been surveyed and interpreted since the XIX<sup>th</sup> Century, including the first attempts to interpret their origin. Moraine systems were used by Penck and Brückner (1909) for their model of Quaternary glaciations and subsequently many of them had been surveyed in three different editions of the Italian Geological Map.

The stratigraphy of these systems in the old map series (the I and II edition of the Italian Geological Map, dating back to the last century, at a scale 1:100,000) reflected the Penck and Brückner (1909) model of four different glaciations, and they were mapped using a mix of litho- and climatostratigraphic units. These criteria were also applied to correlate end-moraine systems of different glacial basins and their outwash plains, including the terraced surfaces. However, the lacking of data hampered their precise age-attributions, so until the last series of geological maps (CARG Project, at a scale 1:50,000, encompassing the last two decades) their age was based mostly on the soil development and few biostratigraphical data.

In the CARG Project, geological maps were surveyed at a more detailed scale (1:5,000 and 1:10,000), using an allostratigraphic approach and applying the Unconformity-Bounded Stratigraphic Units (UBSU). The detection of discontinuities became relevant in the unit subdivision of the end-moraine systems. Dedicated drillings, combined with systematic application of cross-dating methods (e.g.: <sup>14</sup>C, palynology, paleomagnetism, cosmogenic <sup>10</sup>Be), also allowed to better depict the stratigraphic architectures of the end-moraine systems, highlighting significant differences from one system to another. Some glacial apparatus show more than four units ascribable to different glaciations (e.g.: Ivrea and Rivoli-Avigliana morainic amphitheatres), whereas others show remnants of less glaciations (e.g.: Piave and Tagliamento morainic amphitheatres). Using this approach, the resulting correlation with the outwash deposits became stronger thanks to the detailed study of subsurface stratigraphy; this also let to develop a more constrained stratigraphy throughout the Po Plain. The relationship between the end-moraine systems and the deposits of the related mountain catchments were performed through allostratigraphic profiles, which also showed the ice-elevation of the younger glaciations in the lower reaches of the valleys. In some cases, the low distance with the coastline allowed to trace the discontinuities from the end-moraine systems to the continental/marine transitions and to separate units ascribed to different glaciations. The resulting architecture of the end-moraine systems at the scale of the whole Po Plain, from the Piedmont Plain to the Veneto-Friuli Plain, can now be used as a tool for better depicting the evolution of the glacial advances in the southern slope of the Alps.

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P-2625

## The Penultimate Glacial Maximum in the English West Midlands

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### Abstract

The penultimate glacial event is the most extensive glaciation across the Northern Hemisphere within the last 430 kyr. Globally, its maximum extent is constrained by the marine isotope stratigraphy to c.140 kyr, during Marine Isotope Stage (MIS) 6a/b. The terrestrial glacial event occurs some c.40 kyr earlier across the European continent and the British Isles. On the continent the glacial maximum is considered to be during the Drenthe Stadial (c.165 kyr / MIS 6c) of the Saalian Stage. In the British Isles, the Wolstonian Stage was traditionally considered to represent the penultimate glaciation between the Hoxnian (c. MIS 11) and Ipswichian (c. MIS 5e) interglacial stages. A sequence of sediments from Wolston, Warwickshire, England, forms the stratotype locality of the Wolstonian glaciation. However, the site is devoid of interglacial sediments, with the underlying Baginton Gravels being cross-correlated as the upper reaches of a pre-430 kyr ancient river; thus the Wolston sequence had been considered by some to be deposited during the preceding Anglian/Elsterian Stage glaciation (MIS 12). Recently, new work on the glacial sediments across the English West Midlands has led to a revision of the previous climatostratigraphical interpretation. Optically-stimulated luminescence (OSL) and post-infra-red stimulated luminescence (pIRSL) dating of glaciofluvial demonstrate that the glacial advance represented in the English Midlands occurred during the penultimate glaciation and not the older Anglian/Elsterian event. The relative timing of the penultimate glaciation across the English West Midlands is shown in Figure 1. This glaciation is considered to have reached its maximum extent north of Moreton-in-Marsh, Warwickshire. The deposition of the terminal moraine, previously attributed to the Anglian Stage, is here proposed as the regional event stratigraphic stratotype to represent the penultimate glacial maximum during the Wolstonian Stage as the Moreton Stadial (c.180 kyr / MIS 6c). Here the glacial ice terminated against a natural topographical barrier, the Jurassic Escarpment, which did not exist in its current form during earlier glaciations.

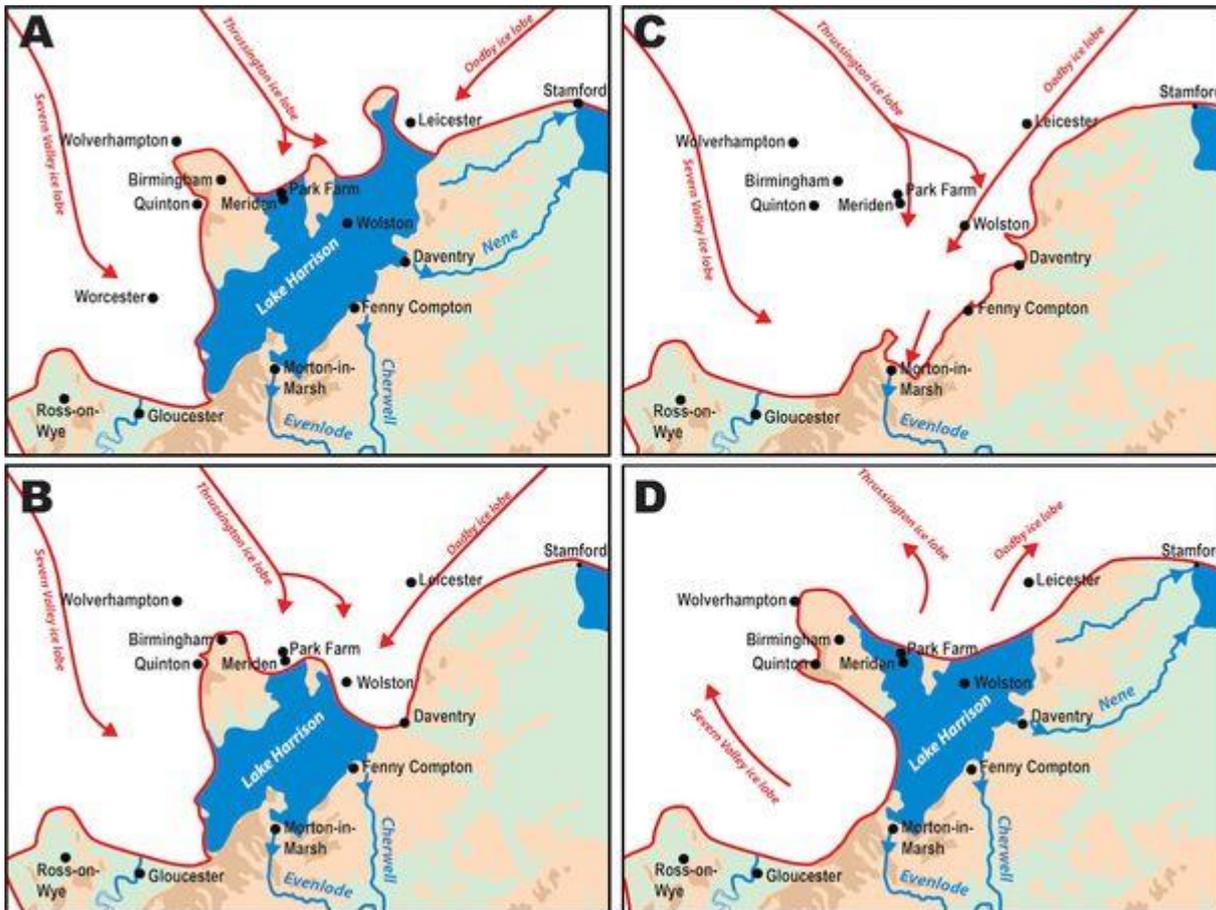


Figure 1. The history of Lake Harrison during the Wolstonian glaciation, reconstructed from Shotton (1953) and (Bishop, 1958). [A] The initial height of Lake Harrison. [B] The gap at Daventry was blocked by ice advancing from the north-east, maximum lake height of 132.5 m OD (Bishop, 1958). [C] The Penultimate Glacial Maximum at Moreton-in-Marsh. [D] Wolstonian de-glaciation and renewed expansion of Lake Harrison post-Wolstonian PGM.

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P-2626

## Investigations into the late Quaternary evolution of the Bristol Channel

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### Abstract

A synthesis of publicly-available bathymetric and borehole evidence derived principally from the EMODnet and the proposed Atlantic Array projects, combined with a wealth of other existing disparate data sources, has revealed important insights into the Pleistocene history of the Bristol Channel. The history of the latter shares much in common with the English Channel. Although it was initiated during the Neogene, sediment boreholes throughout the Bristol Channel confirm the area was glaciated in the Pleistocene. Till underlies marine deposits and in some areas is visible morphologically as submerged morainic landforms. In the central and eastern Bristol Channel the submerged valley course of the proto-Severn is visible in new high-resolution bathymetric surveys. This former river course, and associated tributaries, cross-cut glacial sediments in the Bristol Channel, it is therefore presumably of Devensian (Weichselian) late-glacial age. At least two phases of glaciation are recorded in the Bristol Channel, one related to the southern limits of a Late Devensian Welsh Ice Cap which reached into Swansea Bay and another older glaciation that is associated with ice that filled the entire outer and central Bristol Channel. The age of the older glaciation is still open, although it predates the Late Devensian. On Lundy, an island in the outer Bristol Channel, exposure ages from glaciated bedrock suggest an earlier Devensian age for ice retreat. However, it remains possible that the 'older' Bristol Channel glaciation is represented by more than one event, with tills found in borehole records being of different ages in the outer and central areas. It is evident therefore, that Pleistocene glacial and fluvial activity, combined with subsequent post-glacial marine transgression (from c. 10.0 14C ka BP), directly account for current morphometries of the Bristol Channel and Severn Estuary, and the current geography of the SW British Isles.

This work is a contribution to the IQUAME project.

**P-2627**

## **Quaternary Map of Poland in scale 1:2 500 000, an input to the new edition of IQUAME 2500 GIS**

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### **Abstract**

Completion of a Polish part of the International Quaternary Map of Europe to a scale of 1:2 500 000 (IQUAME2500) will be finished by the end of 2019. Not only the Polish Geological Institute – National Research Institute is to contribute to the international IQUAME2500 project but it also develops its own digital Quaternary Map of Poland as well as an appropriate web viewing service (WMS). Primary input data comes from the digital databases of the Geological Map of Poland 1: 200 k and the Detailed Geological Map of Poland 1: 50 k. The authors' compilation of the latter covers the whole territory of Poland. Several other maps in different scales produced during a bilateral cooperation with the adjacent countries (Belarus, Germany, Lithuania, Slovakia and Ukraine), together with data from a new edition of the Geological Map of Poland 1:500 k will be also used for the purpose of the project. The Polish data is collated and processed in the ArcGIS environment. The methodology of the performed works follows the 'IQuAME 2500 – Semantic Transformation' guidelines provided by the German Geological Survey and mostly consists in mapping national dictionaries to the IQUAME vocabularies, then reclassifying and generalising the original geological units. In accordance to the IQUAME requirements the map will be semantically compliant with the European INSPIRE directive (Directive 2007/2/EC of the European Parliament and the EU Council from March 14, 2007 ) as well as with the international Geoscience Markup Language (GeoSciML). The structure of the work database remains flat but at the same time it reflects main elements of the GeoSciML data model. This solution follows the one applied in the OneGeology initiative (the international initiative of geological surveys and organizations) and will facilitate easier transition to the proper GeoSciML files in the next steps. The data portrayal of the Quaternary Map of Poland will be based on symbols from the first IQUAME edition as well as the 'Guidelines for the review' prepared by the German Geological Survey.

The study is a contribution to the scientific project financed by the National Fund for Environmental Protection and Water Management as one of the tasks performed by the Polish Geological Survey (project 22.1514.1801.00.1).

**P-2801**

## **The future of Quaternary geomorphology lies underground**

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### **Abstract**

Little detail is known about the Quaternary evolution of upland Britain and Ireland. Multiple glaciations shaped these landscapes, but the maximum extent of the last British-Irish Ice Sheet is still being clarified, and its vertical variation is poorly constrained in space and time. Almost nothing is known about earlier upland glaciations, partly because surface evidence was subsequently reworked. Help is at hand, by studying British and Irish karst caves in glaciated northern and western areas. Caves have a special 'museum' property to preserve evidence of palaeo-environments, from their location, morphology, hydrology, dimensions and contents. Caves tend to develop at successively lower levels during each deglaciation, as recharge and discharge points follow glacially-eroded valleys downwards. Diameters of phreatic passages and entrenchment depths of vadose canyons can also act as timescale proxies, perhaps confirmed by sediment dating. By using integrated studies of museum attributes and working backwards in time and upwards in elevation, cave history, the varying glacial, deglacial and interglacial climatic regimes, and the uplift and erosion of the local topography can be deduced, and extrapolated beyond the immediate karst area.

Early successes with this approach include: the evolution of a Welsh landscape (Simms and Farrant, 2011); the development of a Yorkshire dale (Waltham *et al.*, 2010) and at Victoria Cave after MIS13 (Lundberg *et al.*, 2010); postglacial entrenchment (Checkley and Faulkner, 2014); deglacial speleogenesis (Murphy *et al.*, 2015); and the ten-stage development of Toerfjellhola in Norway since MIS12 (Faulkner, 2013). Further resolution of more surface and underground glacial karst histories will require a holistic multi-disciplinary collaboration among geological, geomorphological, sedimentological, glaciological, hydrological, meteorological, seismological and speleological communities.

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**P-2802**

## **An investigation of taphonomic processes in speleothem palynology.**

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### **Abstract**

Fossil pollen, preserved in depositional environments such as lakes and bogs, is widely used to reconstruct vegetation change through time. The corresponding reconstruction of past vegetation communities using fossil pollen trapped in speleothems has recently been demonstrated to be a viable alternative where other more conventional depositional records are not available. In addition, speleothems offer a potential advantage in the ability to tie pollen spectra to robust radiometric dates across a wide range of ages, i.e. far beyond the radiocarbon limit, and independent of calibration issues associated with radiocarbon dating. However, despite speleothem palynology's emerging importance, little is known about the taphonomic processes that influence the dispersal of pollen onto and preservation of pollen within speleothems as compared to lakes and bogs.

In this project we explore taphonomic processes involved in speleothem palynology, by comparing multiple fossil pollen sequences from caves, coupled with nearby, coeval lacustrine pollen records. This approach allows us to cross-calibrate the two proxies, providing a more faithful climate and vegetation reconstruction while also highlighting any taphonomic biases between the two archives. Our research site lies within the Southwest Australian Floristic Region (SWAFR) — a region with extraordinary plant species richness (the Region contains 7380 native vascular plants, 49% of which are endemic, many under threat) characterised by tectonic stability and deeply-weathered, infertile soils. This project hopes to provide new insights into questions such as, how does such a biodiverse ecosystem evolve given such infertile substrates? Ultimately, our new records will contribute to our greater understanding of the evolution of the SWAFR.

P-2803

## Croatian caves as a study sites for the reconstruction of the Quaternary environments

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### Abstract

Although relatively small in surface, Croatia appears to be well-suited for the Quaternary environmental reconstructions from several different aspects. It is located on the crossroad of continental European and maritime Mediterranean influences that varied and shifted along with Quaternary climate changes. Besides, almost half of its continental territory and vast submarine part is karstic, with probably more than 10000 known caves. Speleothem-based studies have already been conducted in dozens of them revealing the Quaternary history with more or less success. At first glance, continental (subaerial) caves generally offer good potential due to accessibility throughout the year, distributions over a relatively restricted area but within different altitudes and climate settings, abundance of speleothems etc., but during the cave monitoring and laboratory work numerous obstacles emerged – from the meteorological, biological and technical hindrances at the research sites to the  $^{14}\text{C}$  and U-Th dating issues. Nevertheless, certain progress of the palaeoenvironmental reconstruction from MIS 10 to the Recent is evident. Valuable environmental records have also been archived in thousands of years old ice accumulated in several ice-caves located in the highest Croatian regions.

Submerged (submarine) caves, with present number of more than 230 discovered along the eastern Adriatic coast, offer an additional Quaternary story related to the sea-level changes. Their occurrence below the sea surface is already irrefutable evidence of former lower sea-level stands, as well as speleothems within them. Moreover, in ideal situation, speleothems with their interrupted growth and alteration of spelean and marine deposits can record sea-level fluctuations. In spite of numerous setbacks caused by boring marine organisms, high initial Th and/or low U concentration, Late Pleistocene–Holocene relative sea-level changes along the Croatian coast has been partially reconstructed. Sea-level oscillation which can be attributed to MIS 5a interstadial that was marked with two distinct sea-level highstands (double peak) was one of the best resolved.

Additional challenges for palaeoenvironmental reconstruction are common in submerged features that are in-between aforementioned continental and submarine end members, namely in i) submerged springs (*vruljas*) which once were caves, then coastal springs and presently have hydrological function as submerged fresh- or brackish water spring and ii) coastal anchialine caves which also host fresh, brackish and sea water habitats. Both types are relatively common (>150) along the Croatian coast and are subject of multidisciplinary researches.

**P-2804**

## **Seasonal variations of uranium concentration and isotope in river and cave waters in NE Sichuan, central China and implications**

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### **Abstract**

Uranium (U) concentration and isotope ( $^{234}\text{U}/^{238}\text{U}$ ) ratio in speleothems have been increasingly used as proxies for past climate and environment, especially for soil moisture conditions. This is particularly important for reconstructions of the Asian summer monsoon (ASM) using speleothem oxygen isotope ( $\delta^{18}\text{O}$ ) because interpretation of speleothem  $\delta^{18}\text{O}$  caused intensive controversy in recent years. Although U concentration and  $^{234}\text{U}/^{238}\text{U}$  ratio in speleothems from NE Sichuan, central China were previously proved to be appropriate proxies for past climate and environment and to support interpretation of speleothem  $\delta^{18}\text{O}$  as indicators of the ASM intensity and rainfall amount, it's not clear whether the arguments were verified by modern cave monitoring.

Here we present the monthly U concentrations and  $^{234}\text{U}/^{238}\text{U}$  ratios of river and karst cave waters which were collected from NE Sichuan, central China during the period from 2011.7 to 2012.7. Both the U concentrations and  $^{234}\text{U}/^{238}\text{U}$  ratios show higher values during relatively dry period, i.e. the winter and spring seasons; lower ones in summer and autumn seasons. The U concentration and  $^{234}\text{U}/^{238}\text{U}$  ratio display significant positive correlations in both river water and cave water, which is different from the negative correlation usually observed between U concentration and  $^{234}\text{U}/^{238}\text{U}$  ratio in groundwater.

The seasonal variation of U concentration is in line with long-term variation of U concentration observed in speleothems in NE Sichuan, where higher speleothem U concentrations correspond to colder and dryer climates and vice versa. The variations of U concentration, on both seasonal and millennial time scales, can be interpreted with changes in redox conditions of soil layer and limestone capping karst cave. Higher rainfall leads to more moisture reserved in soil layer and limestone, which results in more reductive conditions and less mobility of U in soil layer and limestone, and eventually less U in river and karst cave waters. An opposite picture can be observed with lower rainfall. Therefore, the U concentration is an appropriate indicator of rainfall amount and summer monsoon intensity.

The seasonal variation of  $^{234}\text{U}/^{238}\text{U}$  ratio is opposite to long-term variation of  $^{234}\text{U}/^{238}\text{U}$  ratio in speleothems which displays lower values in cold-dry climates and higher ones in warm-humid climates. The mechanisms controlling  $^{234}\text{U}/^{238}\text{U}$  ratio warrant further investigation. (This work is financially supported by the National Natural Science Foundation of China (Grant Nos. 41271212 & 41473093))

P-2805

## Caves as a tools for dating and reconstruction of relief changes in mountain areas – a case study from Tatra Mts.

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### Abstract

The problem of the Tatra Mts. valleys development is discussed for a long time. Up to date, glacier activity during the Last Glacial Maximum is supposed to be a major factor determining present mountain valleys hydrology and morphology. However, the initial numerical dating results of speleothems shown that main karst springs were originated earlier than 200 ka and valleys incision in Quaternary was estimated as 80 - 100 m.

Presented research focuses on determining the age of the recent system of karst water circulation in several of main Tatra Mts. valleys: Bystra, Kościeliska and Chochołowska, which is directly related to age of valley incision and morphology. The key to getting the information is study of karst systems located at the bottom of the valleys or on a small elevation. The caves constitute a kind of "traps" and give a much greater chance of the preservation of sediments (and deposition processes records) in a period of intense denudation at the surface. Close relation between karst forms, karst drainage system, cave morphology and valleys as erosional base makes it possible to study changes in mountain morphology, valleys levels, determination of the periods of intensive valley incision etc. basing on karst studies. The evolution of cave system can be reconstructed basing on sedimentological characteristic of cave deposits and their numerical dating. As a major proxy of karst system age, the age of the oldest speleothems in active cave level can be used. Speleothems are autochthonic deposits which are formed under vadose conditions, so the age of oldest speleothems gives estimation of minimum age of cave passage drying caused by erosional base lowering (e.g. creation of a new, low-lying karst spring).

Intensive studies of caves morphology in conjunction with U-series speleothems dating suggest minimum two stages of karst drainage development. In the older stage, now abandoned caves drained massifs. The oldest dated speleothems from the high-located caves (e.g. Czarna Cave, Miętusia Cave) are at least 1.2 Ma old. The direction of paleoflow changed as a result of the water captures depending on valley incision, e.g. drainage of Gąsienicowa Valley by Kasprowa Niżnia Cave in Bystra Valley. The age of active system of big karst springs may be estimated as more than 300 ka (middle Pleistocene). In the later stages, the evolution of cave systems was controlled by glaciation-deglaciation cycles.

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P-2806

## Relation of river terraces and active cave levels: a case study from the Demänová Caves (Western Carpathians, Slovakia)

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### Abstract

Presented research focuses on determining the age of the recent allogenic karst drainage in mountain area and its relation to age of the valley incision. The key to achieving this goal is a study of fluvial modelled karst drainage conduits located at the altitude close to valley's bottom. The caves are a kind of "traps" and give a much greater chance of the preservation of sediments (and deposition processes records) during intense landform denudation on the surface. Close relation between karst surface landforms, karst drainage, cave morphology and river terraces controlled by erosion base makes it possible to study changes in valley morphology, including the determination of the stages of intensive or interrupted valley incision.

The evolution of cave system can be reconstructed from sedimentological characteristic of cave deposits and their dating. Speleothems represent the best kind of cave deposits for such a type of studies and, in general, their crystallization time can be linked with the vadose conditions. Thus their age gives a minimum age of dewatering of cave passage caused by the lowering of the erosion base.

The Demänová Caves (DC) are one of well-known multilevel cave systems in the allogenic mountain karst. The DC were described as a typical example of the relationship between the development of cave levels and the river terraces of the Váh River and Demänovka Stream in the Liptov Basin. Since the middle of the last century Droppa and following researches have distinguished 9 to 10 cave levels and have related them to stages of the interruption of valley incision and the formation of river terraces. The ages of cave levels were determined according to altitude correlation with terraces of the Demänovka Stream and Váh River from the Late Pliocene (uppermost levels) to Weichselian-Holocene (lowest-lying, active river passages).

Results of research conducted during last decades on the DC, including speleothem dating by U-series method, show that age of some passages with active Demänovka Stream (approximately at the same altitude or several meters below the surface river bed in the middle part of Demänová Valley) is significantly older than one estimated within the former scheme. Relation between cave morphology, speleothems and clastic deposits suggests long and complicated history of passage evolution with still active underground stream, i.e. several stages of partial or even complete infilling by clastic sediments and their subsequent erosion. The oldest period of cave fill, recorded as relicts of flowstone layers perching 2–2.5 m above active bed of the underground stream, is dated on Early Pleistocene (> 800 ka).

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P-2807

## Late Pleistocene paleoclimate proxies from cave sediments and speleothems in the Estremadura region of central Portugal

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### Abstract

The Estremadura region of west-central Portugal is home to a large limestone province (Maciço Calcário Estremenho) with many well-known caves and rockshelters, some of which contain important archaeological sites. Proxy records from the Portuguese margin indicate large environmental responses to Late Pleistocene climate fluctuations in this region, including rapid changes in sea surface temperature, upwelling intensity, and forest cover during transitions between mild/humid interstadials and cold/arid stadials. The most severe conditions occurred during Heinrich stadials (HS) associated with iceberg rafting events in the North Atlantic. This poster presents proxy records of weathering intensity and hydroclimate from two caves in the Estremadura region that illustrate the terrestrial impacts of these climate fluctuations.

The cave site of Lapa do Picareiro records Late Pleistocene variations in physical and chemical weathering intensity on the Serra de Aire massif. Excavations at the site have unearthed more than 10 m of sedimentary fill dating to approximately 9-75 ka, containing abundant faunal remains and Middle/Upper Paleolithic archaeological evidence. Bone preservation in the cave is good and disturbance by bioturbation, dissolution, or erosional processes is limited. Rhythmic bedding in the central part of the cave, where clast-supported coarse éboulis beds alternate with muddy finer éboulis, suggests a connection with Late Pleistocene climate. Several sedimentological parameters, especially clast size and magnetic susceptibility (MS), show good agreement with paleoclimate records. Cold/arid HS are represented by prominent coarse clast beds with little fine sediment and MS minima, while milder interstadials correspond with muddy beds and abrupt MS peaks. The MS record faithfully records Greenland stadials/interstadials and HS back to at least 45 ka, offering a valuable tool for interpreting archaeological evidence at the site.

Speleothem studies from nearby caves provide detailed records of effective soil moisture over the last two glacial stages. One stalagmite from Buraca Gloriosa overlaps with the period of record at Lapa do Picareiro (9-75 ka), and provides high-resolution proxies based on growth curves and isotope ratios ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ , and  $\delta^{234}\text{U}$ ). The speleothem record is consistent with the MS signal from Picareiro, and more broadly with paleoclimate proxies from offshore sediment cores and Greenland ice cores. The cold/arid HS intervals are marked either by hiatuses in stalagmite growth or by strong isotopic excursions interpreted to represent strongly reduced soil moisture conditions. Several notable paleoclimate features are evident in both the cave sediment and speleothem records, including the prolonged harsh climates during HS3, HS4, and HS6, the bipartite structure of HS2, a period of progressively more humid climate between H2 and H1, and the apparent severity of the Younger Dryas in this region.

P-2808

## Making sense of the faunal accumulation and palaeoecology at the Toll Cave through the multidisciplinary study of cave bear remains

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### Abstract

The inherent characteristics of caves make them good places that records, among others, the Quaternary fauna and flora, permitting the landscapes reconstruction. The Toll Cave is part of a karstic system located 50 km to the north of Barcelona (Spain) and one of the most interesting levels belongs to Upper Pleistocene (dated ca. 49,000 years BP). In this cave, different remains of carnivores and ungulates have been recovered but more than 90% corresponds to the cave bear (*Ursus spelaeus*). To shed some light on these accumulations, multidisciplinary work that combines a taphonomical and dental microwear analysis is being carried out. The objective is to elucidate the origin of the faunal accumulations and the role that the interaction between carnivores and humans could have played in the cave.

From a taphonomic perspective, we analyse mortality patterns, osteometry and taphonomic alterations in order to answer the questions of how the accumulation has been generated, what is the cause of the death of individuals, what is the demographic composition of the group by age and sex. Our data show that cave bear at Toll Cave died during hibernation. Additionally, a combined study of stable isotope analysis of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in bulk-collagen and dental microwear analysis was applied to provide information about the cave bear diet at different timeframes (average diet of life vs. last days/weeks before death). As the cave bear individuals found at Toll Cave died during hibernation process, tooth microwear will inform about its diet at an important seasonal event in the life of these animals. Taking this into account, microwear analysis make it possible to establish the feeding habits of the cave bear before hibernation, which is more varied than during the rest of the year. We also considered what are the post-sedimentary processes that have modified the original sample after the death of the animals.

P-2809

## Contextualising the caves of South West England

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### Abstract

The caves of South West England have long been recognised as important archives of Quaternary landscape change including fauna and archaeology. Investigation of their archaeology and palaeontology was placed on a scientific footing by William Pengelly (1812–1894). He developed sophisticated recording techniques at his excavations in Brixham Cavern and Kent's Cavern, notably the adoption of a three dimensional grid system of recording. Continued excavations and research to the present day have permitted the application of modern dating techniques and reanalyses of fauna and archaeology from deposits spanning the last 500,000 years<sup>1,2</sup>.

Alongside such endeavours, there have been significant advances in understanding the nature and timing of Quaternary landscape evolution in the south west peninsula over similar timescales. Of particular relevance are studies that elucidate the timing and extent of sea level change and now submerged landscapes, as well as improved chronological control on fluvial sequences. In open contexts, river terrace deposits are the most common locations for the discovery of Palaeolithic artefacts, although in the south west beyond the River Axe, these tend to be low density/single findspots<sup>3,4,5</sup>.

This poster seeks to combine these different records of landscape change to present a summary overview for the region. Cave sequences will be situated in their landscape context and the record related to the current understanding of hominin occupation. A brief case study of ongoing research at Ash Hole Cave will be used to demonstrate the continued potential of cave sites in contributing to our understanding of the dynamic relationship between human- and landscape change; especially when a broad geoarchaeological approach is taken and new, multidisciplinary methods applied.

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P-2810

## Constraining the chronology of dwarf elephant evolution using Quaternary deposits in coastal caves of the Mediterranean

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### Abstract

The mid-19th century to early-20th century saw the discovery of remarkable paleontological specimens in caves across the globe, among them dwarf elephants in Quaternary sediments of coastal caves of the Mediterranean (e.g. Spratt 1867; Falconer, 1868; Bate, 1907). However, this was followed by rather enthusiastic excavation that left very little material for future geochronologists to work with. We have visited previously-studied sites on Crete, Sicily and Malta and collected the minimum amount of material required to obtain MC-ICPMS U-Th and OSL age for a robust chronology of island evolution and body-size change in mammalian species. Without estimates of the timing of fossil emplacement in the sedimentary record, spatial patterns and rates of parallel evolution in island settings remain poorly constrained.

The coastal caves studied present challenging settings because of the complexity of their stratigraphy and inadequate excavation notes and archival documentation. As an example, we focus on a single site, Grotta Spinagallo, near Siracusa, Sicily, which, over the course of numerous excavations over 50 years ago, provided many specimens of the smallest elephant in the fossil record - *Palaeoloxodon falconeri* (shoulder height of female 0.9 m).

Attempts to obtain age estimates for bones and teeth from the middle Pleistocene by U-Th, ESR and amino-acid racemisation techniques are generally considered unreliable. We analysed >45 sub-samples (<100 mg) from calcite speleothem deposits that remain on the cave wall and, most importantly, exhibit unambiguous stratigraphical relationships with in-situ fossil remains. We illustrate improved methods for documenting the complex stratigraphy using an interactive cave survey with zoomable photo-mosaics and annotations. Diagnostic bones, now in museum collections, were found in 'reddish earth' that appears to have been emplaced between 350 and 230 ka based on U-Th ages of intercalated calcite flowstones. Three cave earth samples on this same material provide OSL ages > 200 ka. We have also sub-sampled calcite veneers (< 1mm depth) on a mandible and tibia of *Palaeoloxodon falconeri* from Spinagallo Cave that are stored in the Palaeontological Museum of the Catania University and obtain ages for the bone of  $>220 \pm 4$  ka and  $>300 \pm 20$  ka ( $2\sigma$ ).

P-2811

## Do the cavities in non-karst rocks provide paleontological materials? A case study of granite grottos in the Middle Urals

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### Abstract

In mountainous areas, cave deposits represent an important source of the Late Pleistocene and Holocene paleontological materials. This is particularly relevant to the Ural Mountains stretching submeridionally for more than 2000 km from the Arctic Ocean in the north to the steppes of Kazakhstan in the south. There are now more than 200 caves described in the region. Karst topography is highly developed on the western slopes of the Urals, with many caves, basins, and underground streams. The eastern slopes, on the other hand, have fewer karst formations; instead, rocky outliers and frequent outcrops of granite rise above the flattened surfaces. The areas of prevailing basalt and granite rocks have long been considered as unpromising sources of the paleontological materials. Outcrops of orogenic granitoids are confined to the East Uralian tectonic zone and form a chain of isolated massifs, which is known as the main granitic axis of the Ural Mountains. The granite island cliffs called Kamennye Palatki (stone chambers in Russian) create attractive features in the landscape and are extremely popular among local people. Ancient people used them as temporary shelters and sanctuaries. Archaeological studies at granite outcrops have a long history, but the only locality with the documented paleontological record is Shaytanoozersky Kamennyi Ostrov-1 (57°20' N, 60°13' E). The grotto is formed of granite blocks separated from the rock. About 10000 bone remains of mammals, birds, and fish are examined, and palynological analyses of the sediments is carried out. Types of fossilization and preservation characteristics of bone remains are described for both small and large mammals. Two complexes of mammalian bone remains, dated to the Late Pleistocene and Holocene, are identified. The Late Pleistocene complex is radiocarbon-dated (22460±340, IPAE-219, SOAN-3824; 23179± 1420, IPAE-220, SOAN-3825). Among small mammals, collared lemmings (*Dicrostonyx sp.*), narrow-skulled vole (*Microtus gregalis*), and steppe lemmings (*Lagurus lagurus*) prevail. *Rangifer tarandus* and *Equus uralensis* predominate among large mammals, along with numerous remains of *Marmota bobac*. In the Holocene complex, two stages are distinguished: an earlier one, including the Late-Pleistocene relic remains representing *Marmota bobac*, and the later one lacking marmot bones and containing only «forest» animals. The bird and fish remains, which could be identified to genus and to species, all show the Holocene type of fossilization; all these taxa inhabit the region until the present day. The results of the paleontological investigation of natural cavities in granite rocks, recently recognized as a specific type of paleo-archives in the Ural Mountains, provide some methodological clues for paleoecological studies in granite terrains.

P-2812

## Extinct sloth remains and their environmental context from an underwater cave in western Cuba

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### Abstract

Underwater caves have been found to contain rich assemblages of paleontological and archaeological materials. Recent investigations at a subaquatic cave in western Cuba, Cueva Margarita 1 (CM1), have revealed the bone remains of at least three rare, extinct sloths. The bones include an individual of the species *Megalocnus rodens* and two individuals of the species *Neocnus gliriformis*. These animals were endemic to Cuba and are believed to have gone extinct 4000 years ago. A network of sediment cores were collected from CM1 to study the water level history of the cave, the environmental context of the paleontological materials, and landscape change outside the cave during the late Holocene. The sediment cores consist largely of sand-sized calcite particles along with organic matter, in addition to large quantities of seeds from *Cecropia* and *Ficus* trees. The main mechanism by which the seeds entered the cave is through droppings from frugivorous bats and birds, and their presence is likely indicative of times of low water level. In addition, fossil pollen analyzed in the cores closely tracks the seed data, although other tropical species, such as the tree *Didymopanax morototoni*, and the vine *Combretum fruticosum*, are also present in the pollen data. The seeds and pollen provide insight into the nature of the forest surrounding the cave, and the possible habitat in which the sloths lived. In the Neotropics today, two and three-toed sloths live predominantly in *Cecropia* and *Ficus* trees, which suggests the forest nearby CM1 was suitable sloth habitat. There is little information on the specific environments in which now-extinct mammals in the Caribbean lived, and this study illustrates how sediments from underwater caves can be used to provide context for paleontological research.

**P-2813**

## **Luminescence dating challenges in Lower Danubian loess, Romania**

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### **Abstract**

Loess-paleosol sequences are in the focus of environmental research in Central-Eastern Europe because they offer presumably quasi-continuous terrestrial records of environmental change. As such, reliable dating approaches are crucial. Age models can be based on different methods, e.g. correlative approaches or absolute dating approaches. For the Urluia loess-paleosol sequence, which provides a high-resolution record covering the Last Glacial Cycle in the Lower Danube-Black Sea area, correlative and luminescence age models do not agree with each other (Böskén et al., 2018). While the performance of the luminescence data speaks for a reliable chronology, the radiometric ages for the samples presumably covering the MIS 4-5 interval do not fit the stratigraphic evidence. As ages in the lower half of the section do not increase with depth, field saturation has been suggested. To further explore the reasons behind this chronostratigraphic discrepancy, luminescence samples of the Vlasca loess-paleosol sequence, also in the Lower Danube area, were investigated. This contribution presents a detailed luminescence dating approach using OSL and pIRIR protocols for quartz, polymineral and feldspar samples. Furthermore, the question whether the observed discrepancy between the dating results and the stratigraphy represents a regional pattern or perhaps intrinsic luminescence properties are responsible will be discussed.

Böskén, J., Zeeden, C., Hambach, U., Veres, D., Klasen, N., Brill, D., Burow, C., Obreht, I. and Lehmkuhl, F. (2018). Consistency challenges between correlative and luminescence age models for the last ~150 ka in the Lower Danube Basin loess-paleosol sequences. Geophysical Research Abstracts 20, EGU2018-7986, EGU General Assembly 2018.

P-2814

## Quantifying post-glacial landscape erosion on Calvert Island, western Canada using catchment-averaged and bedrock $^{10}\text{Be}$ erosion rates

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### Abstract

Terrestrial cosmogenic  $^{10}\text{Be}$  nuclide concentrations can be used to ascertain rates of landscape erosion, but may be influenced by changes in remnant glacial landforms and sediment supply. We present erosion rate estimates from 21 sites centred on Calvert Island on the western coast of British Columbia, Canada (51.6°N, 128.1°W). This region is notable for its general lack of glacial landforms and sediment cover, despite being covered by the western Cordilleran Ice Sheet until around 18–14 ka. Our data include thirteen erosion rates from exposed bedrock sites at altitudes of 9–679 metres above sea-level on Calvert Island and surrounding islands. We compare these with catchment-averaged erosion rates from seven watersheds on Calvert Island. Apparent catchment-averaged erosion rates are 118–263 mm ka<sup>-1</sup> (mean = 180 mm ka<sup>-1</sup>), an order of magnitude higher than bedrock rates of 27–52 mm ka<sup>-1</sup> (mean = 43 mm ka<sup>-1</sup>). When compared to  $^{10}\text{Be}$ -derived erosion rates from northwestern USA and the European Alps, our rates are all within expected ranges for small, recently glaciated catchments. However, the significant difference between bedrock and catchment rates is intriguing given that both groups have experienced a similar exposure history since ice sheet retreat. A variety of controls are considered, but one possibility is that post-glacial stripping of sediments has occurred across this landscape, mobilising glacial sediments containing low  $^{10}\text{Be}$  concentrations. If some of these sediments still reside in modern catchments, they could increase apparent erosion rates from catchments compared to bedrock sites. Consequently, erosion rate estimates in this region should consider mobilisation of glacial sediments within catchments following ice retreat.

P-2815

## Luminescence dating of loess in Armenia - Challenges towards a chronostratigraphy

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### Abstract

Luminescence dating methods are key tools for establishing numerical chronostratigraphies in loess research. With the introduction of the post-IR IRSL (pIRIR) protocol in the recent past, it is now possible to determine more reliable ages from K-feldspar, using luminescence signals, which are only slightly affected by signal loss due to anomalous fading. Despite this methodological advance, difficulties in successfully applying luminescence dating to sedimentary archives still remain. These challenges include e. g. age underestimations in age ranges > 100 ka, as well as regional/site dependent mineralogical characteristics leading to poor luminescence properties. Therefore, it is not possible to generally apply standard luminescence approaches to loess archives.

In this respect, the southern Caucasus region is challenging for luminescence dating because of its major volcanic influence. Within the framework of a DFG-funded project (German Research Foundation) several Pleistocene loess-palaeosol sequences comprising at least three glacial/interglacial cycles are investigated in Armenia. The main goal of this study is to establish a chronostratigraphical record for these sequences.

Comprehensive pIRIR test measurements were applied to test parameters like stimulation temperatures, in combination with elemental and mineralogical characterizations of the sample material. These first investigations have revealed a number of obstacles for successful age determination: 1) The coarse-grained K-feldspar fraction cannot be used for dating due to poor luminescence properties, possibly resulting from very heterogeneous mineral phases within the single mineral grains. 2) The polymineral fine grain fraction shows unusual behavior due to decreasing equivalent doses with increasing stimulation temperatures above 250°C. 3) Despite good agreement of pIRIR ages with ages derived from fine grain quartz up to 60 ka, the pIRIR ages have a strong tendency to underestimate the expected ages above this range. This finding is confirmed by an Ar/Ar age of a distinctive tephra found within all investigated profiles.

In addition, two luminescence dating approaches were tested as a possible alternative to pIRIR: The red Thermoluminescence (TL) signal of quartz as well as pulsed IRSL measurements of the polymineral fraction.

This poster presents and critically discusses pIRIR results along with an evaluation of the potential of the tested alternative measurement procedures.

P-2816

## Bayesian age modelling of the last deglaciation in the southern sector of the Scandinavian Ice Sheet

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### Abstract

Bayesian modelling offers a methodology for integrating various types of numerical dating and constructing consistent chronologies of geological sequences. Although it is routinely used for modelling radiocarbon chronology of lake sediments or archaeological deposits, it has been much less widely applied to model chronologies of palaeo-ice sheet retreat based on spatially distributed sites and multiple methods of numerical dating. Here, we present a Bayesian approach to model the timing of the last deglaciation of the southern sector of the Scandinavian Ice Sheet (SIS) in NW Poland and NE Germany. The study area covers ~850 km of the last SIS southern front, from the Vistula ice stream (B3) in the east, to the Odra ice stream (B2) in the west (Fig. 1).

We used published cosmogenic nuclide (CN), luminescence (OSL) and radiocarbon (<sup>14</sup>C) ages relevant to the last SIS retreat after the local Last Maximum Glaciation. Our modelling is based on: over 100 CN surface exposure ages of erratic boulders resting on glacial landforms; over 40 OSL ages of sand deposits; and more than 10 <sup>14</sup>C ages of organic and calcareous deposits intercalating tills left by the last SIS. The dating sites are distributed along the ice sheet limits that correspond to the glacial phases of the Late Weichselian as identified in continental Europe (Fig. 1). The relative age of the ice margin fluctuations during the last SIS retreat was inferred from the morphostratigraphy of glacial landforms and the lithostratigraphy of glacial tills. These produced the relative order models used as prior information, which constrained the independent probability distribution of each age in a sequence. Based on this distribution, we modelled ages for three palaeoglaciologically different regions: the Vistula ice stream, the inter-stream area and the Odra ice stream, and obtained three sequences of the ice margin retreat. This allows to construct a consistent chronologies of the last SIS retreat and to model the rate of ice front recession along three, palaeoglaciologically diversified, longitudinal transects.

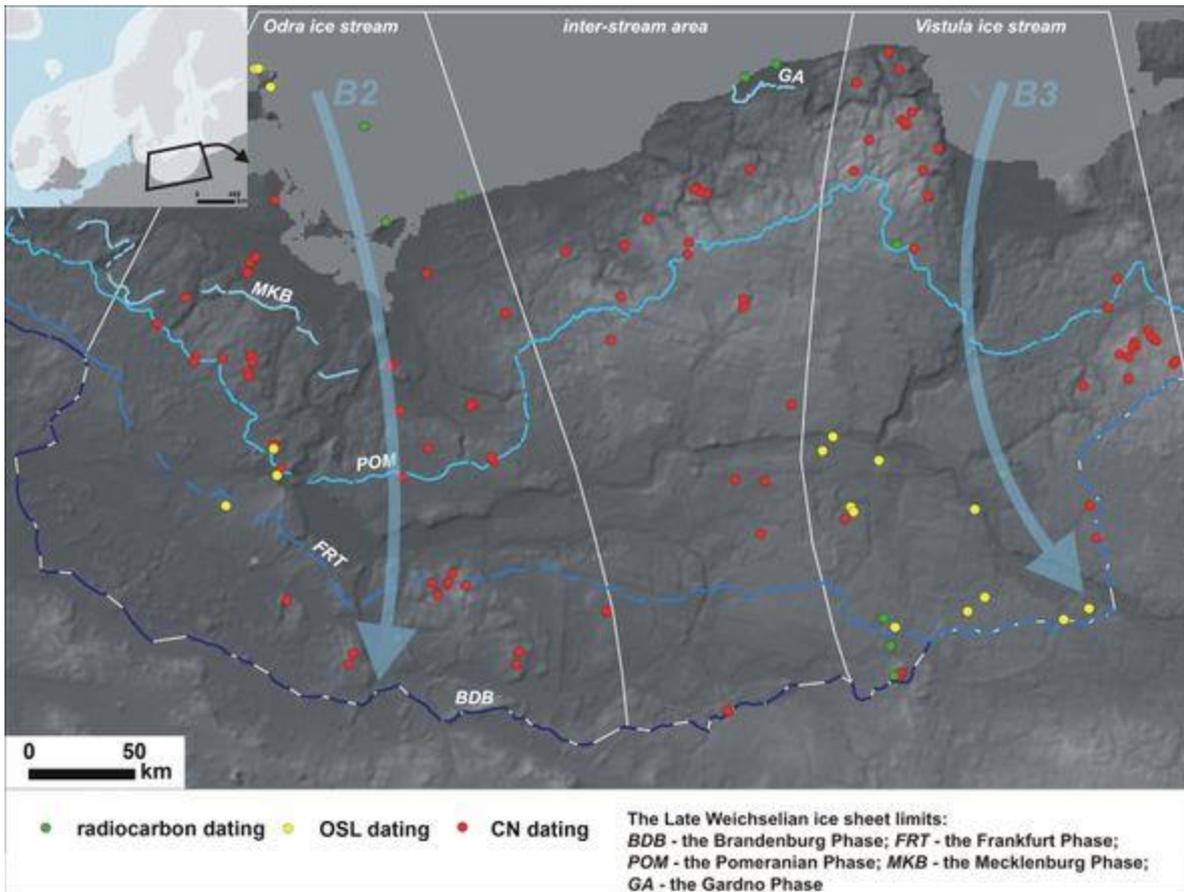


Fig. 1. Study area with the Late Weichselian ice sheet limits and sites of numerical dating used in the Bayesian modelling.

**P-2817**

## **Geomorphic feedbacks on the climate control of the moraine record**

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### **Abstract**

Length variations of glaciers are commonly attributed to climatic changes and their deposits are widely used to reconstruct past glacier extents and climates. In steep mountains, however, a layer of rocky debris on many glacier surfaces modulates their response to climate change and complicates paleoclimatic interpretations. Although the influence of debris cover on ice melt is well established, the coupling between temporally varying headwall erosion and glaciers has not been considered so far. Here, we study the response of glaciers using a numerical model that links feedbacks between mountain glaciers, climate change, hillslope erosion, and landscape evolution. We modulate hillslope erosion with temperature change by tracking frost cracking damage and permafrost in the headwall above the glacier. Our simulations use glaciological parameters meant to loosely represent glaciers in the Khumbu region of Nepal, though our conclusions are relevant for mountain glaciers in most ranges globally. We compare simulated glaciers with and without the effects of hillslope erosion. Because heavily debris-covered glaciers tend to have low surface velocities, changes in glacier length and moraine formation can lag debris supply changes by hundreds to thousands of years. We consider glacial-interglacial- and Holocene-scale temperature changes and periodicities. The relationship of the headwall elevations to the frost cracking and permafrost windows determines when in the climate cycle hillslope erosion feedbacks will take effect. The frequency-magnitude relationship for landslides onto the glacier surface is a strong control on any resulting moraine record. We develop a decision tree to determine which glaciers are likely to be influenced by debris and in which portion of a climate cycle. This decision tree considers modern climate, air temperature lapse rate, aspect, basin hypsometry, headwall area, and proximity to the modern permafrost and frost cracking windows.

P-2818

## Inter-comparison of karst denudation measurement methods (KADEME)

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### Abstract

Denudation of Earth surface as a result of rock weathering is the fundamental process governing the landscape development. Weathering of rocks occurs by physical, chemical and biological processes. Ultimately, these processes transform rocks, and provide the material that forms soils. In karst regions, dissolution of carbonate rocks is a dominant process controlling denudation.

In order to quantify weathering and/or denudation rate of a certain carbonate area several different methodological approaches can be used. The most used methods are: [1] the exposure of rock tablets to the natural environment, [2] the use of micro-erosion meters on rock surfaces, [3] measuring the concentration of cosmogenic radionuclides on exposed rocks, [4] measuring water hydrochemistry to infer amount of carbonates being dissolved and [5] quantifying the differential erosion on bare-rock surfaces of known age. Every method has pros and cons and there is no consensus on which method provides the more reliable denudation rates. Not all methods quantify denudation over the same timescale and in all cases there are assumptions between acquired data (measurements) and the calculated denudation rates (interpretations). Since weathering is a slow geological process, the accuracy of denudation rate measurements is difficult to validate. Significant differences among methods have been reported by researchers that have used more than one method at the same location. Additionally, comparison of denudation results at regional scale suggests that different methods may have results differences exceeding one order of magnitude.

Although local factors can be important contributors to explain the scatter of reported denudation rates, the different methods never have been calibrated together using the same boundary conditions at one single location. As a consequence, at the moment there is no evaluation on the accuracy of available methods, and it is uncertain if any particular method provides results significantly biased compared to other methods.

Therefore, the aim of this study is to apply all possible methods that could be studied in a single location to evaluate if their results replicate within their uncertainties. Two study sites in Mediterranean climate region with different soil properties have been selected: Krnić (Croatia) and Ramacastañas (Spain). The different context will allow evaluating if the conclusions are extrapolated to different scenarios. The inter-comparison of denudation measuring methods will allow for the first time the unequivocal identification of strengths and flaws of the different methods. This is an important study to know the accuracy of available methods for the study of denudation and its important implications for the study of the Quaternary.

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**P-2819**

## **Denudation of dolostone karst, the case of Eagle Cave system (Spain)**

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### **Abstract**

Evolution of cave systems is in great extent impacted by rock weathering. These processes include widening of cave passages and collapse of blocks from cave ceilings. Denudation of the surface above cave system additionally enhances thinning of bedrock above caves, favouring the cave ceiling collapses. These processes result in exposure of cave passages to the surface and formation of unroofed caves. In the area of Eagle Cave, in central Spain, collapse breccias and flowstone speleothems exposed at the surface indicate the existence of unroofed caves. The cave has a main hall where subsidence and ceiling collapses are ubiquitous, showing that collapses, whether they result in unroof caves or not are common.

To quantify the denudation rate on the region, we measured denudation rate using rock tablet method at this location. Depending on the lithology that composed the cave bedrock the denudation rate varied between  $1.75 \pm 0.66$  and  $2.48 \pm 1.07$   $\mu\text{m}/\text{yr}$ . However, dating of speleothems exposed to the surface (outside the cave) in unroof caves around Eagle Cave, provides dates as young as 213 ka BP. This is surprising, since apart from existence of speleothems exposed at the surface, cave morphology of the unroof caves is completely lost, supporting a very dynamic process of destruction of cave galleries. The denudation rate calculated by the rock tablet method seems to be too small even to eliminate the collapse blocks of a thin ceiling over the studied speleothem. As previously highlighted in previous studies, different methods to estimate denudation rate provides results that differ in orders of magnitude. Our result supports such conclusions.

Therefore, the main goal of this ongoing research is to apply different methodologies to measure denudation rates, compare their results and estimate which are the benefits and problems that the different methods are providing. As well to improve our understanding of karst denudation rates and the accuracy of the methods used for their evaluation.

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P-2820

## IRSL feldspars single-grain geochronology of glacial lakes and ice retreat in the northeastern Canadian shield

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### Abstract

In the cold-based glacial environments of numerous plateaus from the Canadian Arctic region, the timing of the retreat of the Laurentide ice sheet is of limited knowledge due to the scarcity of datable organic material, and abundance of inherited cosmogenic isotopes in available boulders. Here, we report the results of an extended infrared stimulated luminescence (IRSL) dating program conducted on feldspar single grains on plateaus of Boothia Peninsula, Southern Baffin Island Northwest Baffin Island and Barnes ice cap vicinity. We obtained 36 IRSL ages: 27 on glaciolacustrine deltaic sediments, 2 glaciomarine deltaic sediments, 2 glaciofluvial sediments, 3 littoral sediments, and 2 aeolian sediments. About 600 grains per samples were analyzed. Multiple samples were dated for each ice margin positions, allowing results cross-validation. An important relationship between the sedimentary setting and the importance of IRSL signal bleaching before deposition will be presented and discussed. Glaciolacustrine sediments are shown to be especially variable in the IRSL signal bleaching before deposition, reflected in important dispersion of the single grains ages. The method of age determination from the distribution of single-grain IRSL ages is also discussed. The results show a good correlation with a chronology based on <sup>14</sup>C dating (converted to calendar years) on post-glacial marine littoral shells and inland peat (from various authors, reported in Dyke, 2003).

P-2821

## New Constraints on Quaternary Slip Partitioning at the Eastern Termination of the Altyn Tagh Fault in NW China

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### Abstract

The Altyn Tagh Fault (ATF) is a >1600 km long sinistral fault that marks the northern boundary of the Tibetan Plateau. Previous studies suggest that late Quaternary slip rates along the eastern edge of the ATF diminish towards the east, where the deformation is assumed to be accommodated by a set of thrust faults that splits from the ATF. Here, we examine the possibility that sinistral deformation near the eastern termination of the ATF may also be accommodated along the NE striking ~200-km-long Sanwei Shan fault (SSF) located ~60 km north of the ATF. To characterize the sense and magnitude of slip accommodated along the SSF, we mapped beheaded channels and alluvial fans, and measured indicators for slip orientation on outcrops. At a site located ~30 km east of the city Dunhuang, we found a well-preserved sub-vertical fault surface dipping 83 degrees to the SE with horizontal striations that indicate lateral shear. Fault zone of only several meters and core width of dozens of centimeters suggests that this fault may be fairly juvenile. A beheaded channel mapped ~400 m west of the active channel as well as ~100 m of left-lateral shift of the active channel both indicate left-lateral sense of slip. At another site located ~40 km east of the first site we found a sequence of laterally translocated Quaternary alluvial fans that record up to 600 m of sinistral offset along the SSF since their deposition. Luminescence dating of alluvial sediments from these two sites indicates 1-2 mm/yr of slip across the Sanwei Shan fault during the last ~100 ka. Our results provide new constraints on possible Quaternary slip partitioning at the eastern edge of the Altyn Tagh fault system.

P-2822

## Multiple-generation sandwich-like layers with soft-sediment deformation structures in glaciolacustrine succession of Dyburiai site, NW Lithuania

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### Abstract

One of the most indicative factor, widely used during determining of seismic or non-seismic mechanisms triggering development of soft-sediment deformation structures (SSDS), is the sandwich-like vertical distribution of layers, i.e. repetitive sequence of deformed layers interbedded by non-deformed sediments. The sequence, comprised of up to nine deformed layers, varying in the following general characteristics: 1) thickness (5 to 50 centimetres); 2) grain size (sandy silt, silty sand, fine sand, silt); 3) bed continuity along with top and base boundary character; and 4) the overall general type of deformation, was observed within a glaciolacustrine succession in the Dyburiai (NW Lithuania), situated within the steeply, incised Miniija river valley. The succession is covered by Upper Weichselian glacial till of the Last Glaciation (MIS 2).

The layers with SSDS, traceable in horizontal extent along a 35-m wide section, exhibit an extraordinary variety of deformation styles. Layers that are coarser-grained (more sand) are dominated by complex load casts – often detached – and pseudonodules of differing scale that display either well-preserved primary intact or deformed sediment lamination.

In the former case, non-deformed internal laminations indicate that the liquefaction process was relatively rapid, and the degree of fluidization was modest due to gentle lithological diversity of sediments. The latter layer group includes finer-grained (more silt & clay) sediments with water and/or sediment-escape structures that inject into overlying sediments – in some cases cutting more than one layer. Their presence suggests an instantaneous increase of internal pressure.

Moreover, the brittle deformations observed in fine-grained deposits cut and intersect the then ductile SSDS, pliable structures that are interpreted to have been formed during preceding stage of plastic deformation. Thus, displacement and/or brecciation along faults had occurred subsequent to the SSDS genesis. This phenomenon clearly indicates an occurrence of a second distinct phase of the deformation process, most likely connected to the ice-sheet loading and glacial till deposition.

All the aforementioned deformed layers features – when taken in context with their described characteristics, along with separately examined interactions related to single SSDS dynamics –

suggest those SSDS are in-form artefacts of an abrupt external force that caused the rapid liquefaction of water-saturated sandy and silty sediment. Their genesis occurred shortly after the deposition of the primary prototypical SSDS form, but before the Last Glaciation ice-sheet advance.

The OSL dating results suggest that intra-morainic silty/sandy succession was deposited, and subsequently deformed, during the Marine Isotope Stage 5d or Early Weichselian.



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**P-2823**

## **Triggers for clastic dikes and indicative criteria of their earthquake origin: an overview**

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### **Abstract**

Clastic dikes are often the only evidence of past disasters in poorly exposed areas and therefore their findings are extremely important for earthquake study. However, the variety of their origins greatly complicates the use of clastic dikes to assess the seismic hazards within the manifold environments. In addition to earthquakes, main triggers include desiccation of soft deposits, tectonic extension because of creep, flood, glacial loading, diagenesis in permafrost area, freeze-and-thaw action, tsunami, an inflow of fluid-generating clays in the region of high temperatures and overpressures and subsequent fracturing, storm waves, mass movement, and meteorite impact. Several triggers result in both Neptunian and injection dikes.

A review of differences between the non-seismic and seismic structures shows that characteristic features allow excluding some non-seismic forms from paleoseismological analysis with a high degree of reliability. Thus, all clastic injections except those of seismic genesis are geo-referenced to geological objects (channel banks, glaciers, mud volcanoes, landslides, tsunamigenic beds, and meteorite craters). Besides, most of them are common in the subsurface layer to a depth of 1 m and have a cylindrical shape. In contrast, the configuration of seismically induced injection dikes implies a length many times greater than the width and a height varied from a few centimeters to the first ten of meters at a width less than 1 m. The dikes up to 15 cm wide occur the most frequently and those greater than 1 m are generally associated with lateral spreading through the horizontal extension forces (Obermeier, 1996).

Neptunian dikes are often up to the first meters wide and have a laminated structure marking a stage-by-stage infilling of fractures. However, not all of them contain these characteristics and, therefore, for example, a permafrost wedge could be mistaken for liquefaction features. On the other hand, Neptunian dikes also form in seismic shaking, but identification of their earthquake origin without other residual deformation is challenging. In this regard, for paleoseismic tasks, it is better to rely on injection dikes and to take into account Neptunian ones only when additional evidence (surface ruptures, fractures with a displacement of at least 0.1 m, structural analysis, relation to active faults etc.) is available. Revision of all known features and specific descriptions of clastic dikes has defined 12 general and 12 individual geological and structural criteria (for study in sectional view), which make it possible to establish confidently the earthquake origin of the injection dikes caused by fluidization from seismic liquefaction. The author is going to present and discuss them on the special session of the 20th INQUA Congress.

P-2824

## Soft-sediment deformation structures caused by three trigger mechanisms. Case study from Slinkis, Central Lithuania

Małgorzata Pisarska-Jamroży<sup>1</sup>, Szymon Belzyt<sup>1</sup>, Barbara Woronko<sup>2</sup>, Albertas Bitinas<sup>3</sup>

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### Abstract

Different geomorphic processes can result in similar looking deformation structures. When in search of a structure's provenance the identification of a trigger mechanism(s) is not inconsequential, especially when that trigger(s) has in evolution reworked an earlier generation of deformations. Two important points are here presented: 1) there are distinct lithological differences between deformation structures caused by differing trigger mechanisms, each having arisen in a singularly particular way so as to allow their classification; and 2) there are attendant temporal associations that further help to explain the developmental course of soft-sediment deformation structures (SSDS).

An extraordinary array of Pleistocene deformation-structure layers has been observed in a five-metre high riverbank section. The exposure is comprised of a succession of fine-grained meandering river terrace deposits in the Slinkis outcrop close to Serežius village, occurring along the Dubysa River valley at near its junction with the Nemunas River. We suggest three different site-specific trigger mechanisms are responsible for the development and/or reworking of a previously formed arrangement of SSDS.

The first group of deformation structures—ice-wedge casts and small-scale faults—are linked to periglacial processes that indicate a break in sedimentation had occurred. The second group of deformation structures—detached and undetached sandy load casts, silty flame structures, and injection structures like fluid-escape structures—are connected to occurring liquefaction (probably linked to earthquake activity). The fine-grained sediments were first deposited on the floodplain. Shortly after deposition the sediments were likely again deformed as an effect of glacio-isostatic adjustment—an artifact of shock-induced liquefaction of water-saturated sediments during consolidation. The Slinkis outcrop is positioned between two superregional W–E trending fault zones—Šilutė-Polock and Northern Prieglius-Birštonas—being a region classified as the most hazardous seismotectonic zone in Lithuania (Lazauskiene et al. 2012). The third group of deformation structures—brittle deformations like reverse faults—are linked to glaciotectonic processes. Faults cut and intersect load structures associated with the second group of deformation structures that had developed as an effect of a precedent liquefaction processes. The Last Glacial ice sheet had advanced resulting in the deposition of thick glacial diamictons at the uppermost part of succession, and is coeval with the development of reverse faults along the entire geologic column as described in the Slinkis outcrop.

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P-2825

## Specific soft-sediment deformation structures of the Eastern Baltic Region: correlation with tectonic framework and seismic activity

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### Abstract

For many years the entire eastern onshore of the Baltic Sea has been considered as a low seismic activity area. There were two main reasons that seismic activity has not been adequately assessed: 1) *a priori* prevailing opinion that the region, as a stable part on the Eastern European Craton, is of a very small seismic activity, and 2) lack of experience and skills to identify reliable traces of palaeo-earthquakes. But this opinion began to change essentially after a few earthquakes that occurred in 1976 in Estonian Osmussaare island (4.7M), in 2004 in the Kaliningrad Region of Russian Federation (5-5.2M).

The large amount of palaeoseismological data collected from different regions in recent years show that each earthquake trigger creates a signature on the geology and the geomorphology. Moreover, it was observed that in a number of earlier publications the all soft-sedimentary structures (SSDS) were attributed to the structures triggered by different geological processes – permafrost, slope processes, glaciotectonism, activity of living organisms, soil-forming processes, etc. But it was obvious that a part of the mentioned SSDS could have been caused by processes of sediment liquefaction what, possibly, was triggered by earthquakes caused by glacio-isostatic crustal rebound. There is a problem with the trigger mechanisms because liquefaction can be induced in many ways including, e.g. earth tremors, meteorite impact, tsunami and sediment loading. However, no criteria are known to distinguish liquefaction induced by different sources. Moreover, multi-triggering mechanisms can lead to multiple origins of SSDS, so it is difficult or even impossible to decide which one finally produced the SSDS in sediments. Finally, insight into the apparent discrepancy between the tectonic reaction of the earth crust during ice advance and ice retreat is necessary, and tracing faults in the bedrock which may have been reactivated during glaciation and deglaciation phases.

The seismo-tectonic framework of the Eastern Baltic Region has been outlined several times during the last decades, but not yet reliable tectonic framework was carried out – rather different tectonic and seismotectonic maps of the Eastern Baltic region exist. Moreover, correlation of SSDS with tectonic framework and seismic activity are still problematic due to number of reasons: it is impossible to associate single earthquake with some certain faults unambiguously due to significant errors of location of seismic events and faults location; the identification of the seismogenic faults is rather complicated due to the small scale of tectonic structures; not all the earthquakes in the Baltic Region are related to fault zones; etc.

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**P-2826**

## **Sand injectites in Quaternary sediments of the Central Yangsan Fault zone, SE Korea**

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### **Abstract**

Since the 2016 Gyeongju Earthquake (Mw 5.8), the Quaternary fault research around the Yangsan Fault Zone is now under investigation in order to extract paleoseismological information for assessing earthquake hazard assessment. However, because of thick Quaternary cover as well as relatively low slip rates, it is difficult to recognize Quaternary fault on the surface, particularly in the central part of the Yangsan Fault Zone. Therefore, earthquake-induced, soft-sediment deformation structures (seismites) can give us useful paleoseismological information. Thus, we conducted a trench survey on the fluvial terrace in order to find the seismites and extract paleoseismological information from them. We have excavated the ground and acquired 4.6 m deep, 14 m long, and 4 m wide trench section. Based on grain size and stacking patterns, the Quaternary sediments on the trench section were divided into 8 units, mostly deposited by episodic river floods together with minor debris flows. We found vertical to horizontal aligned sand patch or dikes at a depth of  $\sim 3$  m from the surface. They are composed of moderately to well sorted coarse to very coarse sand. This kind of structures can be formed by biological activities; however, we inferred them as sand injectite based on their occurrence and ichnological analysis. In addition, an undeformed overlying muds layer is inadequate to build up the pore pressure to underlying sediment layers. Therefore, we interpreted they are seismites. According to the  $C^{14}$  age dating from drilling core acquired from nearby areas, age of equivalent Quaternary sediments have been estimate at  $> 50,000$  yrs BP. Therefore, this contribution shows that, at least, one moderate to strong earthquake ( $> Mw 5.0$ ) occurred 50,000 yrs BP. around central part of the Yangsan Fault Zone.

P-2827

## **Pleistocene lacustrine sediments with multiple, sandwich-like deformed layers (Baltic Sea bluff at Baltmuiža, western Latvia)**

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### **Abstract**

The Baltmuiža site is located at the Baltic Sea bluff in the western Latvia. The study area was completely covered by Late Weichselian ice sheet, and at the end of glaciation experienced an additional, local ice-advance event of so called Apriki glacial tongue. As an effect of the advance, older sediments have underwent a heavy diapirization. Late Weichselian till is underlain by – up to 40-metres-thick – sands and silty sands. They were deposited at the margin of an extensive freshwater basin, in MIS 3 according to OSL dating results. Along the Baltic Sea bluff near Baltmuiža in these sediments occur layers with ‘trapped’, internal soft-sediment deformation structures (SSDS). Five layers with SSDS, sandwiched in generally not deformed sediments, were recognized there. The deformed layers are commonly rich in load casts and pseudonodules, injection structures and fluid-escape structures. Additionally, the thickest layer with SSDS is divided into sublayers characterized by different-scale (from millimetres up to 15 centimetres) load casts and pseudonodules, separated from each other by deformed clay laminae. Almost all layers with SSDS have an eroded top boundary.

Comparing the size of deformation, extent and structural features, the recognised layers with SSDS seem not to be directly connected with commonly observed in the vicinity of the Baltmuiža site glaciotectionic deformations (large-scale diapirs, folds, reverse faults). What is more, due to the basal ice sliding of Apriki glacial tongue, small-scale Late Weichselian subglacial deformations are limited to a thin layer of the topmost part of the studied sediments. The SSDS developed metadepositionally, in multiple stages, most probably just after the deposition of lacustrine sediments during MIS 3. Furthermore, Late Weichselian glaciotectionic processes caused that the layers with SSDS are deflected from the original horizontal position. The most probable trigger mechanisms responsible for the origin of the studied layers with SSDS include: (1) the glacioisostatic rebound affecting the crustal faults instability, (2) a local, seismic event (tremor) of moderate magnitude, caused e.g. by glaciotectionic processes. As a trigger that induced Late Weichselian modifications of previously developed SSDS cannot be excluded: (1) an ice loading at the final stage of glaciation, and (2) a local seismic event (tremor) of moderate magnitude caused e.g. by ice-blocks fall/collapse.

P-2828

## Soft-sediment deformation structures in diatomaceous mud related to a well-constrained historical earthquake record (Lago Riñihue and Lago Calafquén, Chile)

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### Abstract

Previous studies proposed a link between earthquake magnitude or seismic intensity and the type and size of different soft-sediment deformation structures (SSDS). However, most of these studies were done on prehistorical records in outcrops inhibiting a direct comparison between recorded earthquake parameters and SSDS. Our study investigates SSDS in sediment cores of Chilean lakes and evaluates their occurrence and style by comparison with a well-constrained earthquake record based on historically documented seismic intensity and corresponding turbidites in depositional basins.

Sediment in the Chilean lakes consists of laminated diatomaceous mud intercalated with fine-sand tephra layers. We observe four different types of SSDS using X-ray computed tomography scanning: i) disturbed laminations, ii) folds, iii) faults and iv) mixed layers. Detailed core correlation using tephra and lahar marker layers allows for pairing of SSDS with individual events through the well-dated earthquake-induced turbidite record. The five recorded earthquakes had Modified Mercalli Intensities (MMI) of VII½ and VI½ at site. We observe more SSDS (i.e. at more coring sites) for the earthquakes causing higher intensities at site, suggesting a positive relation between seismic intensity and SSDS occurrence. Furthermore, disturbed lamination occurs most at MMI VI½, whereas folding is almost only observed for MMI VII½ events. These findings are in agreement with those obtained by studies in other settings (e.g. Lake Lisan). Nevertheless, we also observe SSDS that cannot be linked to any of the five large earthquakes. These could be related to smaller seismic events or other triggering mechanisms. Also, our data suggests a linear relationship between SSDS occurrence and slope gradient (ranging from 0.2°-4.3°) implying that gravitational downslope stress influences a slope's propensity to SSDS development. However, we suggest that SSDS occurrence at slope angles of 0.2° is solely influenced by seismic shaking as these slopes are considered stable. High-resolution peripheral quantitative computed tomography (HR-pQCT) scans of different SSDS types ranging over layers of both tephra and diatomaceous mud will help further investigate the mechanisms behind SSDS formation by studying their basal shear surface in very-high resolution.

Our study site allows for the investigation on the influence of different lithologies (i.e. diatomaceous mud and tephra layers) on SSDS development. Moreover, the correlation of individual SSDS with well-studied historical seismic events in two different lakes provides a unique opportunity to directly study the relation between seismic shaking, slope gradient and SSDS formation.

P-2829

## High-resolution seismic study as a tool for sequence stratigraphic evidence of latest Pleistocene-Holocene sea-level changes of the Korea Strait

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### Abstract

An extensive grid of high-resolution seismic profiles combined with sediment data give a good evidence for the high-frequency sequence stratigraphic reconstruction in this area. The results reveal that the shelf sequence forms a high-frequency sequence, which consists of a set of lowstand, transgressive, and highstand systems tracts formed during the latest Pleistocene-Holocene. Three systems tracts include eight depositional systems, each with different seismic facies and geometry. During the LGM, the sea level was about 120-130 m lower than present and the paleo-shoreline was located on the shelf margin near the Korea Trough. Most of the shelf was completely exposed, resulting in subaerial erosion associated with paleo-channel incision by the Nakdong and Sepojin Rivers. The paleo-river extended to the shelf margin, directly supplying large amounts of terrigenous sediments to shelf margin and trough region. These sediments were trapped within the trough and adjacent area, which form the lowstand prograding wedge (SU1) and the mass flow deposit (SU2), regarded as the lowstand systems tract.

The transgressive systems tract between the transgressive surface and maximum flooding surface includes five depositional systems, which show a succession of backstepping depositional arrangements: (1) ancient beach/shoreface deposit (SU3), (2) incised-channel fill (SU4), (3) thin sand sheet (SU5) (4) sand ridge system (SU6), (5) estuarine/deltaic complex (SU7). Five depositional systems can be grouped into two distinct groups (paralic and marine) bounded by a ravinement surface. Lower three depositional systems (SU3, SU4, SU7) belong to a paralic component that consists of the sediment preserved from shoreface erosion. The top of paralic unit is truncated by a ravinement surface and overlain by marine component. The marine component includes three depositional systems (SU5 and 6) consisting of the sediment produced through shoreface erosion during the Holocene transgression. The highstand systems tract above the maximum flooding surface is composed of a prodelta/shelf complex (SU8) consisting exclusively of recent muds. As the sea level reached the present position (6 ka), the sediment derived from Nakdong and Seomjin rivers are deposited in the inner shelf, forming the SU8 as a inner-shelf mud deposit.

**P-2830**

## **The first geological record of the historical earthquakes in the Korean Peninsula**

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### **Abstract**

Since the 2016 Gyeongju earthquakes ( $< M_w 5.8$ ), SE Korea, paleoseismological information has been important to assess the seismic hazard assessment in those area. After detailed geomorphic analysis, we excavated the ground on the Quaternary segment of the Yangsan Fault, to gather its paleoseismological information. The trench site is composed of alternating layers of sand (or gravelly sand) and mud, inferred to have been deposited by episodic flooding on alluvial fan surface, and their  $^{14}\text{C}$  age is younger than 1400 B.P. We also found a series of soft sediment deformation structures (SSDS; load and flame structures). Based on the detailed sedimentological analysis together with context-based evaluation, we interpreted the SSDS to have been formed by seismogenic liquefaction and associated fluidization. This interpretation is also well matched with historical liquefaction records of the 1643 Ulsan earthquake in SE Korea. Thus, this finding is the first geological records of the historical earthquakes in SE Korea and implies the minimum magnitude of the 1643 Ulsan Earthquake exceeding  $M_w 5.0$ .

**P-2831**

## **Stone pavements: a promising archive for paleoenvironmental research!?**

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### **Abstract**

Reconstructing the evolution of arid landscapes is vital but challenged by the limited availability of appropriate environmental archives. A widespread surface feature of arid landscapes – stone pavement – traps eolian fines and promotes formation of an accretionary archive, growing with time and thereby recording essential information about the conditions under which it evolves. Here, we give a state-of-the-art overview to stone pavement research and discuss constraints for reconstructing Quaternary environmental change. We present regional studies from Jordan, Israel, the Canary Islands and the western USA, and finally focus on the chronostratigraphic interpretation of stone pavements and their eolian fines, using OSL dating.

P-2832

## Late Quaternary paleoenvironmental evolution of the proximal area of the Atuel-Diamante distributive fluvial system, South America

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### Abstract

Distributive fluvial systems (DFS) have been described worldwide under diverse climatic and tectonic setting. Studying the deposits of present DFS contributes to understanding Quaternary landscape evolution, doing paleoclimatic inferences, and improving facies models for interpreting sedimentary records. The eastern Andean piedmont, southern South America, shows several DFS, like the recently defined Atuel-Diamante DFS (Fig. 1). The Atuel and Diamante rivers carry seasonal meltwater from the Andes Cordillera and flow to the east. They are deeply entrenched in the San Rafael tectonic block where, at its eastern piedmont, they generate the DFS. This system has been barely studied in terms of its geomorphological, paleohydrological and landscape evolution. A doctoral thesis recently finished and associated investigations in progress have started to expose and interpret its morphology and late Quaternary history. In this presentation we characterize the deposits of the proximal area of the Atuel-Diamante DFS, with the aim of interpreting the late Quaternary paleoenvironmental evolution and to infer paleoclimatic variability. Methodology included geomorphologic mapping by remote sensing, field survey, stratigraphic section analysis of pedosedimentary facies, with AMS and luminescence chronology. We studied 5 localities along a SW-NE transect (Fig. 1a) where information was obtained at exposed deposits, pits and by augering. Present climate is temperate semiarid, influenced by the Andes rain shadow and the South Atlantic and South Pacific anticyclones. The fluvial drainage is, at present, a misfit system due to the current interglacial, the presence of agricultural irrigation networks and hydroelectric power dams on the Atuel and Diamante rivers. The proximal area, besides the gravel-sand Atuel and Diamante streams, shows many abandoned meandering channels and associated floodplains, with deposits dominated by silty fine sand and silt, together with minor gravelly sand-silt, forming fining-upward successions. Stabilized dune fields restrict, to the north and south, the studied DFS, where the aeolian medium to fine sand was also described and sampled to decipher the aeolian-fluvial relationship. Previously obtained chronology shows, in the Atuel River, a late Pleistocene-early Holocene record in an upper most, 8 m thick, fluvial terrace, suggesting important fluvial aggradation during the last glacial termination and a significant change in the system with extensive incision at early-mid Holocene. OSL ages in progress will provide detail about the mid-late Holocene evolution of the Atuel-Diamante DFS, and all together will offer data for paleoclimatic inferences.

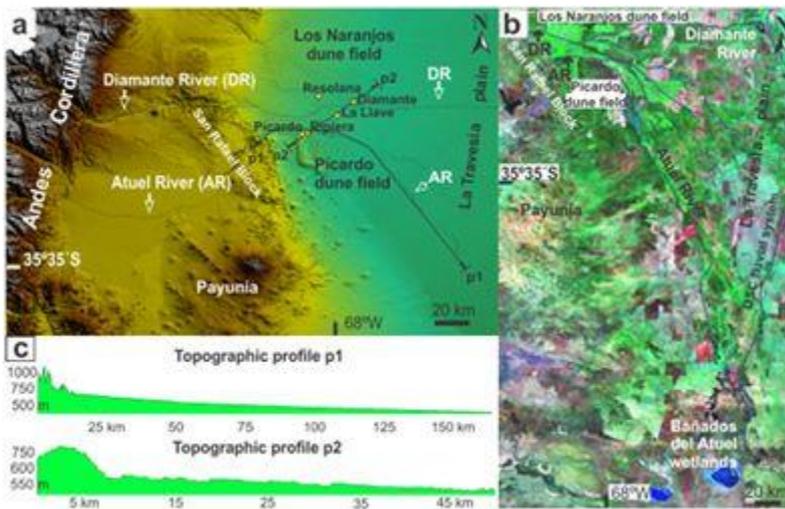


Figure 1: The Atuel-Diamante DFS, eastern piedmont of the San Rafael Block, and related tectonic structural and geomorphological elements in: a) SRTM digital elevation model, and b) Landsat ETM image; c) topographic profiles p1 and p2 along longitudinal and transverse transects, respectively. Diamante, La Resolana, La Llave, Ripiera and Picardo are study localities.

**P-2833**

## **Grain size and their potential correlations to the dune stabilization along the Keriya River in the Taklamakan Desert, northwestern China**

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### **Abstract**

We studied the grain-size characteristics of the surface sediments from fixed, semi-fixed, mobile sand dunes and fluvial sand first and then discussed their possible link to the desertification process along the Keriya River, in the southern part of the Taklamakan Desert. Gaussian and Weibull function fitting techniques are used to quantitatively separate the poly-modal grain-size distribution system into independent individual components. We found out that the Gaussian distribution is better than Weibull function fitting in the case of Keriya River sediments. In addition, two to four sub-populations are identified by End Member Mixing Analysis. End Member 1 (EM1) with mode at  $2\mu\text{m}$ , correlates with well-sorted populations of finer-grained collected from the loess of Kunlun mountains above 3000 m. It should be transported by the westerlies, representing the atmospheric background value; EM2 with mode at  $10\sim 13\mu\text{m}$ , correlates with samples that contain moderately sorted populations and associated with vegetated interdunes, sandy loess and fluvial sand. This portion should be carried by East Asian winter monsoon (EAWM); EM3 with mode at  $56\sim 90\mu\text{m}$ , associated with samples of moderately to poorly sorted fine-grained collected from areas of vegetated interdunes, loess, sand loess and fluvial sand. This should be transported in the form of suspension by the EAWM; EM4 with mode larger than  $250\mu\text{m}$ , associated with moderately well sorted coarse and very coarse-grained sands collected from fluvial sand and mobile sand dunes, reflecting transportation in the form of saltation by the EAWM or fluvial processes. Finally, we compared the Landsat 8 image (2008) with Landsat 8 image (2018), and observed a decrease of NDVI, indicating that the desertification expanded along the Keriya River. The grain size result indicated that along with the increase of desertification level, the EM1 and EM2 populations decreased, while the EM3 and EM4 populations remarkably increased. These regional variations are probably associated with the reducing fixation degree of the dunes in the last decade.

P-2834

## Wind induced changes in barchan-to-parabolic dune morphology and their sedimentological reorganization

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### Abstract

The development and transformation of barchan-to-parabolic dunes can be led by vegetation establishment, which may be induced by climate change and/or human intervention. However, little is known about the impact of wind strength change-induced vegetation restoration on dune morphology and the surface sedimentary features response to this process. Here we show that increased growing season NDVI related to the significant decrease in drift potential (DP) in the Mu Us Sandy Land during the entire study period (1982 to 2015). Further temporal analyses indicate that the increasing NDVI trends were largely contributed by decreased wind strength and temperature changes during the earlier study period (1982-2006). Furthermore, the increasing NDVI was consistent with the slightly increasing trend of precipitation from 2006 to 2015. Therefore, the initiation of dune transformation may have been caused by reduced wind strength favouring vegetation establishment and growth. Once dunes surfaces are covered by vegetation, the transformation processes are more sensitive to precipitation changes. To reveal the response of sedimentological reorganization during the dune transformation processes, grain-size characteristics along the longitudinal profile of three different types of dunes were examined. From barchan dune through transition dune to parabolic dune, with the increase of the fine sands (125-250 $\mu$ m) proportions, the mean grain size ( $M_z$ ) gradually decreased; in addition, as the very fine sands (<125 $\mu$ m) class increases, the sorting ( $\sigma_1$ ) of sand dunes gradually became worse. The decreasing wind strength lead to partly transport of fine sands on the upper part of dune windward slope, resulting in the progress coarsening and the reduction of dune height at the crest area. No distinct trend in sorting and mean grain size on the windward slope of transition dune, indicating that sand in transport had little influence on the particle size distributions. Conversely, the progressive of sorting and coarsening of sands towards the crest of parabolic dune, implying that vegetation limited the sands from upwind of dune, changed the effective source of dune into the underlying source deposits or reworking pre-existing aeolian deposits and trapped the sands on the crest area.

P-2835

## Using post-IR IRSL luminescence methods to constrain the timing of alluvial “cut and fill” in the Great Karoo, South Africa

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### Abstract

Headwater valleys in the Great Karoo, South Africa record past phases of incision, aggradation and wetland formation as alluvial “cut and fill” deposits. Until now, an understanding of their age structure has been confounded by: (i) a lack of organic material for <sup>14</sup>C dating; and (ii) the frequent unsuitability of quartz for luminescence dating (in terms of both quartz performance and the relatively high environmental dose rates). To resolve this, we investigated the suitability of K-feldspar post-Infrared Infrared Stimulated Luminescence dating (pIRIR) methods at several outcrops exposed in a low-order tributary (Africanders River) of the Wilgerbosch catchment in the Sneeuwberg.

Single aliquot pIRIR protocols perform well, with consistently good recycling, good dose recovery and low recuperation. A critical concern, given the sedimentary context and use of the post-IR feldspar signal, is the issue of adequate bleaching prior to burial. This is considered via comparison with the more easily bleached (but fading) IR50 signal and with a limited number of rigorously screened quartz ages (Oldknow and Hooke, 2017). The latter approach demonstrates good overlap with the pIRIR<sub>170</sub> ages: (e.g. LV509: 8.2 ± 1.5 ka (quartz); 8.5 ± 0.8 ka (pIRIR<sub>170</sub>)). pIRIR methods using the less fading prone, but also less bleachable high temperature post-IR stimulation temperatures (pIRIR<sub>225</sub> and pIRIR<sub>290</sub>) are shown to result in significant age overestimates. However, measured fading rates for the pIRIR<sub>170</sub> signal are small (g values 0.1-1.6% per decade) allowing us to establish a new chronology comprising 23 pIRIR<sub>170</sub> ages.

The ages are all (given 1σ uncertainties) in the correct stratigraphic order. The chronology reveals four major phases of net aggradation: (i) 2.6 m of sediment accumulated from ~58-40 ka and was followed by a phase of soil formation; (ii) minor incision followed by a further 2 m of floodplain aggradation occurred ~39-37 ka; during which time an elevated water table resulted in the formation of wetlands; (iii) 1.6 m of sediment accumulated from 30-25 ka; and (iv) approximately 4 m of sediment accumulated ~14.6 ka. These phases of aggradation (with the exception of ii) were interrupted by at least two phases of incision at: (i) 37-30 ka (draining the wetland); and (ii) 25-17 ka. During the Holocene, infilled palaeogully architecture (e.g. LV627: 5.7 ka) attests to phases of incomplete incision with subsequent refilling. This study demonstrates the great potential of the pIRIR<sub>170</sub> protocol to constrain the timings of past geomorphic and hydrological changes in this semi-arid landscape, revealing major landscape adjustments throughout the late Pleistocene. The environmental drivers of such adjustments will be considered.

Oldknow CJ and Hooke JM. 2017. Alluvial terrace development and changing landscape connectivity in the Great Karoo, South Africa. Insights from the Wilgerbosch River catchment, Sneeuwberg. *Geomorphology* 288, 12-38.

P-2836

## **Abrupt changes in atmospheric circulation at the southern margin of the Taklimakan Desert: perspectives from loess and oasis sediments**

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### **Abstract**

The Taklimakan Desert, the largest sand sea in China, is one of the most important dust sources and of the extreme arid region in the world. The complex stratigraphy of eolian deposits in desert margin with multiple mechanism of transporting processes and lack of organic matter for dating have hindered the progress of studying paleoclimate changes in this setting. Here we investigated the loess and oasis deposits from the south margin of the desert by numerous AMS <sup>14</sup>C and OSL dates and environmental proxies. We identified millennial-scale abrupt regional moisture changes during the late last Glacial and interpreted they appear to be influenced by the interplay of Asian summer monsoon circulation and mid-latitude Westerlies jet streams.

One striking sedimentation hiatus of regional dust deposition occurred during ca. 70-15 ka, while an episodic outbreak accumulation period (ca. 15-10) was observed at two loess sites on foothills where gully landform supports the eolian cannibalism hypothesis. We also observed the different mechanism of dust transporting processes at different altitudes of 2700 m and 3700 m asl in the same region. Based on a reasonably reliable chronology of the Holocene, the dust records clearly confirm an out-of-phase relationship between the low and high elevations in this region. We examined the concurrent locations and intensity of subtropical jet stream (SJS) and polar jet stream (PJS) to interplay with the low-level atmospheric circulations, e.g. East Asian winter monsoon. We found that lower level convergent and upper level divergent could explain this out-of-phase relationship for the sedimentation records at 27,00 and 3700 m asl. in the southern margin of the Taklimakan Desert.

P-2837

## Working at the frontiers of drylands research out in the field and back in the lab: using portable luminescence readers.

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### Abstract

Reconstructing environmental change in dunefields, locations where aeolian dunes interact with fluvial systems and lake shorelines, requires wide spatial coverage and dense chronologies. This is extremely time-consuming and resource intensive if laboratory-based luminescence dating of samples is used in isolation. Portable luminescence readers (POSL) (Sanderson and Murphy, 2010) provide a useful means of generalising chronologies within simple systems, and of helping to understand more complex systems through a combination of *in situ* analyses and laboratory procedures. Here we explore datasets from: (i) 148 dune and 100 lake shoreline samples across southern Africa and (ii) dune damming sediments (DDS) within the Negev, Israel (Roskin et al., 2017), where insights into bleaching histories, sediment luminescence sensitivity and sample age can be gained through a combination of simple POSL profiling and laboratory calibration of luminescence-sensitivity, coupled with SEM analysis.

The southern African datasets show that POSL signals from bulk samples regressed against laboratory-based ages on quartz can be used to calibrate POSL signals into first-order age estimates, and that a regionally-specific approach is needed for different dunefields across the subcontinent ( $r^2$  of 0.99, 0.93, 0.81 and 0.52) (Stone et al., 2018). Sample composition, such as quartz to feldspar ratios, account for the largest spatial contrasts, and sample luminescence-sensitivity may also influence signals. For the lake shoreline data, factors other than sample burial age are contributing to the POSL signals but with no clear single factor. The Negev case study shows an example of reflexive geomorphology in a more complex DDS setting using POSL alongside laboratory irradiation and SEM analysis. The different DDS could be identified from bulk samples at this vegetated linear dune (mostly stabilised since the Younger Dryas), after accounting for: (i) luminescence sensitivities through calibration, (ii) inherited luminescence signals based on depletion rates and (iii) stratigraphic position. Apparent ages for emplacement of both fluvial and aeolian units can be established providing a coherent basis for interpreting the environmental history of the DDS.

Overall the POSL approaches discussed here provide cost- and time-effective means of generalising chronostratigraphies over large areas in both simple and complex systems, in order to reconstruct Quaternary environmental changes.

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**P-2838**

## **Late Pleistocene and Holocene dune accumulation in the Shaybah area, eastern Saudi Arabia**

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### **Abstract**

Large compound crescentic megadunes characterize the northern Rub' Al-Khali sand sea in Saudi Arabia and the Liwa area of the United Arab Emirates, where they form a distinctive wet aeolian system with near surface groundwater levels. Studies in the Liwa area suggest a long (>150 ka) history of episodic aeolian accumulation influenced by fluctuating Pleistocene groundwater levels, as well as rapid Holocene accumulation (Bray and Stokes, 2003; Stokes and Bray, 2005). Little evidence exists for latest Pleistocene dune accumulation, unlike in areas of linear dunes to the north in the UAE.

Dune and interdune deposits were studied and sampled for OSL dating and mineralogical analysis in the Shaybah area of the Eastern Province of the Kingdom of Saudi Arabia. Dune samples were collected from sands exposed in a large sand quarry excavated in a large (167 m-high) mega-crescentic dune. Interdune sabkha samples were collected from aeolian sand deposits exposed in pits excavated for road building materials.

Field observations of fine grey laminae interbedded with the dune sand suggest that the sands were deposited at a time when there was more dust deposition. The presence of root casts suggests that there was some vegetation present when these sands were deposited.

We report the results of the OSL dating and compare them to the record from Liwa and elsewhere in the region. Preliminary and unpublished ages from Shaybah and Liwa suggest that latest Pleistocene dune accumulation occurred throughout the area, contrasting with previous models for the Liwa area (Stokes and Bray, 2005).

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**P-2839**

## **Holocene dune activity in the Thar Desert, India.**

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### **Abstract**

The sand dunes in the Thar, which are predominantly shaped by southwest Indian Summer Monsoon (ISM), provide an important archive of past climatic and geomorphological change. Whilst a small number of studies have undertaken geochronological investigations of dunes using luminescence dating, studies have been sporadic and have tended to rely on older dating protocols [1]. As a result, the temporal and spatial analyses of Thar dune accumulation histories and their comparison with growing multiproxy framework of past environmental dynamics become difficult. To address this, systematic sampling of dunefields was carried out in different regions in the desert. Sites were selected to form a transect across the modern precipitation gradient, and linear and parabolic dune forms, which have a high sediment preservation potential, were targeted. Optically stimulated luminescence (OSL) dating was used to provide a chronological framework, with the aim of inferring dune sensitivity to palaeoenvironmental change, and the time scales over which they register and preserve the palaeoenvironmental record.

Presented here is a new set of 60 OSL-dated dune accumulation chronologies from the Thar and their comparison with a range of proxies from both terrestrial and marine records. The chronology shows a near continuous record of dune accumulation throughout the Holocene. In contrast to previous studies, there are widespread records of dune accumulation between ~11.7 ka and ~8.5 ka coinciding with early Holocene monsoonal intensification, as well as during mid- to late Holocene when monsoons were weak. High accumulation rates are reported in the last century, suggesting that potential drivers of dune mobility in modern times include a strong anthropogenic dimension [2]. The comparison of Thar dune records with other terrestrial records demonstrates that there is no clear, consistent relationship between the timing of dune accumulation and periods of aridity as suggested earlier. The study concludes that a strategic approach to sampling coupled with robust dating protocols allow the scope for a more complex chronology to be identified and subsequently enhance our understanding of dunefield development and palaeoenvironments.

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**P-2840**

## **Pollen transport and deposition in semi-arid and arid lands from North Africa**

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### **Abstract**

The main objective of this study is to provide key information toward developing a comprehensive model of pollen transport and deposition in arid lands. Recently, Holocene sedimentary sequences have been retrieved in sebkha temporary lakes (playa-lake) from Tunisia (North Africa), and pollen analysis were undertaken (Lebreton et al., 2015; Jaouadi et al., 2016). However, pollen-based environmental reconstructions in semi-arid and arid lands are limited by a lack of knowledge regarding the processes controlling pollen transport and incorporation into the sediment, and the implications of such processes for the interpretation of fossil pollen records.

Water is the most important transport agent of pollen assemblages buried in sebkhas and other local humid sedimentary environments in arid lands. The pollen record is mainly controlled by inputs from the rivers catchment area by surface washes and sediments reworking during flood events. It is important that we characterise such processes and evaluate their implications for the interpretation of fossil pollen data. In this study, we present a dataset of sixty modern pollen spectra obtained from soil surface samples gathered in Central Tunisia in different steppe biomes located between the Mediterranean forest and the Sahara. Samples were collected in watersheds, watercourses, and on the surface of sebkhas in order to monitor pollen production, dispersal and sedimentation of the dominant plant taxa in the local and regional vegetation.

The results indicate a good overall correspondence between the pollen record on the surface of the temporary lakes and the vegetation associations of the watersheds. However, pollen records are less accurate 1) during extreme flooding events with clastic sediments reworking and 2) in some subdesert environments and small catchment area where pollen spectra reflect local halophytic vegetation.

P-2841

## Investigating a glacier under danger of extinction: dating the ice of Monte Perdido glacier, Central Pyrenees, Spain

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### Abstract

Continental-scale surface temperature reconstructions show, with high confidence, multi-decadal periods during the Medieval Climate Anomaly (950-1250 AD) that were in some regions as warm as the late 20th century. These regional warm periods did not occur as coherently across regions as the warming in the late 20th century, but they have been used to hypothesize that this warming forced the Pyrenean glaciers to disappear. Thus, the current ice that we observe in relict glaciers would have been formed during the Little Ice Age (1600-1850 AD). To test this hypothesis and confirm whether or not warming of the last 50 years exceeds the natural variability of the last millennia, we present the preliminary results obtained from an ice coring in Monte Perdido glacier in the Central Pyrenees, northern Spain, which is the first ice coring in this mountain range. Initially, to find the areas where we could expect the oldest ice, we developed a numerical model of glacier dynamics that tracks the ice particles from their deposition at the top of the glacier till their melt at the glacier front. This model requires, as input data, the ice-thickness distribution, which was determined by means of georadar field campaigns. Dating the ice has been approached by various techniques, including <sup>210</sup>Pb and <sup>14</sup>C dates (on organic remains, pollen concentrates and water-insoluble organic carbon –WIOC– on ice). The study of ice samples taken along an elevation transect from the oldest ice to the most recent layers allowed us to date the glacier ice. Additionally, it provided a new record of past climate variability allowing to better understand the climate system, its natural variability in the past and the impacts of abrupt climate changes on the high mountain environment. This study includes stable isotopes analyses ( $\delta^{18}\text{O}$ ) as potential paleothermometer, the interpretation of pollen content in terms of vegetation cover, the quantification of chemical content (e.g. eolian dust, heavy metals or black carbon) and the identification of microorganism associations (bacteria). The interpretation of all these proxies and dating outcomes as a whole provides evidences of the persistence of the glacier during the Medieval Climate Anomaly. It also suggests that other recent warm periods were not warmer (or drier) than late twentieth century, and proves that we are facing an unprecedented retreat of the Pyrenean glaciers.

P-2842

## Equilibrium Line Altitude reconstruction of the LGM paleoglaciers between the south-eastern Alps and the Northern Dinarides

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### Abstract

The south-eastern European Alps are characterized by a forealpine belt facing the foreland with relieves rarely exceeding 2000 m in elevation. During the Last Glacial Maximum (LGM), this area saw the growth of isolated glaciers around the highest peaks. Because they were disconnected from the major ice-streams, which flowed down the Alpine valleys towards the foreland, their reconstruction is an important tool for establishing paleoclimate conditions using the calculation of their Equilibrium Line Altitude (ELA). Through field and remote sensing analyses we reconstructed the paleoglaciers of the Mount Raut (2025 m a.s.l.) in the Carnian Forealps, the Mount Chiampon – Cuel di Lanis (1700 m a.s.l.) in the Julian Forealps and the Trnovski Gozd (1495 m a.s.l.) in the Northern Dinarides.

The Mount Raut is one of the highest mountains located close to the Friuli Piedmont plain, and its cirques hosted a glacier during the last glaciations. The frontal moraines are well preserved close to the Lake Ca' Selva at about 600 m a.s.l. According to the glacier reconstruction obtained with the tool GlaRe (Pellitero et al., 2015, 2016), the LGM ELA of the Raut paleoglacier was calculated at ~1340 m a.s.l. The Mount Chiampon – Cuel di Lanis is a 6-km long crest with several cirques in the northern side and well-preserved moraines at 600-800 m a.s.l. Five paleoglaciers were distinguished. They provide ELAs at ~1200 m a.s.l. (Monegato, 2012). The Trnovski Gozd karst plateau hosted small glaciers with an overall area of ~5 km<sup>2</sup>. Glaciers covered the karstic relief on the north-facing slopes below the highest crest and their ELA was estimated at ~1240 m a.s.l. (Žebre et al., 2014).

In respect to other ELAs available in the Alps (Federici et al., 2016), these lower values may suggest a lowering of the mean annual air temperature towards the east. Low-elevated ELAs were calculated also for the Little Ice Age (LIA) glaciers of the Mount Canin (Colucci, 2016). Considering the present-day high mean annual precipitation of the Carnian and Julian sectors (about 2500 mm and 3200 mm w.e.), low values of ELAs both during the LGM and the LIA could be supported by the maintaining of these precipitation rates during the cold phases. This allowed the growth of many isolated glaciers in the forealps during the LGM and the spread of the Tagliamento glacier in the Friuli Piedmont plain despite its low-elevated accumulation area, not exceeding 2800 m in elevation.

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**P-2843**

## **A unique lacustrine record of the Alpine Lateglacial and the Lateglacial-Holocene transition from the centre of the Eastern Alps (Austria)**

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### **Abstract**

The reconstruction of the Alpine Lateglacial is in general based either on the succession of end moraines or on lacustrine and peat deposits. Palynologically investigated records consisting of lacustrine and glacial deposits from sites close to modern glaciers are missing so far.

The sediment sequence of Lake Stappitzer See in the Seebach Valley (Mallnitz, Carinthia) is filling this gap. It is located in the still glaciated Hohen Tauern mountain range surrounded by peaks of 3000 metres altitude. End moraines of the Little Ice Age and the Egesen stadial (Younger Dryas, 12.8-11.7 ka) are present in and close to the cirques. However, evidence of a valley glacier during the Gschnitz stadial (<sup>10</sup>Be exposure age 16.6±1.4 ka, Ivy-Ochs et al. 2006) is missing in this valley. This is in sharp contrast, to neighbouring valleys where Gschnitz end moraines are well developed. The deposits of the Auernig rock avalanche occur c. 6 km downstream of the drill site. Based on U/Th isochrones dating, the catastrophic slope failure happened at 17.5±1.4 ka. Terraces and delta deposits just upstream of the rock avalanche deposits indicate the formation of a large lake dammed by the landslide.

In 2001, Fritz & Ucik published a comprehensive study on the chronology of climatic and vegetation change of the Seebach Valley. Their interpretation of the lacustrine record of two drill cores is in some issues in contradiction to the scientific consensus. On occasion of a study on the erosion chronology of the Seebach Valley (Grischott et al. 2017), the cores were re-analysed regarding palynology and sedimentology (Drescher-Schneider & Reitner 2018). Taking in consideration also the reconstructed palaeoglaciation and the age of the Auernig rock avalanche, following results of the revision are notable: The basal sediments in 160–118 m depth were deposited by the Seebach Valley Glacier advancing in a proglacial lake dammed by the Auernig rock avalanche during the Gschnitz stadial. The sediments contain pollen derived from soils or deposits of older interstadials or interglacials. The record between 118 and 80 m shows glacio-lacustrine depositional conditions in contact to decaying ice. The following banded silt (80–48 m) is free of any indication for a lake in direct contact to glaciers. The corresponding pollen flora represents that of a grass tundra with first shrubs typical for the Oldest Dryas. The Bølling/Allerød-Interstadial (80–71 m) with a reforestation and the following massive climatic deterioration of the Younger Dryas (Egesen stadial, 71–61 m) are based on palynological evidence. The Holocene succession starting in 61 m depth with the early Preboreal is not continuous.

Drescher-Schneider & Reitner J.M. 2018: Die Neuinterpretation der Stappitzer See–Bohrungen im Kontext der Klimageschichte und Landschaftsentwicklung.- Carinthia II, 208/128, 369–398, Klagenfurt.

**P-2844**

## **First steps towards a glacial chronology of the Verbano lobe, Italian Alps**

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### **Abstract**

Reliable glacial chronologies for many of the major LGM piedmont glaciers on the southern side of the Alps have been recently established based on radiocarbon and cosmogenic nuclide dating. However, less is known on the timing of the Last Glacial Maximum in the central part of the southern Alps, where the Toce/Ticino and Adda glacier systems remain chronologically unconstrained. Scattered radiocarbon ages are available (Scapozza et al. 2014), but do not yield information on LGM maximum advance(s) or final glacier retreat from the forelands. This is particularly unfortunate as the glaciers of the central southern Alps were linked to the major Alpine ice domes.

The present study aims to overcome this gap of knowledge. Mapping and cosmogenic nuclide dating of the Verbano lobe will give insights into the timing and extent of the Last Glacial Maximum and possible (re)advances of the Toce/Ticino glacier system. So far, thirty rock samples from glacially deposited boulders have been collected for surface exposure dating on the western part of the piedmont lobe, both north and south of Verbania. First Beryllium-10 ages have been determined. Preliminary results show that one of the outermost lateral moraines, that was lately believed to have formed prior to LGM (Bini et al. 2009), is clearly of LGM age. The LGM extent of the Verbano lobe must have been significantly larger than proposed by Bini et al. (2009). The present data set together with field evidence further suggests a glacier re-advance following LGM that ceased with a rapid meltdown of the glacier.

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P-2845

## Ice thickness and internal structure of two small glaciers in the Pirin Mountains (Bulgaria) assessed by geophysical investigations

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### Abstract

In the present study we examined the thickness and internal structure of two small glaciers in the Balkan Peninsula, using geophysical investigations. According to several recent findings the southernmost glaciers in Europe are located in the Pirin Mountains (Bulgaria) (Grunewald and Scheithauer, 2010). However, because their total area (between 0,5 and 1 ha) is very small, they are sometimes considered as perennial snow patches. Because a sufficiently strong electrical impedance contrast exists at the ice/snow and ice/ground interface, ground penetrating radar (GPR) is a useful tool for mapping the internal structure and the thickness of small ice bodies. Two small glaciers (Snezhnika and Banski Suhodol) (fig.1) and several snow patches were investigated using a MalåGeoSciences ProEx system with a 100 MHz unshielded rough terrain antenna. The measurements were performed in two different campaigns, in August 2017 and October 2018. All the radargrams revealed sharp reflections, indicating very well the contact between the snow/ice body and the bed topography. In the case of Snezhnika and Banski Suhodol glacierets, two different parallel and almost continuous reflections were identified. The upper reflections indicate the contact between snow/firn and ice and were identified at 3-5 m depth at Snezhnika and 6-8 m depth at Banski Suhodol. The lowermost reflections occur at 9-14 m at Snezhnika and between 14 and 17 m at Banski Suhodol, suggesting the contact between the ice body and the bed topography. The GPR measurements confirmed the presence of glacial ice bodies in the Pirin Mountains, with a maximum thickness of 10-12 m. In addition, electrical resistivity tomography surveys were conducted in the Banski Suhodol site, confirming the occurrence of permafrost in a talus slope below the glacier. The moraines around both glaciers do not host glacial ice or permafrost. High resolution digital elevation models for both sites were derived from aerial images taken by a cost-effective Unmanned Aerial Vehicle (UAV). In the following years the use of repeat UAV surveys and GPR measurements will allow us to evaluate more carefully the state of the southernmost glaciers in Europe.

### Acknowledgement

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**P-2846**

## **Paired moraine-dammed lake assemblages in the Cordillera Blanca (Peru) and implications for paleoclimatic reconstructions**

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### **Abstract**

The tropical mountain range of the Cordillera Blanca is a key locality of proglacial lakes in high-mountain settings worldwide. A genetic classification of major lake types with their specific barriers and a generalized model for the distribution of the present lakes and paleolakes was set up. The origin of the lakes and their recurrent distribution patterns are linked to certain stages of the Pleistocene to modern glaciation and their corresponding geomorphological landforms. Characteristic repetitive moraine sequences are found in the upper parts of numerous valleys of the Cordillera Blanca associated with lake formations. In terms of the spatial arrangement of the lake types, combined lakes are classified as a distinct composite lake type, which occur also in other tropical mountain ranges, such as in the Bolivian Andes and Central Peruvian Andes. In the Cordillera Blanca, the lakes occur at nearly the same elevation or at successively lower elevations, and form characteristic lake sequences of two or more lakes. They may occur as multi-moraine-dammed lakes or mixed combined lakes such as moraine-rock-dammed lakes or multi-debris-dammed lakes. From special interest are in this study the paired moraine-dammed lakes with two individual lakes (e.g. Lagunas Qoyllurcochas, Lagunas Safuna Alta and Baja). They are dammed by the Great Endmoraine (GEM), primarily formed during the Little Ice Age and earlier, and the pre-GEM, formed during the Holocene. Both moraines are located in rather close vicinity to each other at a distance of 1–3 km. In contrast to the prominent sharp-crested GEM, the pre-GEM is a low-amplitude end-moraine complex, which usually does not exceed a few meters to tens of meters in height. The latter is often composed of several inserted moraine ridges or an irregular hummocky moraine landscape. It is argued here that the process of formation of these combined lakes is mainly controlled by a combination of distinct topographical and climatic factors. These have to be considered in regard to studies of the paleoclimatic reconstruction. Moreover, the occurrence of these lakes represents a special situation for the risk potential of glacier lake outbursts.

P-2847

## Landform composition and functioning within proglacial systems of the central European Alps

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### Abstract

Proglacial systems are enlarging as glacier masses decline. They are in a transitory state from glacier-dominated to hillslope and fluvially-dominated geomorphological processes. They are a very important meltwater, sediment and solute source. This study makes the first quantitative, systematic and regional assessment of landform composition and functioning within proglacial systems that have developed in the short term since the Little Ice Age (LIA). Proglacial system extent was thus defined as the area between the LIA moraine ridges and the contemporary glacier. We achieved this assessment via a series of topographic analyses of 10 m resolution digital elevation models (DEMs) covering the central European Alps, specifically of Austria and Switzerland. Across the 2812 proglacial systems that have a combined area of 933 km<sup>2</sup>, the mean proportional area of each proglacial system that is directly affected by glacial meltwater is 37 %. However, there are examples where there is no glacial meltwater influence whatsoever due to complete disappearance of glaciers since the LIA, and there are examples where > 90% of the proglacial area is probably affected by glacial meltwater. In all of the major drainage basins; the Inn, Drava, Venetian Coast, Po, Rhine, Rhone and Danube, the proportions of the combined land area belonging to each landform class is remarkably similar, with > 10 % fluvial, ~35 % alluvial and debris fans, ~50 % moraine ridges and talus/scree, and ~ 10 % bedrock, which will be very helpful for considering estimates of regional sediment yield and denudation rates. We find groupings of the relationship between proglacial system hypsometric index and lithology, and of a slope threshold discriminating between hillslope and fluvial-dominated terrain, both of which we interpret to be due to grain size. We estimate of contemporary total volume loss from all of these proglacial systems of 44 M m<sup>3</sup>a<sup>-1</sup>, which equates to a mean of 0.3 mm.a<sup>-1</sup> contemporary surface lowering. Overall, these first quantifications of proglacial landform and landscape evolution will be an important basis for inter- and intra-catchment considerations of climate change effects on proglacial systems such as land stability, and changing water, sediment and solute source fluxes.

**P-2848**

## **Development of two small relict lakes located in NE Poland beyond the extent of the Last Glaciation**

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### **Abstract**

An occurrence of lowland lakes beyond the maximal extent of the Last Glaciation (Weichselian) is extremely rare. Currently, in NE Poland there are only two small natural water bodies: Lake Gorbacz and Lake Wiejki, both located in the Gródek-Michałowo Depression, the large, infilled by peat, form of terrain. They are relicts of much larger lakes (or one lake) that have been functioning here since the end of the Last Glaciation. At that time and at the beginning of the Holocene a number of lakes in this region of Poland was much higher. However, most of them became overgrown and transformed into peat bogs in different periods of the Holocene. The genesis of these Late Weichselian/Early Holocene water bodies has not yet been determined. Because in many of them, below a thin layer of sand, the lake and/or mire sediments accumulated during the Eemian Interglacial occur (also in the Gródek-Michałowo Depression), the so-called thermal karst is considered the most likely cause of their formation.

One core of sediments was collected from surrounding area of both existing lakes using the Instorf drill. The thickness of core from Lake Gorbacz (LG) vicinity was 5.8 m, and from near of Lake Wiejki (LWk) – 5.0 m. We investigated them by palynological method as well as by method of plant macrofossil remain analysis. The age of studied sediments was determined by radiocarbon method. In the LWk profile calcareous gyttja was recognized in the bottom. The first peat layer (4.55 m) was deposited in the first half of the Atlantic period (6029-5630 cal. BC; MKL-4187). This peat was described as Carici-Brayelti, what indicates that peat-forming process was initiated by sedge-brown moss community. After that, still in the Atlantic period (5638-5230 cal. BC; MKL-4186), mire surface was overgrown mainly by brown mosses what is confirmed by Bryaleti peat in the profile. The next succession sequence was formed by sedges. They were replaced by peat mosses in the Subatlantic period (201 cal. BC-244 cal. AD; MKL-4185).

**P-2849**

## **Simulating changing Holocene distributions of palsas and peat plateaus in North America**

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### **Abstract**

Permafrost peatlands represent a globally vast, organic carbon store which is particularly sensitive to climatic change. The distribution of permafrost within peatlands at coarse spatial scales is evidenced by the presence of palsas and peat plateaus, landforms which are closely controlled by climatic factors. Frozen temperatures render these ecosystems largely inert, but thaw and the development of saturated conditions significantly enhances carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) emissions, presenting positive feedback mechanisms which threaten to accelerate future climate change. Although predictive models of permafrost degradation are well-developed for mineral soils, the thermal properties of organic soils complicate the response of peatland permafrost to climatic changes. As such, the extent and severity of future thawing has remained highly uncertain at hemispheric scales, as confident simulations of permafrost peatlands are only currently available for Fennoscandia. Bioclimate modelling of palsa distribution in Fennoscandia has shown that these features occur primarily in extremely cold, precipitation limited environments. Preliminary analysis indicated that bioclimate models of palsa distribution in Fennoscandia perform poorly in North America, suggesting that the climatic controls on permafrost development within peatlands may display interregional variability. This likely reflects the greater range of climate in North America along continental-to-maritime gradient. North American palsa lines are likely to have tracked north and south in response to Holocene climate shifts, but the lack of a generally applicable palsa distribution model means we are currently unable to simulate past or future changes.

We developed a catalogue of palsa and peat plateau distribution in North America (> 300 sites), and combined this with an existing catalogue from Fennoscandia. We used modern climate data to develop a bioclimate model that can be used to simulate past and future changes in the bioclimatic envelopes of palsas and peat plateaus. I will statistically relate this extensive dataset of permafrost peatland landforms to contemporary climate data to construct an advanced logistic regression model with which to predict the distribution of permafrost peatlands in North America. We will then incorporate into our model outputs from the HadCM3 Earth System model to hindcast permafrost peatland developments throughout the Holocene. Hindcasted distributions will provide new evidence with which to constrain the timing of permafrost aggradation and degradation in peatlands, enabling comparisons with estimates from traditional palaeoecological techniques. An improved understanding of permafrost peatland developments throughout the Holocene will also enhance the reliability of projected future permafrost peatland distributions under anthropogenic climate change. In this presentation I will briefly outline the project's aim and importance, talk through the model building process and present novel simulations of Holocene permafrost peatland developments.

**P-2850**

## **Peatland development and possible responses to the Holocene environmental changes in Central European Russia**

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### **Abstract**

The reconstruction of peatland developing processes is based on radiocarbon dating of lowermost peat horizons and plant macrofossil analysis of peat samples from 40 mires in the Meshchera lowlands (the central part of the East European Plain). The landscape of this region are formed on thick fluvio-glacial sands and characterized by flat relief, high level of ground water and large areas of pine forests and numerous mires. This area is belongs to so-called Polessye-type of landscapes. All studied peatlands are located on watersheds and high river terraces and formed by forest paludification. Phases of peatland initiation were compared with Holocene fire regime revealed from macro-charcoal data and climatic reconstructions available for this area.

The obtained results showed that the peatland developing process of these areas took place throughout the Holocene. The ages of basal peat samples showed that the majority of the studied peatlands formed between 9000 and 6000 cal yr BP, during the Holocene thermal maximum. The highest number of mires formed between 7600 and 6000 cal yr BP. The second period of active paludification ranged between 3700 and 3200 cal yr BP. According to climatic reconstruction this period was characterized by increased temperatures and driest conditions entire the Holocene and high fire frequencies. The last phase of peatland initiation occurred between 1500 and 1700 cal yr BP and was coincided with increase of human induced forest fires during human occupation of the area during the Early Iron Age. In the periods of the climatic cooling and increase of humidity in periods between 5000 and 4000 cal yr BP and 3000 and 2000 cal yr BP the lowest number initiated.

In contrast to the areas located in the taiga zone, where the active peatland growth correlated with wetter and cooler epochs, in the Meshchera lowlands the stages of paludification coincided with phases of dry and warm climatic conditions and the increase in the frequency and intensity of fires. Obviously, the peatland formation process in these areas was influenced by the fire regime of the territory. After severe forest fires, accompanied by the death of the forest stand, the water balance of the study area was changed by reducing evaporation and increasing surface runoff, which led to the waterlogging of the territory.

According to the plant macrofossil analysis of peat, all studied peatlands were in the eutrophic stage of development during the entire Holocene. The transition to mesotrophic conditions in different mires ranged from 1400 to 400 cal yr BP. It is possible that periodic fires and burning of peat deposits contributed to the supply of nutrients to the peatland ecosystems and provided eutrophic habitat conditions.

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P-2851

## Quaternary evolution of the Navamuño peatland (Iberian Central System)

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### Abstract

The geometric and genetic characterization of the Navamuño depression peatland system (ND) has been depicted using geophysical and geoprobes surveys. ND is a pseudo-endorheic system (~14 ha surface area) located in the Sierra de Béjar (Iberian Central System, ICS) and included in the Natura 2000 European protection network. The genesis and evolution of ND is associated to the neotectonic and glacial dynamics during the Quaternary times and is the first sedimentary basin with these features that has been surveyed until 20 m depth in these areas. The rest of ICS's peatlands do not reach this depth, staying around 8 m and belonging Holocene ages. Refraction seismic, magnetic resonance sounding (MRS) and electrical resistivity measurements were the geophysical techniques used. The stratigraphic of the peatbog was obtained and three main geophysical units (G1, G2, G3) were identified. These units had been grouped into two sedimentary bodies: an ancient sedimentary body (G3) of unknown age, and a shallower sedimentary body (<20 m depth) that embraces the Upper Pleistocene (G2) and the Holocene (G1). The geometry and facies distribution of units G1 and G2 was examined using the Sequence Stratigraphy principles. On the one hand sedimentary unconformities linked to the geometry of the geophysical units reveals that the depression was dammed, almost at the MIS2. On the other hand, geomorphological mapping reveals that the depression was under the influence of the former Cuerpo de Hombre glacier and was an ice-dammed lake synchronous to build-up of the lateral moraine during the MIS2. A general coarsening-upward trend was identified using a dynamic penetration probe and a direct-push borehole, revealing a MIS2/MIS1 shallowing upward sequence.

We conclude that the Navamuño's boundaries are forced by extensive faults leading the geometry of the basin and its high sedimentary rate ( $\approx 1$  mm/yr). The depression is interpreted as a small tectonic basin filled with glaciolacustrine, glaciofluvial and post-glacial deposits of shallow pond/peat bog environment.

P-2852

## Climate change and vegetation evolution during the last glacial period recorded by mountain peatbog in the western subtropical China

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### Abstract

The vegetation system in subtropical China was strongly affected by the decrease of temperature and the weakening of monsoon during the Last Glacial Maximum (LGM), and the regional vegetation changed significantly. However, there are still great differences in the understanding of vegetation types and distribution patterns in subtropical China. The knowledge of climate change and the process of vegetation evolution and migration during the LGM, and whether the expansion of grassland-meadow replaced the subtropical broad-leaved forest remain controversial.

Western Guizhou is located on the eastern slope of the Yunnan-Guizhou Plateau, which is the second step in China. It is in the semi-humid area of the western subtropical China. The vegetation types and distribution patterns are closely related to the southwest monsoon. In order to reveal the response of vegetation to climate during the LGM, better understand the mechanism of southwest monsoon change, regional environmental evolution and predict future climate change, AMS<sup>14</sup>C dating and pollen analysis were carried out on a peatbog collected in Western Guizhou mountainous area on the eastern slope of Yunnan-Guizhou Plateau. The preliminary results show that:

At the late stage of MIS3 (ca. 36-21 cal kyr BP), deciduous-evergreen broad-leaved forests were inferred from pollen data, which were mainly composed of *Quercus* (evergreen and deciduous), *Castanopsis/Lithocarpus*, *Fagus* and temperate species such as *Corylus*, *Carpinus* and *Betula*, with a small amount of pine and hemlock-based coniferous forests and shrubs which dominated by *Rhododendron*. While understory herbs were predominated by Poaceae and Cyperaceae. This stage indicated a cool climate, but the regional climate was still wet.

During LGM (ca. 21-16 cal kyr BP), the characteristics of pollen assemblage showed the constructive species which mainly represented by deciduous *Quercus. D.* and *Corylus*. It suggested that the vegetation was dominated by deciduous broad-leaved forest, reflecting the spatial shift of deciduous broad-leaved forest of northern subtropical zonal vegetation. Gramineae was still the dominant herbage, but there was no expansion of grassland vegetation, while Cyperaceae was almost disappears, indicating that the climate in the region was further drier and colder.

In the last deglacial period, the vegetation transitions from deciduous broad-leaved forest to deciduous-evergreen broad-leaved forest which dominated by *Quercus.D.*, *Corylus* and *Castanopsis/Lithocarpus*, indicated that the evergreen broad-leaved forest expanded northward and the climate gradually rose and warmed up.

The vegetation succession and climate change in the LGM recorded by pollen from the mountain peatbog in Western Guizhou indicated that the vegetation succession in this area during the last glacial maximum. It was mainly characterized by the expansion and contraction of deciduous broad-leaved forests, and the climate experienced cool-wet-dry-cold-cool-wet, which generally corresponded well with the solar radiation in the northern hemisphere at low latitudes in summer.

P-2853

## Post Little Ice Age peat and carbon accumulation in northwestern Québec, Canada

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### Abstract

It is expected, that ongoing climate change will alter high-latitude peatland vegetation dynamics and carbon cycling. Peatlands are globally important carbon sinks, even though they release carbon dioxide and methane to the atmosphere through plant respiration and peat decomposition. Peatlands act as environmental archives and can be used to reconstruct past changes and develop analogues for future projections. However, it is not yet fully understood how high-latitude peatlands will respond to ongoing climate change. We used plant macrofossils and peat property analyses as proxies to reconstruct recent changes in vegetation assemblages and carbon dynamics following the Little Ice Age period in high-boreal and low-subarctic regions in northwestern Québec, Canada. Our results from twelve surface peat monoliths, collected respectively from four peatlands located in two distinct ecoregions, suggest high peat and carbon accumulation rates from AD 1950s. Successional changes in plant macrofossils show heterogeneous responses, even though some consistent changes occur within the same region. The northernmost study region shows higher average apparent accumulation rates that could be linked to a larger increase in the growing season length (GDD > 0 °C) and changes in climatic conditions (temperature and precipitation). The average apparent recent carbon accumulation rates from both regions vary between 50.7 and 149.1 g C m<sup>-2</sup> yr<sup>-1</sup>. Our results highlight the need to integrate multiple records from each studied peatland, but also from different peatlands within one region in order to disentangle the internal versus external variability of the signals recorded.

P-2854

## Indicator value of oribatid mites in determining past permafrost dynamics in northern European sub-Arctic peatlands

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### Abstract

#### Indicator value of oribatid mites in determining past permafrost dynamics in northern European sub-Arctic peatlands

Permafrost dynamics play an important role in the surface hydrology and carbon balance of northern peatlands. Plant macrofossil analysis with radiocarbon dating has been widely used in detecting past permafrost dynamics in peatlands, however, there is a lack of permafrost-specific plant indicator species, which makes it challenging to determine the exact timing of historical permafrost aggradation. In this study, we investigated the indicator value of oribatid mites in determining past permafrost dynamics in sub-Arctic peatlands. Previous studies have shown that oribatid mites are suitable bioindicators of natural and anthropogenic changes in ecosystems, but their potential as indicators of permafrost occurrence and dynamics has not been investigated before. We carried out analyses of subfossil oribatid mite assemblages in Holocene peat profiles from two mires in northern Finland and Russia, and compared the results with earlier plant macrofossil analyses from the same profiles. For reference, present-day species compositions of oribatid mite communities in the same study areas were investigated in permafrost (palsa mire) and non-permafrost (aapa mire) peatlands and across five types of peatland vegetation: lichen, *Empetrum hermaphroditum*, *Rubus chamaemorus*, *Sphagnum* spp., hollow type and *Carex* spp.

In general, permafrost dynamics were well reflected in oribatid mite assemblages in our subfossil data. A change from a community of hydrophilous species to one consisting of taxa related to drier surface conditions was visible in the profiles at around the same time when first permafrost aggradation occurred. We found three promising oribatid mite indicator species. *Carabodes labyrinthicus* and *Chamobates borealis* were significantly more abundant in permafrost peatlands than in non-permafrost peatlands and in microhabitats of lichen and *Empetrum hermaphroditum* vegetation and low soil moisture content, and became the dominant species in peat profiles at the time permafrost was aggraded. Another Oribatida species, *Neoribates aurantiacus*, was found in low numbers, but was clearly associated to the presence of lichens and low humidity conditions across our present-day and subfossil datasets. This is particularly valuable since lichens are normally not preserved in peat deposits.

Our results indicate that Oribatid mites can contribute significantly to multi-proxy approaches that aim to reconstruct environmental conditions in permafrost peatlands as they include promising indicator species. The presence/abundance of the three identified indicator species, together with the general species composition of oribatid mite communities can give insights into dynamics and timing of local permafrost aggradation and humidity conditions.



P-2855

## Changes in Late Quaternary circumarctic ground ice and soil organic carbon simulated by a simple model

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### Abstract

Permafrost is a large reservoir of soil organic carbon (SOC), accounting about half of all the terrestrial storage, and almost equivalent to two times of the atmospheric carbon storage. Therefore, its degradation under global warming may lead to a substantial amount of additional greenhouse gas (GHG) release, and to further warming. In addition to gradual degradation through heat conduction, importance of abrupt thawing or erosion of ice-rich permafrost is recently recognized. Such ice-rich permafrost has been evolved on a long timescale (i.e., hundreds to tens of thousands of years).

Though important, knowledge on the “vulnerability distribution”, i.e., location of, and stored amount of ground ice and soil carbon in ice-rich permafrost is still limited largely due to scarcity of accessible in-situ data. Understanding of the processes, and geographical distribution of the vulnerability are necessary for enhancement of Earth system models as the permafrost-carbon process remains one of the large sources of uncertainty in climatic and biogeochemical assessment and projections of the Arctic.

In this study, conducted as a part of three-year research project (2-1605, ERTDF of ERCA, Japan), a simple two-box numerical model was developed to simulate the long-term evolution of ground ice and SOC in the circumarctic region. The model has two compartments, above-ground and ground. The former is driven by annual mean air temperature and total precipitation to calculate the carbon input to the ground (i.e., litter fall) and regulate subsurface thermal conditions, whereas the latter calculates carbon and water budget, including ice content, of the ground. The circum-Arctic domain (north of 50° N) is sectioned by 1 degree both in longitude and latitude. The distributed driving data and boundary conditions were prepared for the period from 125ka to the present, derived from ice sheets reconstruction data (ICE-6G\_C dataset) and Greenland ice core data (the SeaRISE project), modified through the present-day reanalysis data (ERA-Interim and the University of Delaware products), as well as outputs from global climate models (CMIP5/PMIP3).

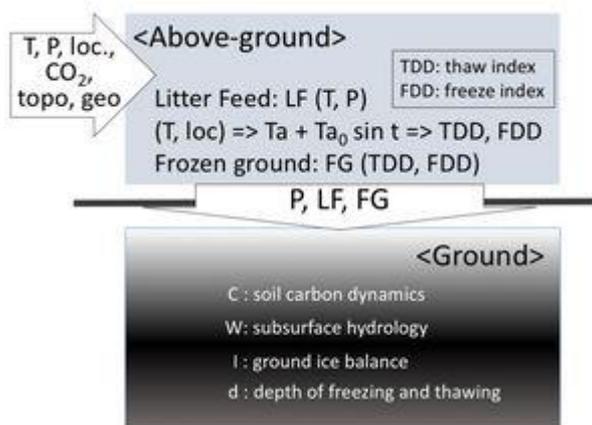


Fig: Schematic diagram of the two-box model

The circumarctic core data were compared to the simulation results at the corresponding locations for soil carbon dynamics to validate model process (e.g., decomposition, impacts of ground freezing), and for sensitivities on key parameters (e.g., time constant for carbon decomposition). The changes in geographical distribution in ground ice, soil moisture, and soil carbon content as well as frozen ground (i.e., permafrost and seasonally freezing ground) through the Late Quaternary demonstrated reasonable geo-characteristic differences, contrasting behavior between the glacial and non-glacial periods of the region, and the evolution of the vulnerable areas.

P-2856

## Identifying the key prerequisites of ecosystem resilience: a case of tropical peatland in Sumatra, Indonesia

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### Abstract

The success of conservation nowadays relies on the support of local community that is often lacking due to the neglect to socioeconomic aspects. Thus, socioeconomic activities of local people, especially those whose livelihood depends entirely on the natural resources, needs to be accommodated. To ensure ecosystem sustainability, the socioeconomic activities certainly need to be compatible with conservation and should not undermine the ecosystem's resilience. An understanding of ecosystem resilience and its key prerequisites thus become crucial in incorporating socioeconomic aspects into conservation.

However, understanding ecosystem resilience (resistance and recovery) is challenging for it is a slow process that might take decades or centuries. Long-term ecological information is certainly required yet often lacking. Fortunately, this knowledge gap can be filled by palaeoecology.

Aiming to assess the ecosystem resilience and to identify its key prerequisites, particularly to human disturbance, a palaeoecological study, including the analyses of pollen and spore, charcoal and carbon (C) content, is conducted on the Sungai Buluh peatland in Sumatra, Indonesia. Its vicinity to the Muara Jambi temple complex, remains of the former Malayu Empire, provides a unique opportunity to understand ecosystem resilience to human disturbance.

The palaeoecological record from the Sungai Buluh suggests that the Malayu Empire people conducted activities on the peatland that altered vegetation composition of the peatland and slightly reduced the peatland's C sequestration capacity. Nevertheless, the peatland recovered in terms of its vegetation composition and its C sequestration capacity after the cessation of human disturbance following the site abandonment.

Here, two key prerequisite for peatland resilience are identified: (i) a maintained hydrological condition, and (ii) sufficient old vegetation remnant. Socioeconomic activities thus may be permitted to be conducted on the conserved peatland as long as those activities are considered "resilience-friendly" i.e. will not significantly impact the key prerequisites of peatland resilience.

P-2857

## Late Holocene peatland permafrost aggradation-driven greenhouse gas forcing to the atmosphere, in Seida, NE European Russia

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### Abstract

Impact of the permafrost development on greenhouse gas (GHG) dynamics and climate has been scarcely studied. We applied palaeoecological methods, plant macrofossils and radiocarbon dating, to study permafrost dynamics in Seida, NE European Russia. We combined palaeoecological data with on-site GHG measurements in order to model past radiative forcing (RF) during the late Holocene. The data suggest that the widespread late Holocene landscape change associated with the permafrost development resulted in a distinct increase in GHG emissions to the atmosphere. Hence, it appears that permafrost initiation triggered by a cooling climate generated a positive, i.e. warming RF impact driven by increase in CO<sub>2</sub> emissions. The results highlight the importance of Arctic peatlands for atmospheric GHG dynamics.

**P-2858**

## **Testate amoebae from peatlands in the Alaskan continuous permafrost zone**

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### **Abstract**

Continuous permafrost peatlands represent a global carbon store of  $\sim 144$  Pg C, yet little is known about how the vulnerability of this store will change with climate warming. Multiproxy palaeoenvironmental studies of peatlands have been conducted in the discontinuous permafrost zone, but there have been no investigations in continuous permafrost, despite the uncertainty of their future as a carbon sink or source. We present the first analysis of contemporary testate amoebae from the continuous permafrost zone, from a range of peatlands on the Alaskan North Slope and create two new transfer functions for reconstructing water-table depth and porewater electrical conductivity. We then use these transfer functions to perform palaeoenvironmental reconstructions from two peat cores at Toolik Lake, Alaska.

**P-2859**

## **From bog to fen - palaeoecological reconstruction of a calcareous spring fen on Saaremaa island, Estonia**

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### **Abstract**

This study of the Kanna calcareous spring fen on Saaremaa Island (Estonia) elucidates the history of fen development and vegetation diversity over the last ca. 9200 years. Pollen, including spores, non-pollen palynomorphs, macrofossils, loss-on-ignition and humification index analyses were carried out to reconstruct fen succession, vegetation development, environmental changes and human impact. Hierarchical clustering, ordination analysis and linear regression were applied to examine the vegetation composition and richness patterns through time and to identify the potential environmental drivers underlying these patterns. Our results suggest reverse mire development (bog to fen), a rare occurrence contrary to typical mire autogenic succession (groundwater-fed to rainwater-fed). Kanna developed as a small bog for the first 2000 years from 9200 to 7200 cal yr BP. Changes to the hydrological regime around 7200 cal yr BP — due to warmer and drier climate and land uplift — caused a shift from ombrotrophic to minerotrophic environment. Typical spring fen characteristics developed ca. 5000 cal yr BP and continued until ca. 400 cal yr BP, when the fen was fed by calcareous mineral-rich groundwater and harboured different calcareous and relict species contributing to very high diversity. We conclude that general shifts in Kanna fen succession, vegetation community and diversity are associated with climatic changes. The present high-diversity of the fen is a result of a long-term stable fen environment, which may have been even higher in the past. However, the pollen richness has decreased during the last 400 years, possibly due to anthropogenic or natural factors.

**P-2860**

## **Searching for drivers of the fen-bog transition**

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### **Abstract**

During the course of their development, peatlands commonly transition from wet, nutrient-rich, methane-emitting fens; to drier, nutrient-poor, carbon dioxide-emitting bogs. These changes in wetness and trophic status represent decreasing hydrological connection between a peatland and local sources of surfacewater and shallow groundwater. Such hydrochemical changes also cause pronounced shifts in plant assemblage along a semi-predictable successional gradient, and are thus identifiable in plant macrofossil records from peat cores. It is currently unclear whether fen-bog transitions are an inevitable consequence of continued peat development raising the growing surface above local hydrological influences; or whether transitions are triggered by external drivers such as climate change. Spatial gradients in modern distributions of fens and bogs would appear to suggest a climatic control, meaning that future warming may cause changes in their distributions through altered peat accumulation rates and trophic status, with implications for greenhouse gas budgets and biodiversity. However, until now, no comprehensive database of fen-bog transitions has been available, and primary palaeoecological studies rarely consider more than a handful of sites, hindering the identification of general principles. We present interim results from an ongoing effort to develop a comprehensive database of published fen-bog transitions from around the world that will provide a basis to study the drivers of this phenomenon. Our secondary database mainly comprises study sites from North America and northern Europe, but also contains sites in Arctic Russia, Patagonia and southern Europe. In the majority of study sites, high quality plant macrofossil records reported in the primary literature allow us to identify a three-stage sequence of rich fen, poor fen, bog. In other cases, lower quality data allow us only to distinguish between herbaceous and bryophytic macrofossil zones. In all cases, we have estimated the ages of transitions by respecifying age-depth relationships using the original chronometric data reported alongside macrofossil records. Once completed, our database may become a valuable resource for peatland palaeoecologists. We plan to analyse the database using independent metrics of palaeoclimate change to identify any climatic triggers for fen-bog transitions.

**P-2861**

## **Multi-proxy approaches for the reconstruction of past palaeoenvironmental changes in Scotland: Piecing together Pictish social/environmental transitions from peat deposits**

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This preliminary paper aims, through detailed environmental analysis (pollen, NPP, a strong chronology (eight  $^{14}\text{C}$  ages) and XRF analysis) to expand our understanding of Pictish settlement, landscape and land-use during the early medieval period. A 1.86 m core was extracted from a valley fen adjacent to the Waters of Bogie, slightly south of the village of Rhynie in north-eastern Scotland, and within 270 m of a Pictish settlement and Crow stone dated to the 6<sup>th</sup> century. The bottom of the core produced a calibrated age of AD 260-415 and all but one of the radiocarbon dates are in good chronological order. Initial pollen counts have revealed relatively good preservation with a number of distinct changes in the vegetation record. Most of these changes appear to be associated with natural environmental transitions linked to a weakening in fluvial/stream energy after the 12<sup>th</sup> century and a gradual accumulation of peat, although some evidence also suggests agricultural activity.

In the archaeological record evidence, from the nearby Pictish settlement, highlights high status metalworking as well as a range of Continental imports (e.g. late Roman Amphora pottery and fragments of imported glass drinking vessels from western France), signifying that Rhynie was an important power centre during the early Medieval period. A series of radiocarbon dates and Bayesian modelling however indicate only a short phase of construction and use during the late fifth to mid-sixth centuries. What is particularly interesting about the palaeoecological results is that there is evidence of cereal pollen and a pronounced representation of herbivore dung fungi throughout the record, which suggests continuity of farming activities from AD 260-415 onwards, despite the 6<sup>th</sup> century abandonment of the Pictish settlement.

P-2862

## Holocene alluvial peatland dynamics in Flanders, Belgium

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### Abstract

Rivers and alluvial floodplains are dynamic environments that experience natural and anthropogenic impacts. Sustainable management of these ecosystems requires a thorough understanding of the functioning of floodplains and their sensitivity to changes in internal and external driving forces. During the Early and Middle Holocene, most NW European floodplains were stable environments with limited floodplain aggradation resulting in the formation of peat. During these times, floodplains consisted mainly of large marshes where peat accumulated and river channels were absent or small. During the Late Holocene these environments changed completely towards single channel meander rivers with overbank deposits, and peat accumulation disappeared. Although this general framework of Holocene alluvial peatland evolution has been well established in previous research, it is still uncertain how these peatlands are controlled by internal and external drivers (such as topography, climate and human impact) and how the initiation date, growth rate and end date of peat growth are influenced by these drivers.

Four river catchments in Flanders were selected in this study, with varying soil properties, topography, and duration and intensity of human impact. The Dijle catchment (750 km<sup>2</sup>) is located in the central Belgian loess belt, the Mombeek catchment (90 km<sup>2</sup>) in the sandy loam region, and the Grote Nete (525 km<sup>2</sup>) and Zwarte Beek catchments (50 km<sup>2</sup>) in the sandy Campine region. A multi-proxy approach, including sedimentological proxies, pollen, macrobotanical remains and testate amoebae was chosen to reconstruct peatland characteristics and changes in external drivers. A database of 176 radiocarbon dates ranging over the different catchments was used to provide a chronostratigraphic framework.

Radiocarbon dating results show that alluvial peat growth started at the beginning of the Holocene. End dates are highly variable both within and between different catchments, varying from 6000 cal. BP to present-day. This variability can be explained by differences in floodplain connectivity and local differences in initiation and intensity of human impact in the catchment, as shown through the statistical analysis of regional pollen data. Peat accumulation rates are controlled by local variations though. The accumulated peat can be of different types, both *Carex* peat and *Sphagnum* peat can be found in alluvial peatlands, and a change of peat type can occur over time, mainly driven by local floodplain changes, as is shown by the comparison of macrobotanical data with pollen data. To assess the influence of differences in hydrology on peatland evolution, testate amoebae analysis was conducted, however poor preservation of these amoebae in alluvial peat hampered clear results. This in turn, leads to unreliable water table depth reconstructions for alluvial peatlands.

Overall, the study clearly indicates that a multi-site and multi-proxy approach is needed to fully grasp the Holocene evolution of alluvial peatlands and all driving factors involved.

P-2863

## A regime shift from erosion to carbon accumulation in a temperate northern peatland

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### Abstract

Peatlands are globally-important ecosystems but many are degraded. In blanket peatlands, degradation often occurs as erosion, which results in loss of carbon and important habitats over centennial timescales. It is often assumed that, once initiated, erosion will continue until all of the original peat mass has been removed. However, some peatlands are undergoing spontaneous recovery, with switches from erosion to renewed carbon accumulation, a type of ecological regime shift. It is not always clear why recovery occurs or the degree to which peatland ecosystem services are restored. We used palaeoecological techniques to chart the spontaneous recovery of an eroding blanket peatland in North Wales, UK and identify candidate mechanisms responsible for the regime shift. Key questions we address are: i) When did the spontaneous recovery start and what are the possible mechanisms? ii) What successional processes have occurred? iii) Have water levels changed or remained stable since the spontaneous recovery? iv) How much peat (and associated carbon) has accumulated since recovery started?

We present high-resolution plant macrofossil and testate amoebae data, alongside detailed analysis of peat characteristics and a chronology based on <sup>14</sup>C and <sup>210</sup>Pb dating. There is evidence of rapid accumulation of peat after the initiation (e.g., 27 cm peat in  $88.6 \pm 4.02$  years) with a range of successional pathways in peat-forming vegetation (e.g. *Sphagnum fallax* with *Juncus*, *S. fallax* with *Cyperaceae*, *Polytrichum*). Water-table depth reconstruction from testate amoebae indicate moderate-high water tables, with some evidence of standing water, typical of blanket peatlands. Possible causes of spontaneous recovery are linked to land use (e.g., reduction in grazing and burning), external factors (e.g. climate, air pollution), and internal changes to the system (e.g. active erosion causing changes in peatland meso-topography providing a setting for peat-forming vegetation such as *Sphagnum* to re-establish). Our findings contribute to understanding the future responses of peatlands under a changing climate and a wider understanding of ecological regime change.

P-2864

## Dynamic Holocene vegetation and North Pacific hydroclimate reconstructed from a mountain peatland, Molokai, Hawaii

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### Abstract

An organic sediment core from the montane peatland Pepeopae on the Island of Molokai, Hawaii was studied for multi-proxy evidence of ecological and hydroclimatic change. Following a period of soil development, substantial carbon accumulation and the onset of organic matter stabilization began around 10 ka BP (thousands of years before present) under wet conditions. Continuous but variable peat formation was sustained throughout the Holocene, including maxima in carbon accumulation around 9 and 3 ka, that has resulted in a belowground carbon storage today of 144 kg C m<sup>-2</sup>. Using sedimentary *n*-alkane chain length distributions, bog vegetation inputs to the peat was assessed in the context of 14 species of modern bog plant *n*-alkanes. Organic matter was not formed by litter inputs from a single plant type or types, but inputs shifted dynamically in their dominance in response to climate. We generated a new chronology for previously-published pollen data from the study site, which showed a similar tempo and response of vegetation change in the forests upwind of the peatland. Hydrogen stable isotope ratios of sedimentary C<sub>29</sub> *n*-alkanes show negative departures around 9ka and 3ka consistent with increases in storm-derived rainfall. Comparison of Holocene hydrogen isotope values from a contrasting mountaintop site on the Island of Oahu show a similar pattern, but differences in timing that relate to North Pacific atmospheric circulation.

P-2865

## One millennium of human-environment interactions recorded in the Świąte mire (western Poland, Central Europe) – preliminary results

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### Abstract

Over the last decades, historians have faced the necessity of reconstruction of land-use and settlement history not only through the study of the historical and archaeological sources but also by means of paleoenvironmental data. However, the deficiency of high-resolution multiproxy data hampers linking these approaches. This collaborative study creates new opportunities for combining palaeodata with historical sources. The aim of our study is to reconstruct the vegetation changes along with the progressing human impact accompanying the Polish state development. In this high-resolution multiproxy study, we focus on the Świąte fen, located in western Greater Poland (69 km south from Poznań) from which we retrieved 212-cm peat core that dates back to ca. AD 1100. We carried out pollen, plant macrofossil, charcoal, and selected non-pollen palynomorph (NPP) analyses continuously in a 1-cm resolution. Moreover, non-aquatic deposits were analyzed in terms of testate amoebae (TA) content in 2-cm intervals. The mire is characterized by relatively high peat accumulation rate along the entire length of the profile (average: 2.3 mm/yr). From ca. AD 1100 to 1380 the area possessed calcium-rich open water with the floating mosses, such as *Pseudocalliergon trifarium* and *Sphagnum cf. auriculatum*. At the same time, the share of herbs and Cyperaceae was the highest in the entire profile. In this period the occurrence of TA such as *Centropyxis aculeata* and *Arcella intermedia* could have confirmed telmatic habitat. This stage of the fen development was followed by an establishment of *Sphagnum magellanicum* (until AD 1970) and *S. angustifolium*, as well as *Eriophorum vaginatum*. This transition is simultaneous with changes in TA assemblages as reflected by an expansion of *Cryptodiffugia oviformis*, *Archerella flavum*, and *Hyalosphenia papilio*. From ca. AD 1620 up to 2015 *C. oviformis* dominated in TA communities which indicates stable but relatively low water table. From ca. AD 1785 the coring spot dominated by *Sphagnum fallax*, which points to the transition to lawn/carpet vegetation. These conditions were not appropriate for *Archerella flavum*. On the other hand, *Euglypha rotunda*, *E. compressa*, and *Physochila griseola* revealed the co-occurrence with the *S. fallax*. During the last 100 years, the forests were dominated by *Pinus sylvestris* and *Betula* which is an effect of the modern silvicultural activity. These data will be supplemented by historical sources in the future. Research financially supported from the funds of National Programme for the Development of Humanities (Project: NPH012; PI: Piotr Guzowski).

P-2866

## Indicative values of non-pollen palynomorphs in modern peat samples versus palaeorecords - an example from three raised bogs in northern Poland

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### Abstract

High-quality studies of past environmental changes require complementary proxies and continuous sediment profiles. Raised bogs preserve well various subfossils in the oligotrophic peat. We focused on 3 peat cores from ombrotrophic bogs located in northern Poland, along the gradient of increasing continentality (Bagno Kusowo, Gązwa and Mechacz Wielki, respectively). The results of earlier analyses of pollen, testate amoebae (TA), and plant macrofossils were supplemented with non-pollen palynomorphs (NPPs) and additional AMS radiocarbon datings. To further facilitate the interpretation and discussion of results regarding bogs' development, hydrological and vegetation changes, we included data from 90 surface samples, collected in 2015 from the same bogs as cores. The samples represent different microhabitats such as hummocks, hollows, small pools, *Sphagnum* patches in forests, and overgrowing drainage ditches and they vary in regard to modern vegetation. During the collection of samples, additional information about pH, geochemistry, water level, canopy density and vegetation cover (within the frame 50 x 50 cm) was collected. The main aim of the research was to interpret the relationships between NPPs and environmental conditions, including modern samples and palaeorecord. The preliminary results of RDA from the modern pollen and NPP dataset revealed a positive correlation between *Assulina muscorum* (HdV-32A) and HdV-96A and DWT (depth to the water table), whereas a negative correlation was reflected by *Archerella flavum* (HdV-31A). The latter taxon together with a fungal type HdV-90 and *Sphagnum* spores also displayed a negative correlation with the canopy density. In data retrieved from peat cores, Bagno Kusowo and Mechacz Wielki recorded similar patterns of NPPs in relation to DWT, pH, and vegetation. In general, in both sites an increased abundance of humic substances was strongly correlated with the presence of macrofossils of *Eriophorum vaginatum*, *Sphagnum fuscum/capillifolium* and Ericaceae and fungal NPPs *Gelasinospora* sp. (HdV-1), *Chaetomium* (HdV-7A), and HdV-73. However, they were negatively correlated with DWT i.e. their occurrence was related to rather wet conditions. Fungal spores HdV-8B, HdV-123 and HdV-126 corresponded to herbal macroremains whereas HdV-18, HdV-19, and HdV-182 were correlated with more acidic conditions. Different patterns were reflected by the Gązwa bog. In this profile, a positive correlation between the presence of decomposed peat and *Eriophorum vaginatum*, *Sphagnum fuscum/capillifolium* and Ericaceae was not as prominent as in other peatlands. Moreover, DWT was also correlated with the presence of decomposed peat and Ericaceae macrofossils. Fungal NPPs HdV-13 and HdV-96A were linked with the occurrence of Ericaceae macrofossils, whereas *Assulina seminulum* (HdV-32B) and *Geoglossum sphagnophilum* (HdV-77A) were related to higher pH values. Our study reveals that individual history of *Sphagnum* peatland development may enrich interpretations explaining the distribution and ecology of NPPs. Research is financed by the National Science Centre, grant no. UMO-2014/13/B/ST10/02091.

P-2867

## The potential of rich fen testate amoebae communities for the quantitative palaeoecological inferences - an example from Polish lowlands

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### Abstract

Most palaeoecological research applying testate amoebae (TA) as a proxy are conducted on ombrotrophic bogs, which are believed to be more suitable for palaeoclimatic studies. Only several studies regarded the entire oligotrophic-eutrophic gradient that provided novel data on the TA diversity and their habitat preferences in the past. In our study, we focus on a rich fen located in the vicinity of Lake Kazanie in Greater Poland. The exceptional diversity of testate amoebae (over 100 taxa recorded in a 92 cm long profile) gave us an opportunity to fully investigate the transformations of this fen in the last 300 years. The rich fen that developed in place of the terrestrialized lake was dominated in the past by brown mosses *Scorpidium cossoni* and *Pseudocalliergon trifarium*. Among TA, the most numerous were the representatives of *Centropyxis* sp. (with rare *C. delicatula*), *Diffflugia* sp., *Pyxidicula* sp., *Arcella discoides*, *Heleopera petricola*, *Hyalosphenia platystoma*, *Microchlamys patella*, *Paraquadrula irregularis*, and *Parmulina obtecta*. The transition to poor fen conditions in the coring spot took place about 30 years ago when *Sphagnum* mosses (mostly *S. fallax*) spread, contributing to the increase in the peat accumulation rate (from average of 0.15 mm/yr to 1.1 mm/yr). Simultaneously, as quantitative TA-based reconstructions reflected, the water level started to decrease gradually, which might have been connected with some drainage works, and a conductivity dropped, which suggests more acidic conditions. The expansion of *S. fallax* contributed to the appearance and/or spread of *Euglypha* ssp. and *Nebela* ssp., as well as of *Assulina muscorum*, *Corythion dubium*, *Heleopera rosea*, *Pseudodiffflugia* sp., and the regular presence of *Trinema lineare* and *T. enchelys*. In the period of *Pseudodiffflugia* sp. dominance, the prominent decline of TA diversity was recorded. Nowadays the Kazanie fen is mostly overgrown by *Phragmites australis* and *Sphagnum* mosses persist only in the margin areas, among them the coring spot. Hence, other strong shifts in TA taxonomic content and diversity are highly probable in near future on the entire fen surface. Our study provides a rare and intriguing reconstruction of extremely rich fen to poor fen transitions and illustrates well the differences between TA communities occupying acid bogs and alkaline fens. It also stresses the fact that fens appear much more complex and multidimensional habitats for TA. To explain the mechanisms driving TA diversity of fens, which are still poorly recognised, further studies are needed. Such studies are highly important for the predictions regarding the future of valuable but disappearing rich fens in Europe. Research financially supported from the funds of National Programme for the Development of Humanities (Project: NPH012; PI: Piotr Guzowski).

P-2868

## Holocene carbon storage of alluvial peatlands in contrasting river systems

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### Abstract

Reconstructions of peatland carbon stocks and its variability over spatial and temporal timescales can provide important information on the factors governing local peatland dynamics and the carbon storage. Alluvial wetlands contain high amounts of carbon, mostly under the form of peat deposits, and constitute a common peatland type in temperate climates. Throughout the Holocene, most river systems in Europe have known phases of peat formation, but their long-term dynamics in relation to climatic and land cover changes remain poorly understood. In contrast to the high-latitude regions, which have been studied more intensively, human impact in temperate Europe through land cover changes has been much more intense and spread over a longer period of time and might prove to be an important factor in floodplain peatland formation. This study aims to study the Holocene evolution of floodplain peatlands in temperate river systems and to quantify the carbon storage.

In this study, four medium-sized river catchments (< 1000 km<sup>2</sup>) were studied, covering a range of climatic and environmental gradients and varying in degree and timing of human impact. Specifically, the sites were selected in Belgium, in the loess belt (Dijle catchment) and the sandy Campine region (Grote Nete and Zwarte Beek catchment) and in Scotland (upper Dee catchment). To make a detailed reconstruction of the floodplain architecture, soil corings were made along floodplain cross-sections. Combined with soil samples and radiocarbon dating, the Holocene geomorphic evolution could be reconstructed and the phases of active peat growth could be identified.

Overall, the results indicate that the long-term evolution of the fluvial system and the carbon storage is different for each of the regions. As the studied rivers respond differently to the complex interplay of climate, land cover and human impact, a variety of case studies is needed to study the long-term evolution of floodplain peatlands. The floodplains of the Dijle for example were covered by peat-forming alder forest during the Early Holocene. Later, hillslope erosion due to agricultural practices has led to a geomorphic transition towards meandering rivers and a reduction in the floodplain carbon storage. In contrast, floodplains in the Scottish Highlands have known more recent peatland formation, due to a reduction in fluvial geomorphic activity. Overall, the mean carbon storage ranges from 32 kg C m<sup>-2</sup> for the Dee to 66 kg C m<sup>-2</sup> for the Zwarte Beek, with a strong variability within each river system. In general, these case studies indicate that floodplain peatlands are difficult to model, since local peat growth models are insufficient to explain the observed dynamics. Additionally, upstream hydrology and geomorphological dynamics need to be accounted for.

**P-2869**

## **Peatland responses to repeated tephra deposition**

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Throughout the Holocene, Icelandic peatbogs have suffered repeated tephra fall events from volcanic eruptions. Large plinian eruptions have created key isochrones across Iceland, depositing metres of tephra on peatbogs proximal to the source volcano, thinning out over others across the island. This research has explored peatland response and resilience to this external driver from a number of sites across Iceland, using a palaeoenvironmental approach coupled with classical tephrochronology.

The frequent visible tephra layers found in Icelandic peatbogs, combined with radiocarbon dates, has provided robust chronological frameworks. These well support palaeoenvironmental investigation and allow sites hundreds of kilometres apart to be easily stratigraphically correlated. Data shows that the tephra events have been a driver for peatland dynamics and destruction, effecting peat initiation, accumulation, hydrology, and ecology. These results may be used to better understand the vulnerability of modern Icelandic peatbogs to volcanic eruptions and other external drivers such as human impacts and climate change.

P-2870

## Reconstructing Holocene carbon accumulation within two upland peat bogs in SW Wales: assessing the human and climatic impact

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### Abstract

Peatlands represent an important component in the global carbon cycle, storing ~ 30% of belowground carbon, and in Wales (UK) peatlands are the largest terrestrial carbon store<sup>[1]</sup>. However, centuries of persistent human interference have led to ~ 75% of Welsh peatlands becoming degraded<sup>[1]</sup>. This degradation has destabilised peatland carbon stocks and resulted in Welsh peat becoming a source of anthropogenic CO<sub>2</sub> emissions, estimated to be producing ~ 400 Kt CO<sub>2</sub> equivalents per year<sup>[1]</sup>. The impacts of recent human activity, alongside the threat of projected climatic changes, has brought peatland restoration to the forefront of the national environmental agenda. The Carmarthenshire peatlands, a series of six upland bogs in SW Wales, have frequently been subjected to burning and drainage, and their southerly, marginal position puts them at further risk under a warming climate. Using an innovative multi-proxy palaeoenvironmental approach, and in collaboration with Carmarthenshire County Council, this study is the first to reconstruct temporal carbon accumulation rates in response to human and climatic impacts, to inform appropriate conservation strategies. The work is focused on the two sites with the deepest peat depths, Pyllau Cochion and Figyn Common. At Pyllau Cochion, an age-depth model, constrained by 10 radiocarbon dates, is calculated against carbon content to provide a time weighted 'apparent' peat carbon accumulation rate (CAR)<sup>[2]</sup>. This produces an average CAR value of ~ 21 (g C m<sup>-2</sup> yr<sup>-1</sup>), comparable to other northern hemisphere Holocene rates. Carbon accumulation has varied substantially since peat initiation (*ca.* 9800 cal yrs. BP), with the highest rates observed during the Middle Holocene, succeeded by an overall declining trend towards lower values, with an especially pronounced reduction in recent times (*ca.* 700 cal yrs. BP – present). The lowest values in recent times are accompanied by an increase in burning activity and there is an indication that earlier fluctuations in carbon accumulation are associated with shifts in surface wetness. The results are compared to the nearby Figyn Common record. This research has contributed to a Heritage Lottery funded project that centred on implementing conservation measures and promoting public understanding of the sites. This includes a series of artistic impressions, from the Younger Dryas to the present day, that are underpinned by the proxy reconstructions.

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**P-2871**

## **Mid-late Holocene pollen records from the forest-steppe ecotone of the Mid-Russian Upland: Vegetation and fire history, human impact**

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### **Abstract**

Little is known about the history of the forest-steppe ecotone in Eastern Europe and here we report on its dynamics over the past ~7000 cal yr BP. A multiproxy research on peat deposits from several state nature reserves located within the Mid-Russian Upland, European Russia was carried out. Proxies used included pollen and non-pollen palynomorphs, plant macrofossils and micro charcoal particles in combination with radiocarbon datings and estimations of forest cover using the best modern analogue technique.

The data show that during the mid-Holocene (7000-4500 cal yr BP) the dominated landscape was wooded steppe and the boundary between forest and steppe biomes was disposed of 50-70 km further north-west in comparison to its present position. The boundary shifted to the south following climate cooling and an increase in precipitation during the period from 4800 to 2500 cal yr BP. Both birch-pine and mixed temperate deciduous forests of oak, elm, ash and lime with Scots pine and well-developed shrub understory of hazel and alder grew in the region. Over the past 4000 cal yr BP, the total woodland coverage has varied insignificantly, ranging from 30 to 50%, while the structure of the forests has changed radically. Intensive agricultural colonization of the territory accompanied by enhanced burning, soil erosion, felling of trees led to an irreversible reduction of deciduous forests and their replacement by secondary birch with total deforestation during the last 200-400 years.

Three main periods of frequent fires are identified: 3900-3200 cal yr BP, 2000-1600 cal yr BP (Early Iron Age), 1000-400 cal yr BP (Medieval period).

Nowadays the remnants of the primary forest-steppe vegetation are persisted in small locations only and under state protection.

P-2872

## Refining the calibration of oxygen stable isotopes as a proxy for the Southern Annular Mode in New Zealand restiad peatlands

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### Abstract

The Southern Annular Mode (SAM) is a key control on Southern Hemisphere (SH) climate. It has had a positive trend since the 1950s, but its long-term behaviour is poorly understood. Developing reliable SAM reconstructions is critical to understanding SH climate but there are few appropriate land areas from which reconstructions can be derived. New Zealand (NZ) is a sensitive location for detecting past changes in the SAM due to the competing influences of temperate (dominated by the SAM) and sub-tropical climates. Developing a robust insight into past SAM behaviour requires proxies for both temperature and precipitation in order to elucidate regional variations in climate drivers and responses. Stable isotope ratios of carbon and oxygen have the potential to provide such a dual approach, however it is imperative that proxy development is grounded in a mechanistic understanding of the contemporary processes that result in isotopic fractionation and underpin palaeo interpretation.

We previously tested relationships between carbon and oxygen stable isotope ratios in restiad plant cellulose with climate and hydrological variables in NZ to investigate their potential as palaeoclimate proxies in Holocene age peat deposits formed predominantly of *Empodisma* spp. root remains. Here, we refine the calibration and interpretation of the oxygen isotope proxy for precipitation moisture source. We have expanded the spatial and temporal extent of our calibration dataset and, following cryogenic vacuum distillation, additionally analyse the isotopic composition of internal plant waters to better determine and understand plant physiological and isotope fractionation processes. We found precipitation, peatland water and internal plant water to be clearly linked, meaning that source waters for cellulose synthesis are well-defined. Mechanistic modelling using source waters to predict root cellulose isotope values is effective, and correlations between source waters and root cellulose isotope values are significant, but only when an average of internal root and shoot water inputs is used, suggesting that *Empodisma* mobilises sucrose from both roots and shoots to form root cellulose. These results improve our understanding of the physiological and isotopic processes governing cellulose synthesis, providing a more robust foundation for interpretation of the oxygen stable isotope proxy in a palaeo context.

P-2873

## The colour of Draftinge Mosse peatland, Sweden

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### Abstract

Colour is a physical property of light as seen by the human eye. It has been traditionally used to approach, for example, the degree of humification (DPH) and plant remains in peat. To avoid the subjectivity inherent to an individual's perception, parameters defined according to colour spaces, such as CIE Lab, are used. The colour-metric of peat provides an alternative non-destructive and rapid method to study its physical characteristics and obtain information on peat/peatland evolution and environmental drivers.

Freeze-dried and milled peat samples (n=160) from a core collected from Draftinge Mosse (Southern Sweden), spanning the last ca. 8,300 years were measured for colour. Usual CIE Lab parameters: L\* (luminosity), a\* (green to red), b\* (blue to yellow), C\* (chroma) and h\* (hue), were obtained with a Konica-Minolta CR-5 colorimeter. Other analyses available for this core (n=76) include total C and N, C/N ratios, isotopic composition ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ), and a FTIR degradation index (Cb/Lp, carbohydrates/lipids), which allow us to assess the colour results. The studied core can be divided into two main sections according to peat composition, a fen phase and a bog phase.

CIE Lab coordinates, L a\* b\*, and C\* are highly correlated between them (0.73 to 0.99). Hue is only correlated negatively with a\* (-0.63). In general, the colour of the peat varies from very dark brown to dark brown (from 46.8 to 22.38) and chromaticity is low (C\* from 8 to 21). The peat composition seems to have an influence in the colour, the fen showing lower L\*, a\*, b\* and C\* and higher h\* than the bog.

The colour parameters, except for h\*, were negatively correlated (-0.50 to -0.76) to C, N and  $\delta^{15}\text{N}$  and positively correlated (0.68 to 0.78) to the Cb/Lp index and  $\delta^{13}\text{C}$ : the colour gets darker and less chromatic as C, N and  $\delta^{15}\text{N}$  increase, and Cb/Lp and  $\delta^{13}\text{C}$  decrease (i.e. as peat decomposes). The hue (h\*) is moderately correlated to N (0.58) and age (0.64), which means the peat became brownish with time. The a\* parameter is also inversely related to age. We interpret the obtained results as indicative of 1) a long-term control by decomposition (mainly a\* and h\*), and 2) a climatic-controlled decomposition that occurred under decreased or increased wetness, when the peat section was at, or near, the surface of the bog. This shows that quantified colour studies are viable tools for studying decomposition in peatlands.

**P-2874**

## **Geochemical indication of paleoenvironmental changes during the formation ombrotrophic bogs of the South of West Siberia (Russia) in the Holocene**

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### **Abstract**

A characteristic feature of Western Siberia is a lot of eutrophic marshes with inclusion some ombrotrophic bogs, alkaline meadows, solontchaks, as well as lakes, different in size, shape, origin and extent of salinity. According to the research (Larina et al., 2013, 2014) ombrotrophic bogs began to form in Subboreal-Subatlantic periods of Holocene in this area. Beginning of formation water meadow dates from the early to mid subboreal period. Low-power peat deposits were formed at the beginning of Subatlantic period of the Holocene. In regard to the stratigraphic thickness of peat are relatively uniform. Lake sediments often are placed at the basis, and then a layer of lowland peat goes, which is replaced by high peat, sharply or gradually, through a horizon transitional peat. Capacity of the individual horizons may differ due to local factors that determine the rate of peat accumulation. The average rate of vertical growth of peat in Subboreal Subatlantic-Holocene period, calculated from the radiocarbon dates obtained from peat bogs and water meadow Tobol-Ishim forest-steppe, is 0.8 mm / year. The rate of growth of peat is not constant and can change considerably in the separate time intervals.

Geochemical characteristics some of peat bogs were investigated to assess the biogeochemical conditions in the different periods of the Holocene, to identify local, regional and global signal of anthropogenic environmental impact. They reflect the different temporal features organo-accumulation of soil formation, biogeochemical migration of the elements, climate change and vegetation during the Holocene, as well as the specifics of the modern stage of formation of peat.

Geochemical analysis of peat deposits is a source of information on the rate of accumulation and decomposition of organic matter, which are determined by various factors, including climatic and environmental. Indicator of dynamic and direction of these processes can serve as a study finding forms of organic matter in the peat. Fractionation was carried out for some purpose samples of peat, selected from different depths and with different genesis. In selected fractions of humic and fulvic acid were identified stability constants for carboxyl, carboxyl -phenolic and amine-phenolic groups with using potentiometric method. The presence of these groups was confirmed by IR spectroscopy.

Another important indicator of environmental and climatic changes is the concentration of heavy metals that flow into peat deposit mainly from rainfall and long-range Eolian dust. Form finding of metals in peat is also important. This determines the migration ability of metals in peat deposits and sources of metals.

Combination of methods allows reconstructing the conditions, when the peat layers formed.

### **ACKNOWLEDGEMENT**

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P-2875

## Hawaiian paleohydrology: insights from testate amoebae and Cladocera in peatland deposits

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### Abstract

Few high-resolution paleoclimate records exist for the Hawaiian Islands and available records are primarily derived from proxies of vegetation, which are challenging to untangle from human activity in recent centuries. It is critical to develop independent proxies of ecohydrological dynamics to give context to ongoing changes in biodiversity and climate on the islands. Fossil remains of testate amoebae (Protozoa: Rhizopoda) and Cladocera (water fleas) have been used as environmental indicators in paleohydrological studies of temperate and boreal peatlands, especially those dominated by *Sphagnum*. We present the first use of this proxy in tropical montane peatlands in Kohala, Hawaii Island and apply it to a case study of peatlands in Kohala recently dominated by *Sphagnum* moss. Peatland surface soils were collected from a variety of ecohydrological habitats (from water pools to hummocks) and analyzed for modern testate amoebae and Cladocera. We identified 51 taxa from 21 genera of testate amoebae and 4 taxa and genera of Cladocera. Multivariate analysis indicates that the presence and abundance of testate amoebae and Cladocera taxa are significantly controlled by water table depth. A transfer function based on weighted averaging was developed to predict water table depths from species relative abundance data: RMSEP = 9.87 cm,  $r^2 = 0.58$ . We applied the transfer function to a series of peatland cores from Kohala to reconstruct a thousand year history of water table depth fluctuations and to examine the recent (~150 years ago) expansion of *Sphagnum palustre*. Testate amoebae and Cladocera inferred paleohydrological reconstructions show that arid conditions between 1840-1860 and following the 1977-76 winter Pacific Decadal Oscillation shift preceded expansion and establishment of *Sphagnum* moss in Kohala peat. The peat-based paleohydrology is supported by a five-century reconstruction of Hawaiian winter rainfall derived from ENSO teleconnections. The results highlight the potential of utilizing testate amoebae and Cladocera to estimate paleohydrology from peatland deposits in tropical montane ecosystems.

P-2876

## Holocene climate and permafrost history for the western Kenai lowlands, Alaska, from stable isotopes and plant macrofossils

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### Abstract

The current state of permafrost in Alaska and meaningful expectations for its future evolution are informed by long-term perspectives on previous permafrost degradation. South-central Alaska currently has a mean annual temperature of  $\sim 2^{\circ}\text{C}$  and is typically mapped as permafrost free. However, residual permafrost is known to persist in wetlands with spruce protected permafrost plateaus. In the Browns wetland complex of the western Kenai lowlands, two  $\sim 600$  cm cores were obtained within a permafrost plateau in 2014 and the ice-rich peat record was found to span the past 12,000 years. The oxygen and hydrogen isotope ratios of the frozen pore water reflects freeze/thaw and paleoclimatic history that can be integrated with lithology, cryostructural analyses, and macrofossil assemblages. Results indicate rapid peat accumulation and syngentic permafrost development in an early fen system by 12,000 cal yr BP that became a bog by  $\sim 11,500$  cal yr BP. By  $\sim 9,000$  cal yr BP an abrupt shift in lithology to ice-poor silt reflects some combination of a decline in peat accumulation, increase in peat decomposition, and/or hiatus. Pore-water isotope compositions indicate thaw unconformity and/or stagnant multi-annual active layer depths. Resumption of peat accumulation by  $\sim 3,700$  cal yr BP includes brief shifts in fen and bog macrofossil assemblages that could indicate periods of thaw. They co-occur with epigenetic cryogenic textures and steady declines in pore water isotope ratios that reflect an overall cooling trend along with a shifts in atmospheric circulation indicated by other regional records. Similar isotopic trends are evident from the bulk peat cellulose isotope record from nearby Horse Trail Fen and broader geographic comparisons are also made with newly developed lake sediment isotope records from Upper Cook Inlet. As the first continuous post-glacial record of water isotopes from an Alaskan peatland permafrost that links the evolution of ground ice with climate trends, this study provides a framework for future investigations of paleoclimatic signals from similar wetland systems that characterize large regions of Alaska and Siberia.

P-2877

## Climatic controls on peat swamp formation and evolution since 1300yr BP as recorded by phytoliths in the Xishan Mountains, China

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### Abstract

Over the past millennium, there have been several precipitation–temperature cycles characterized by instabilities in the eastern monsoon region in China, but the processes, factors, and anthropogenic activities potentially responsible remain poorly understood. In this study, we present an analysis of phytoliths from borehole core drilled through an ombrotrophic peat mire in Jiangxi Province, China. Our results records three climatic episodes over the past 1300 yr: a warmer interval, c. 800–1305 A.D., similar to the Medieval Warm Period (MWP); a cooler interval, c. 1305–1860 A.D., similar to the Little Ice Age (LIA); and another warmer interval, as the climate entered the Present Warm Period (PWP) after c. 1860 A.D. Quantitative analysis of phytolith assemblages demonstrate that the MWP comprised two intervals: the early MWP, c. 800–1140 A.D., was progressively wetter in a warm–dry setting and late MWP, c. 1140–1305 A.D., was warm and humid. The LIA also comprised two intervals: the early LIA, c. 1305–1610 A.D., was cool and dry, and the late LIA, c. 1610–1860 A.D. was cool and humid. Some abrupt climate events occurred at: (1) c. 1050, 1110–1130, and 1780–1845 A.D. (wet events); (2) c. 1980–1990 A.D. (dry events); (3) c. 920 and 1770 A.D. (warm events); (4) c. 980 and 1050 A.D. (cold events). The transition from the MWP to the LIA, as indicated by phytoliths, was a gradual process that took c. 100 yrs, and exhibited frequent temperature fluctuations. Correlations between the phytolith assemblages and the solar activity, East Asia Summer Monsoon, El Niño, and La Niña are evident. Solar maxima and La Niña-like conditions are related to warmer and humid conditions that led to clay–sand accumulation during the MWP. Solar minima and El Niño-like conditions were associated with a cold and wet climate that led to peat accumulation during the LIA. These observations provide important insights into paleoclimatic change in the eastern monsoonal region of China. It provides reliable information to analyze the response of the Xishan Mountains in SE China to the MWP and LIA, which is helpful to explore the 100-year-scale climate fluctuations and potential mechanism in the scenario of global changing.

Keywords: Paludification; Medieval Warm Period; Little Ice Age; Abrupt climate events; Climate transition; Swamp evolution

**P-2878**

## **Quaternary evolution of the Upper Yellow River: progressive drainage of formerly endorheic Tibetan Plateau basins**

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### **Abstract**

The existence of endorheic drainage basin systems high on the NE Tibetan Plateau, while surprising, can be explained in relation to the 'basin-and-range' structure imposed upon the upland block by the nature of the tectonism that created it, there being a series of elongate basins of various sizes separated by mountain ranges formed from resistant rocks. Many of the basins on the NE Tibetan Plateau, although endorheic earlier in the Quaternary, have been 'captured' by drainage to the ocean, in particular by the Yellow River (Huang He). This has led to 'inversion' of these basins, with a striking change from sediment accumulation to incision by the river and its tributaries into the basin-fill deposits. The progress and timing of the incision is recorded by the disparate terrace sequences in the various basins. The Yellow River drains a succession of basins from its upper reaches to its lower course across the North China Plain: the Yueguzonglie, Zaling, Eling, Zoige, Xinghai-Tongde, Gonghe, Gui-de, Xunhua, Longzhong, Zhongwei-Zhongning, Yinchuan, Hetao, and Fenwei basins, generally connected by gorge-reaches through the intervening hard-rock mountain ridges. The fact that different basins are at different stages of dissection is perhaps key to understanding the evolution of the Yellow River drainage system, a topic that has been debated for many years. There is continuing uncertainty about whether basins have become linked to the oceanic drainage as a result of headward erosion ('capture') or because the fluvio-lacustrine basins have overflowed, either because they have become filled or as a result of tilting caused by lateral variations in uplift of the Tibetan Plateau.

P-2879

## HOLOCENE CLIMATE PULSES AND MARINE REGRESSIONS TRIGGERING FLUVIAL ADJUSTMENTS IN THE NORTHERN LITTORAL OF THE RIO DE JANEIRO STATE, BRAZIL

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### Abstract

In this work, we seek to investigate the connections between the low terraces genesis and marine regressions events induced by Holocene climate pulses. We used absolute dating by optically stimulated luminescence and grain-size analyses in 10 samples collected on low fluvial, marine and marine terraces located on the left (4 samples) and right banks (6 samples) of the Paraíba do Sul river. The low fluvial-marine terraces present sandy fraction decrease up to top (160 cm: 98%; 100 cm: 17%; 50 cm: 5%). Meanwhile, in the low fluvial terraces are predominantly clayey fractions (ranging from 93.8% to 65.8%) and the marine terrace, predominance of the sandy fractions (99%). In general, the low terraces are topographically staggered towards the sea, ranging from 13 to 2 meters above the RSL. Thus, the low fluvial terraces are located about 13 meters, the fluvial-marine and marine terraces around 4 and 2 meters above the current RSL. In the right bank, the low fluvial terraces are distributed into two levels from the water surface of the Paraíba do Sul river (3 m (T1) and 2 m (T2), respectively). The absolute ages were  $0.340 \pm 0.025$  ka (T1) and  $0.25 \pm 0.020$  ka (T2). In the left bank, it is located 12 m from the RSL and the absolute ages were less than 100 years. The fluvial-marine are positioned at 4 and 3 meters from the RSL (left and right margin, respectively). On the left bank, the ages were  $0.45 \pm 50$  ka (160 cm deep),  $0.385 \pm 0.17$  ka (100 cm deep) and less than 100 years (50 cm deep). On the other hand, the ages were  $0.250 \pm 0.035$  ka (150 cm deep),  $0.125 \pm 0.030$  ka (120 cm deep) and less than 50 years (70 cm deep) to the left bank terraces. Finally, the low marine terrace had ages less than 100 years (70 cm deep). The results showed that the geochronology of T1 (right margin) is correlated to the beginning of a marine regression, whereas the T2 is likely related to the second regressive pulse. Likewise, the left bank low fluvial terraces are geochronologically match with the most clayey tops coverings of the low fluvial-marine and marine terraces, suggesting connections with the coastline establishment around 100 years B.P. The ages of the events are correlated to the Little Ice Age and severe droughts recorded in Central America. In this sense, it is possible that a rainfall increase occurred due to Intertropical Convergence Zone (ITCZ) persistence over the Southern Hemisphere along of the late Holocene. Therefore, the increase of fluvial discharge driven by climate pulses triggered marine regressions, coastline displacements, base level lowering and channel entrenchments. We are thankful to FAPESP (grant 2016/00382-9) and CNPq (grant 304414/2014-0) by financial support.

P-2880

## First ESR chronology of the Duero River terrace system in Northern Spain

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### Abstract

Intraplate basins potentially preserve the most complete record of tectonic, geomorphic and climatic evolution within the interior of continents. In the Iberian Peninsula most of the largest Cenozoic sedimentary basins show a change from aggradation to degradation. Determining the cause of the transition from aggradation to degradation and how this was linked to tectonic, climatic, and geomorphic events hinges on the chronology of the fluvial network incision and excavation of the basins fills. Fluvial terrace staircases, as a product of river incision, provide a direct record of incision and are known to be the result of the combination of climatic changes and tectonic uplift.

The incision of most of the Iberian Peninsula basins appears to have initiated in the Quaternary but the precise timing of its initiation is actually poorly known and constrained. In order to overcome the lack of chronologies for these basins, in the following study we started by studying the Duero basin and its terrace system. It is a major intracratonic basin bounded by Cenozoic structures and is characterized by a maximum of 16 terrace levels from +141-144 m to +8-10 m, with the present alluvial plain at +4-5 m (Pérez-González *et al.*, 1994; Santisteban and Schulte, 2007). The only published ages for the Duero basin are by Moreno *et al.* (2012) who confirmed the potential of the Electron Spin Resonance (ESR) dating method applied on bleached quartz extracted from terrace fluvial deposits on the Arlanzón valley, a main tributary of the Duero River located in the NE area of the basin. In this work, ESR was systematically applied to the main river, the Duero River, dating 4 different terraces spanning from the high to the medium levels: T2 (+135m), T3 (+114m), T5 (+90m) and T10 (+41m).

ESR dates are coherent with the analyzed terrace system and allow defining the onset and development of the Duero valley in the center of the basin. Additionally, these results also allow to reconstruct the incision response of the tributary system, comparing these ESR results with those published about the Arlanzón river in NE sector of the basin.

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**P-2881**

## **Holocene dynamic and meander undersizing of an alluvial sector of the Jacaré-Guaçu river, state of São Paulo, Brazil**

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### **Abstract**

Fluvial dynamic is directly linked to the physical constraints of the landscape. Allogenic and autogenic changes impact on the channel's morphology and condition its associated forms. Throughout the Upper Pleistocene and Holocene, the Jacaré-Guaçu river migrated vertically and laterally, developed terraces and a wide floodplain, maintaining the meandering configuration. The relation of the fluvial forms mapped with the fluvial evolution of a specific alluvial segment in the mid-section of the Jacaré-Guaçu river indicates that the presence of a planimetric oversized meander bend, currently placed at a lower terrace level, corresponds to distinct hydrological characteristics from those of now. The mapping, identification and evolutionary interpretation of the selected section were carried out using Rapideye and CBERS-HRC orbital imagery; elevation data from the Shuttle Radar Topography Mission (SRTM) and aerial photographs (1:25,000), along with fieldwork and Optically Stimulated Luminescence (OSL) dating. The abandoned meander located 4 meters above and 600 meters away from the current channel has greater width and length measurements than the ones found on the current Jacaré-Guaçu river, as well as semi-rounded to rounded gravel with up to 30 centimeters at the base of the terraces, which contrasts to the pebbles currently carried by the river. The identified fluvial terrace, widely located at the left bank, shows the preferential displacement of the river towards the right bank, with sand deposits dating from  $\sim 7.6$  kyr to  $\sim 7.9$  kyr (samples collected at 90 and 135 centimeters deep, at different points of the terrace). The remaining and established forms of the floodplain and its respective measurements and dating suggest changes in the precipitation and drainage dynamics, resulting in the undersizing of the Jacaré-Guaçu river in response to climatic implications over the Holocene. Our thanks to FAPESP (São Paulo Research Foundation) for financially enabling this research (Process n. 2016/24390-0).

P-2882

## Landscape evolution of the Gangkou River in the southern Taiwan in respond to sea-level changes and tectonics since late Pleistocene

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### Abstract

Gangkou River is the largest drainage basin in the eastern Hengchun Peninsula of the southern Taiwan. The geomorphic features of the river basin are remarkably wide valley plain with flights of fill terraces and relatively narrow active channel. Such underfit river feature is unusual in a tectonically active area like Taiwan, where rapid river incision usually creates gorges and a flight of bedrock terraces.

Results from field survey, radiocarbon dates and X-ray fluorescence indicate that large-scale aggradation took place between 16ka and 6ka BP and formed fill terraces with relative height of 14m to 20m to the modern channel bed. The fill terraces are consist of floodplain facies sediment. Furthermore, we took a 30-meter long drill on a higher fill terrace near the estuary. The X-ray fluorescence data reveals chemical signals of marine transgression event between 8.5ka and 7.5ka BP at the depths of 5m to 12m from the top of the drilling core, and the accumulation rate of 2.8-3.0 mm/yr is estimated from the core. However, fluvial archive is absent basinwide between 6 ka and 0.5 ka, and only marine terrace (4.9-4.8ka), beach rock (4.5-4.2ka) and sand dune (around 3.4-3.2ka) developed in the same period can be found in the estuary area, yielding a tectonic uplift rate of 0.9 mm/yr. Meanwhile, the beach rock layer covered unconformably the estuary deposit of 8ka. The unconformity indicates a period of river erosion, which could be induced by the tectonic uplifting and gradual sea-level falling since the middle Holocene. Finally, lower terraces with relative height of 2m to 5m were formed around 0.5ka, and the alluvial deposit also covered unconformably the floodplain facies sediment of about 9ka.

In summary, we propose the landscape evolutionary history of the Gangkou River basin, demonstrating that sea-level could be the primary control factor of a coastal drainage basin in an orogenic setting. Our findings point out that rapid sea-level rise and low uplift rate cause significant river aggradation and wide valley in the estuary of Gangkou River during the late Pleistocene to the early Holocene. The aggradation event probably would not stop until 6ka, and the height of sea-level at that moment is about 9 meters higher than the modern one. Afterward, relative sea-level falling induced a long term river incision basinwide.

P-2883

## The long-term evolution of the Douro River as evidenced by strath terrace staircases located at NE Portugal (western Iberia)

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### Abstract

In western Iberia, mechanisms that explain the transition from endorheic to exorheic continental-scale drainage reorganisation are foreland basin overspill, headwards erosion and capture by an Atlantic river, or a combination of both. To explore these controls we have investigated the Portuguese sector of the Douro River, the site of drainage re-organisation. The Douro River routes downstream through weak sedimentary infill of the Douro Cenozoic Basin (Spain), after which the river cuts down through granitic and metamorphic rocks cut by active fault zones (NE Portugal), before reaching the Atlantic coast. We investigated the drainage reorganisation using an integrated remote sensing, field survey and geochronological approach applied to Pliocene-Quaternary fluvial sediments and landforms. The older drainage record is documented by a series of high and intermediate landform levels comprising 1) a high level (1000-600 m) faulted regional fluvial erosion surface, the North Iberian Meseta Planation Surface (NIMPS); 2) an inset level (650-600 m altitude) comprising a broad fluvial surface formed onto a large ENE-WSW depression that overlies resistant Proterozoic and Paleozoic bedrock and 3) an inset (500-450 m) fluvial surface. The younger drainage record comprises an entrenched fluvial strath terrace sequence of up to 9 levels (T9 = oldest positioned at 246-242 m above the modern river base (a.r.b.); T1 = youngest positioned at 17-13 m a.r.b.). Levels T1 and T3 display fault offsets where the cross active NNE-SSW fault zones.

The three lowest terrace levels (T1-T3) were dated using optically stimulated luminescence (OSL) techniques using Quartz-OSL and post infra-red stimulated luminescence (pIRIR). Results ranged from 39-12ka (T1), 57ka (T2) and >360ka (minimum) (T3). Fluvial incision rates of the younger (terrace) drainage record were quantified and temporally extrapolated to model the ages of the high to intermediate elevation levels of the early drainage record. Integration of incision data with fault zone derived crustal uplift values informs on the timing of the endorheic to exorheic drainage reorganization.

We interpret the NIMPS to be part of the endorheic Douro Cenozoic Basin drainage divide erosion. The inset wide fluvial surface at 650-600 m altitude represents the overspill level in the area of the Mesão Frio ridges (drainage divide with the Atlantic drainage). Development of the exorheic ancestral Douro valley is documented in the 500-450 m fluvial surface with our age and uplift modelling suggesting this became established during the upper Pleistocene (3.6 Ma) through to the Early Pleistocene (1.8 Ma). The entrenched river terrace sequence spans the Pleistocene, developing via spatial and temporal variations in rock strength, uplift and cyclic cool climate variability as the river adjusts to the Atlantic base level.

P-2884

## Dating Swiss Deckenschotter with isochron-burial dating

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### Abstract

Swiss Deckenschotter (*Cover Gravels in German*) are the oldest Quaternary deposits in the Northern Alpine Foreland and document the landscape changes during the Early and Middle Pleistocene. They are characterised by a succession of glacio-fluvial sediments intercalated with glacial and/or overbank deposits. A significant phase of incision divided this succession into two units: Höhere Deckenschotter (HDS; Higher Cover Gravels) and Tiefere Deckenschotter (TDS; Lower Cover Gravels). The Northern Alpine Foreland in Switzerland was overridden at least 13 times by the glaciers during the Quaternary, of which eight glacier advances can be tracked in the HDS and TDS sequences. For a long time, HDS and TDS were correlated with the Günz and Mindel glaciations after Penck and Brückner. HDS were correlated with the Günz glaciation and TDS with the Mindel. The timing of the Deckenschotter deposits is still poorly understood and absolute ages are scarce. Recently, a new chronology has been established in several HDS and TDS outcrops by depth-profile and isochron-burial dating techniques. The new chronology suggests that HDS and TDS are ca. 2 Ma and ca. 1 Ma old, respectively. However, it is challenging the existing chronology based on mammal fossils at Irchel, since 2 Ma old deposits are located at the same morphostratigraphical position as 1 Ma old ones. Therefore, how far does the chronology explain the approach “*same elevation means same age*”? The aim of this study is to explore Swiss Deckenschotter deposits at Irchel, the area around Mandach and Lake Constance in detail, to reconstruct the timing of the Early and Middle Pleistocene glaciations with isochron-burial dating, and to implement these results into a more complex landscape evolution model than thought so far.

To achieve these goals, we selected eleven new Deckenschotter sites: three HDS sites at Irchel, three HDS and three TDS sites in the area around Mandach, as well as one HDS and one TDS sites in the region of Lake Constance. One sediment sample consisting of quartz pebbles and at least nine clasts of various lithologies, shapes and sizes were collected per site. After the physical quartz separation, <sup>10</sup>Be and <sup>26</sup>Al were extracted from five clast samples and the sediment sample for the accelerator mass spectrometry (AMS) measurements at ETH Zurich. In addition, sediment analyses were conducted to reveal the sediment source, paleoflow regime, transportation mechanisms and depositional environment. First results will be presented.

P-2885

## Global and local climatic variations during the last interglacial-glacial cycle recorded in loess on the terraces of Dnister River (Ukraine)

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### Abstract

On the slopes of the upper Dnister River a set of Pleistocene terraces (II-V) of various age is developed, all with loess cover. Two lower terraces are located at a similar height, and the loess superstructure in the common fragment represents the last interglacial-glacial cycle. These terraces are represented respectively by sites in Yezupil and Mariampil, situated on both sides of the river valley. The aim of the studies is to assess the impact of local factors on the nature of environmental changes and microclimate features.

After the Eemian pedogenic stage in both sites remained luvisol developed into loess (Yezupil) or on the river sediments (Mariampil). Starting from the Early Weichselian, the rate of loess sedimentation and the soil processes environment in both sites were different. The early glacial is represented by one chernozem horizon (Yezupil), and three such soils separated by loess (Mariampil). Soils formed during MIS-3 are cambisols, in the first case weakly developed, in the second – much better.

Yezupil's success begins with Eemian, but already during the dominance of loose forests. The optimum was dominated by thermophilic multi-species deciduous forests with rich undergrowth, meadow vegetation occurred in depression reliefs, and steppe on hills. In the period of early glaciation, a mosaic of forest patches and open places with steppe vegetation characterized the landscape. During MIS-3 there were steppe, meadow and pioneer communities as well as small pine and birch thickets.

In Mariampil, quite complete stages of the Eemian forest development (warm and temperate deciduous forests in optimum) have been documented. Interstadials was characterized by the continuous presence of pine and oak forests later pine, with a decreasing admixture of other deciduous trees, and forestless areas and forestry enclaves covered by steppe-meadow vegetation. During MIS-4, the landscape was open with groups of pine-birch forest. In the middle part of the MIS-3, there were comfortable conditions for tree vegetation, which occupied the depressions while the slopes and watersheds were occupied by meadow steppe vegetation. During MIS-2, a mosaic landscape with tundra and steppe vegetation with coniferous trees prevailed.

Differences in the vegetation composition indicate the dependence of the local vegetation variation on the site surrounding morphology and their location within the river valley. The Yezupil's surrounding were relatively cooler due to NE exposure, the position in the straight-line NW-SE section of the valley with the probability of the tunnel wind effect. In turn, the vicinity of Mariampil was characterized by a certain quietness. This place was more sheltered, better sunlit and warmer, which caused: SW exposure, covering from the north by a high ridge, location at the break point of the river valley, which could have a detrimental effect on the wind capacity causing increased aeolian sedimentation.

P-2886

## Morphological and geochronological investigations (OSL) in the Miaoli Tablelands (NW Taiwan)

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### Abstract

In northwestern Taiwan depositional terraces are located in the foreland of the Neogene high mountain ranges. The terrace evolution has so far been outlined in general but detailed studies are missing. They are considered to be of Quaternary age. Geomorphological mapping, open-source borehole data interpretation and luminescence dating (coarse-grain quartz-OSL) approaches have been applied to determine the morphology and chronology of the relevant terrace evolution.

Three sub-categories of terraces are classified by their elevation and morphology: 1) *sedimentary highland "SH"* (> 250 m asl., mainly in the eastern part), 2) *sedimentary terraces "ST"* (250 – 50 m asl., in the central part) and 3) *alluvial terraces at the riverbanks, and coastal plain "AL"* (< 50 m asl.). The complete sedimentary sequence of the terraces is > 50m thick. This sequence represents the depositional environmental change that has started from shallow marine, to tidal-flat and beach, subsequently to fluvial environment and then is overlain by aeolian dust. We identified three sub-types of sedimentary successions. Type-I contains the complete sedimentary succession, which represents the terraces in *SH* and *ST*. Type-II contains most parts of the sedimentary succession except the gravel and cobble bed(s), which are indicative of the fluvial environments. This type represents remnants of the terraces in *ST*. Type-III shows very thin (< 2 m) gravel and cobble bed(s) on the top, representing fluvial channel deposits and terraces near the coastal area. We suggest that the different sedimentary successions have a clear relationship to the landform.

Luminescence dating shows that the samples from the beach sediment layers are beyond the range for quartz-OSL signals. The fluvial gravel and cobble bed in the "*ST*" gave OSL ages of ca. 22ka, while the fluvial gravel and cobble bed on the "*AL*" gave OSL ages of ca. 10ka. The different depositional ages indicate the cyclical deposition-erosion-transportation processes have reworked the gravel and cobbles from the "*ST*" to the "*AL*".

The underlying marine and coastal sediments in the studied stratigraphy indicate that the mountain foreland was once a shallow marine environment during a sea-level high stand. Sediment yields from the high mountain ranges are documented as fluvial deposits by the complete sedimentary sequence of the terraces. The regression triggered the fluvial response and the subsequent linear erosion. Once the gravel and cobbles were eroded by denudation and fluvial incision, terraces called tableland today, become a clear morphological feature after uplift. Finally, the elevated erosional base during the early Holocene triggered the latest deposition of the gravel and cobbles in the coastal area. We assume that the combination of tectonic processes, eustatic sea-level changes and surface processes is responsible for the landform development in the study area.

P-2887

## Diachronism of river terrace formation? – Lessons to learn from luminescence dating results

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### Abstract

Revealing an amazing diversity of forms, river systems must always be interpreted as products of their specific landscapes. Extremely sensitive to external and internal forcing, they reflect the particular characteristics of climatological and geological conditions as well as the changes of these conditions. These changes are regularly preserved in depositional series whose varying sedimentary characteristics can be attributed either to palaeoclimatic variations or to tectonic activities and their corresponding changes in fluvial discharge and sediment load. What applies to fluvial sediments in general, is particularly true for river terraces. The importance of fluvial terraces in geomorphology, archaeology and modern river engineering is well documented by a huge and still growing number of studies spanning a wide range of climatic and regional settings.

However, the information gained from fluvial terraces and their significance for palaeoenvironmental research strongly depend on an accurate dating of the terrace formation. Numerical ages are of fundamental importance for the interpretation of sedimentological, morphological and stratigraphical findings. They are essential for assessing the influence of various driving forces and for providing insights into the mechanisms and dynamics of river adjustments over differing timeframes. Without a reliable chronological framework, reconstructing past fluvial environments would not be possible.

In this poster, we present luminescence ages of fluvial deposits originating from an Upper Pleistocene river terrace in a small valley located in the headwaters of the Main River, Germany. For this study, several samples from various locations throughout the river longitudinal course have been analysed. Surprisingly, the determined luminescence ages for material from the lowermost part of the valley are significantly older than those from the middle section, which in turn are older than those from the valley's upper reaches. Based on the evaluation of a high-resolution digital terrain model (DTM) and on intensive fieldwork, we can be sure that all samples originate from the very same morphological unit, a well-preserved late Pleistocene fluvial terrace.

Our results suggest a diachronic alignment of sedimentation ages for fluvial deposits, starting with old ages close the mouth of a river and getting progressively younger for locations approaching the upper reaches. Whether these results only represent a local feature or a general pattern of fluvial response to external or internal forcing, cannot be answered at this point. If these findings were confirmed in other fluvial systems and were not only the result of very specific local conditions, they would be of great relevance for geomorphological research in fluvial landscapes and generally emphasize the particular importance of careful interpretations of ages derived for fluvial deposits.

P-2888

## Neotectonic control on Solani river basin in the western part of the Himalayan foothills, India

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### Abstract

The foothill-fed Solani river is flowing through a longitudinal fault. It forms a river basin of 1933 km<sup>2</sup> area in the western Himalayan foothills of the Ganga foreland basin before meeting the Ganga river. This paper aims to study neotectonic control on the Solani river basin using morphotectonic indices such as longitudinal river profile, channel sinuosity, basin asymmetry, bifurcation ratio, stream gradient index, drainage density, mountain front sinuosity and field studies. Though the Solani river is flowing on a sloping surface (1.7% slope), it shows meandering channel characteristics along with its tributaries. Local convexity in the longitudinal river profile indicates differential uplift or local disequilibrium state of channels due to tectonic perturbation of the faults. The calculated sinuosity index (SI) values depending on the window size are found to be representative of neotectonic influence along the river course. The SI value along the river varies from 1.27 to 1.96. The drainage basin asymmetry factor (AF) 17.41 indicates the main channel has shifted towards the downstream right side of the drainage basin. Bifurcation ratio (Rb) varies from 2 to 3.3, the mean Rb of the entire basin is 2.67. The drainage basin has moderate drainage density of 2.33 indicates low to moderate infiltration of the region. Stream gradient index (SL) of Solani river ranges from 15.9 to 116.8. SL values against river length shows consistent anomalies across active fault zones. Mountain front sinuosity ( $S_{mf}$ ) adjacent to the river basin varies from 1.04 to 1.13 indicating active nature of the region with pronounced uplift.  $S_{mf}$  and the channel sinuosity show a good correlation and suggest neotectonic control. Uplift rate along the Himalaya in the region shows a strong correlation with the morphotectonic signatures of faulting. There are three unpaired terraces in the right bank of the river course indicating temporal activity of the Solani fault in Quaternary.

P-2889

## Geochronology and paleosols study of the lower terraces in the Middle Tagus River (Toledo, Central Spain): paleoclimatic implications

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### Abstract

This study presents new geochronological and paleoclimatic data from the lower terraces of the Tagus River in the environs of Toledo city (central Spain). Within the Upper Tagus basin, a maximum of 22 terrace levels developed from +180 m to +3-5 m (above present river thalwegs). The research is focused on Middle to Late Pleistocene terraces with palaeontological and Palaeolithic (Acheulean and Mousterian) sites preceding the Last Glacial period. Includes new OSL datings on Quartz (Qz-OSL) and k-Feldspar (pIRIR) grains for the terrace levels up to +25 m. Because the Qz-OSL is in saturation for the samples collected from terrace deposits, all measurements were made with the pIRIR protocol. The ages obtained indicate that the terrace at +9-8 m (Lower Valdelobos site) was developed during MIS 3 ( $56 \pm 3$  ky), the terrace at +14-16 m (Salchicha site) during the last interglacial (MIS 5;  $100 \pm 5$  ky) and the one at +20-18 m (Monterrey site) around the MIS7-MIS6 transit ( $180 \pm 15$ ). The +20-18 m terrace is about 4.4 m thick, buried by 1.5-2 m thick fine sands of probable aeolian origin. Beneath this sandy cover, the terrace top deposits displays a well-developed soil profile, corresponding to a typical Haploxeralf, which consists of a dark brown (7.5YR 4/4 m) to strong brown (7.5YR 4/6 m), about 80 cm, thick prismatic argillic horizon with some vertic features. Particle size distribution data show an increase in clay content with depth, ranging from 28.5% to a maximum of 43% from clay illuviation process, occurred after end of deposition of the terrace. Carbonate leaching of overlying sandy materials gave place to development of carbonate nodules (2-3 cm in diameter) and even calcified roots about 4 cm length, preferentially in the lower part of argillic horizon. This process represent a period of increasing aridification, which occurred after the deposition of the aeolian cover with ages of  $15.3 \pm 1.2$  ky (Qz) to  $12.7 \pm 0.8$  ky (Kf). These sand deposits penetrate within the underlying argillic horizon across significant cm-scale sand wedges interpreted as an initial vertic origin enhanced by frost action (ice wedges), during cold periods after terrace deposition. Similar sands of supposed aeolian origin cover the younger terraces and even some older ones (Pinedo Terrace, at +25-30 m), with ages of  $11.8 \pm 1.3$  ky (Qz) to  $11.0 \pm 0.9$  ky (Kf). These data suggest that deglaciation and onset of the Holocene featured enhanced aridification, indicated by carbonate accumulation in soils and occurrence of a generalized aeolian mantling of younger fluvial terraces.

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P-2890

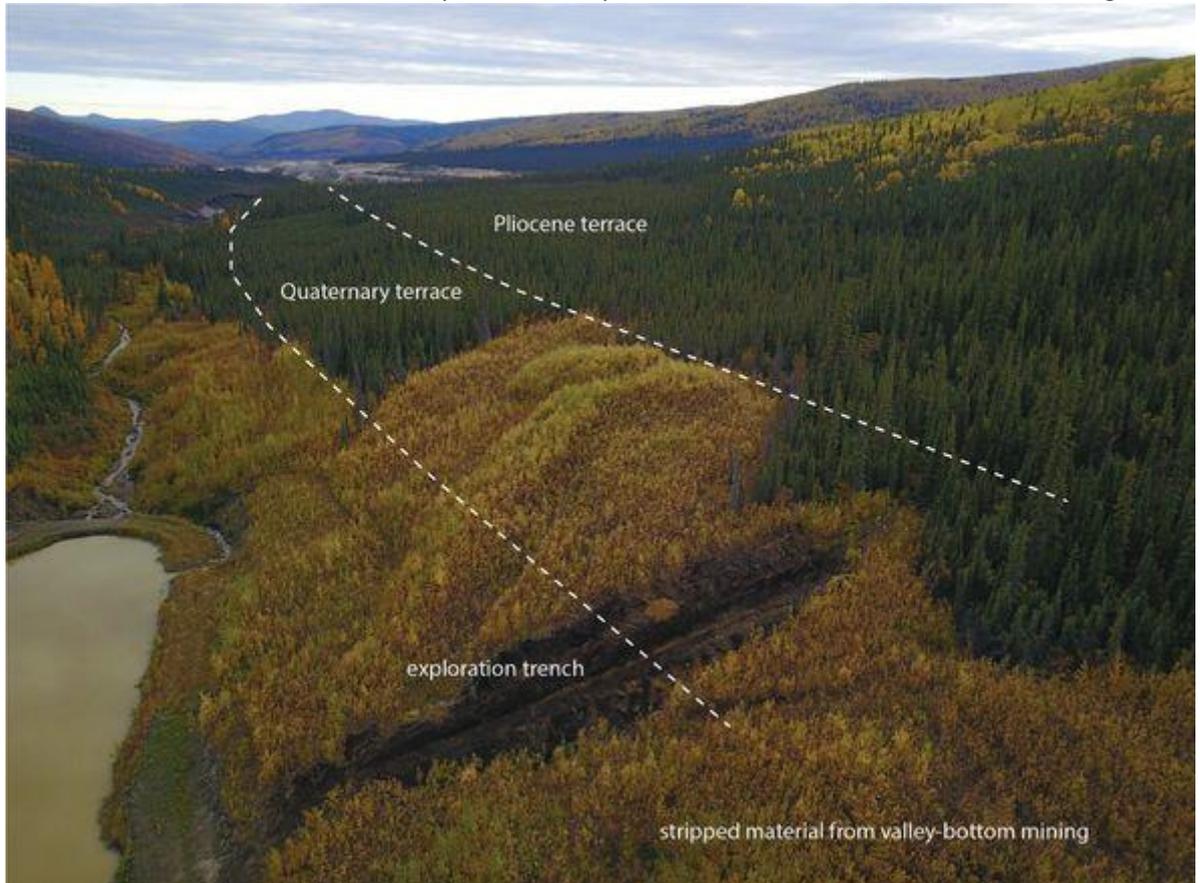
## Evolution of Quaternary fluvial terraces and their placer gold deposits in the Klondike Goldfields, Yukon Territory

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The genesis of Quaternary fluvial deposits and their placer gold content, particularly in mature landscapes, is often linked to pre-Quaternary eluvial and fluvial history. The unglaciated Klondike region of central Yukon Territory contains some of the richest placer gold-bearing streams in the world. These deposits formed through a long process of Pliocene weathering, fluvial sedimentation and reworking, and earliest Quaternary drainage capture that triggered terrace formation. The Pliocene White Channel gravel terraces contain an anomalous abundance of quartz clasts and detrital gold particles, signifying previous environmental refinement. Previous studies suggested that chemical weathering of regolith was the primary process of altering the Klondike schist to clay, contributing to a build-up of vein quartz and gold in the surficial environment. While this is undoubtedly true, recent stratigraphic studies indicate a more complex process of chemical alteration within the fluvial environment. In recent mining exposures, a pre-White Channel gravel deposit (informally termed the Paradise gravel), has been identified stratigraphically below, and adjacent to, the White Channel gravel. Non-quartz clasts within the Paradise gravel were clay-altered at the time of reworking by the White Channel gravel, approximately 4 million years ago. Clay-altered metamorphic and igneous clasts disintegrated into fine particles in the fluvial environment and were transported out of the drainage leading to a higher concentration of quartz within the White Channel gravel. Importantly, placer gold reworked from the Paradise gravel was concentrated at the base of the White Channel gravel forming a rich pay streak.

Terrace formation began at the onset of the Quaternary period 2.84 million years ago when the first continental glaciation diverted the Yukon River into central Alaska causing a lowering of base level. Thick deposits of White Channel gravel were reworked into relatively thin Quaternary fluvial deposits. Placer gold reworked from the Pliocene sediments accumulated into anomalously rich deposits in Quaternary terraces and modern streambeds. The most spectacular placer gold concentrations were recorded in Eldorado Creek where each 500 foot-long claim contained on average 30,000 oz of gold. While most of the valley-bottom deposits have been mined out, modern miners still discover buried intermediate-level Quaternary terraces containing economic gold concentrations. These

terraces are often found on the inside bends of valley curvatures, preserved as a result of lateral channel migration



during incision.

Aerial view of a tributary to Quartz Creek in the Klondike Goldfields. The Quaternary fluvial terrace, inset into the Pliocene terrace is a subtle landform feature often masked by colluviated loess. The exploration trench was excavated in 2018 and discovered economic gold concentrations within the landform.

**P-2891**

## **Plio-Quaternary evolution of the central Apennines: the case of the Medium-Upper Aniene River Valley (Latium, central Italy)**

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The Apennines Chain has been affected by a regional uplift since the Upper Pliocene, with an increase in uplift rate since the end of Lower Pleistocene. In the last decades, many attempts have been made to estimate the timing and magnitude of the topographic growth affecting the chain. Estimations of past surface uplift in orogen interiors are difficult for the lack of geomorphic markers with known original elevation such as marine terraces. For this reason it is crucial to exploit continental indicators of past base levels such as fluvial terraces and planation surfaces. In particular fluvial terraces record changes in fluvial dynamics (aggradation and incision) depending on the interaction between climate and tectonics. Moreover, when carbonate aquifers are present, climate influences the formation of fresh-water travertines which, for this reason, are widely studied to investigate Quaternary climate changes. In this framework the Medium-Upper Aniene River Valley (Central Italy) represents a good testing site to investigate the interaction between surface processes, climate, and tectonics in the context of the Apennines topographic growth. Indeed this portion of the Aniene River Valley is characterized by widespread well-exposed Quaternary deposits consisting in wide fluvial terraces and fresh-water travertines alternated in places with lacustrine and volcanic deposits. Despite the well exposure of outcrops and the dateability of travertines and volcanic deposits, poor efforts have been done in order to correlate the Quaternary deposits along the Aniene River Valley nor to investigate the interaction between deposition, tectonics, and climate. In order to tackle this problem we perform a multidisciplinary approach comprising a topography and river network GIS investigation, a field survey campaign to map the Quaternary deposits along the valley, a geochemical and geochronological analysis of travertine deposits, and a paleontological analysis of lacustrine deposits outcropping in the study area. The results allow to reconstruct the Plio-Quaternary evolution of the Medium-Upper Aniene River Valley in the framework of the uplifting and extending Apennines chain.

P-2892

## **Pleistocene terraced travertines and fluvial deposits, incision and uplift in Acquasanta Terme area (central Apennines, Italy)**

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The Acquasanta Terme area is located in the Marche region (central Italy), on the eastern side of the central Apennine Chain. The Apennine Chain is a Neogene E-verging thrust-and-fold belt formed from the convergence of the Eurasia and Adria-Africa plates and the successive Tyrrhenian Sea opening in Miocene time. The Apennines are affected by a strong regional uplift since the end of the Lower Pleistocene. The interaction between this upheaval and the climate changes generates alternating phases of incision and aggradation in the Apennines valleys. In particular, in the Acquasanta Terme area, four levels of fluvial terraces formed: the first three levels are covered by bodies of travertines. These are thermal water deposits of Middle-Upper Pleistocene, developed exclusively on the SE side of the Tronto River Valley. The travertines bodies, consisting mainly in low Mg calcite, have different lithofacies, represented either by in situ carbonate incrustations on vegetable supports or by deposits showing a "clastic" textures. This lithofacies association define depositional settings varying from pool gradin to waterfall environment and showing progradational and aggradational patterns. Travertine deposition is still active in correspondence of several hot springs in the Acquasanta Terme area. We dated the three carbonate bodies by U-series method, obtaining the time span of deposition: more than 350 ka to about 54 ka (first level), 113 to 53 ka (second level), 79 to 26 ka (third level). Using the age relative to the samples collected close to the base of the travertine bodies (sometimes very close to the underlying fluvial deposits) and measuring the elevation of the river terraces with respect the elevation of the present Tronto River channel, we calculated an incision rate of 0.6 mm/yr for all the three terraces. This result is comparable with the uplift rate estimated for the central Apennines chain.

P-2893

## **A study of late Quaternary sedimentary archives of upper Indus valley, Ladakh: Implications on paleoclimate, provenance and drainage reorganization**

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### **Abstract**

Ladakh, a tectonically active highest plateau of the planet earth, is uniquely located in low latitudes, to study and understand the climate-tectonic interaction during Quaternary, a period of major climate changes. Representing the elevated trans-Himalayan domain, it is bound by the southern Indus-Tsangpo Suture Zone (ITSZ) and the northern Shyok Suture zone. The other remarkable tectonic element present is a crustal scale strike slip fault known as Karakoram fault. The major geological units present in the upper Indus basin include Ladakh granite of the Island arc affinity, the ophiolites and subordinate metapelites. Quaternary deposits in a ~250 km long stretch of Indus were examined to infer the late Quaternary geological history of this valley. The Quaternary deposits in this stretch occur as isolated and incomplete sedimentary sequences of river terrace deposits, moraines derived tills and other glacial deposits and fan deposits at hill slopes, debris flow and alluvial fans and paleo-lacustrine deposits.

On account of the climate cum geographic position of the Ladakh it is worthwhile to evaluate the influence of global and regional climate forces. To facilitate this evaluation, the fluvial and lake deposits are chosen to represent glacial (cold) and interglacial (warm) periods respectively during the Quaternary time.

Based on the morphology of the river valley and other geomorphological considerations and the nature of associated deposits, the study area has been divided in four sectors : (Sector I to Sector IV). Sections at Tsaka La (river terrace deposit in Sector I), Nyoma (Lacustrine sequence in Sector I), Upshi (Composite glaciofluvial deposit in Sector II), Shey, Spituk and Palam (Lacustrine and fan deposits in Sector III) and Zinchan (Lacustrine deposit in Sector IV) were logged, granulometrically analysed, age constrained and studied for provenance signatures using heavy mineral assemblages.

Thus OSL ages obtained represents aggradational activities under fluctuating climatic condition from MIS 5e – MIS 3. Data generated in the present work has been used to provide an event stratigraphy during late Quaternary in the upper Indus valley and accordingly, the glacial stratigraphy of the region has been modified. Lastly terrestrial record of Ladakh was compared with respect to the global climate record (MIS) to see the Synchronicity of Quaternary climate of Ladakh and the present study shows that from MIS5 to MIS4 the influence of regional climate forces in Ladakh waned and the local climate conditions were similar to the global ones.

**P-2894**

## **Might the East Asian Summer Monsoon Control the Formations of the Qingyijiang Terraces in Northern Piedmont of Mt.Huangshan, Southeast China?**

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The Qingyijiang River, which is an important tributary of the lower Yangtze River, drains the northern flank of Mt. Huangshan in southeast China. Field investigation focuses on the natural outcrops along the Qingyijiang River in the Jingxian Basin, where a well-preserved sequence of four terrace gravel layers is present. These Quaternary terraces of the Qingyijiang River offer a valuable archive for palaeoenvironmental changes in a subtropical climate region. Using electron spin resonance (ESR), optical stimulated luminescence (OSL), and palaeomagnetic dating and pollen and grain size analyses, the objective of this study is to reveal the essential controlling factor of Qingyijiang terrace formations. The results indicate that (1) the formation ages of four Qingyijiang terraces were estimated to be ~1300, ~900, ~600, and ~1.5 ka based on ESR, OSL, and palaeomagnetic dating; (2) the Qingyijiang terraces were generated under warm and wet paleoclimatic conditions which were inferred from the pollen and grain size analyses that resulted in four significant wet periods (~1300, ~900, ~600, and ~1.5 ka); (3) the significant wet periods in the study area were mainly influenced by a significant weakening of the East Asian summer monsoon, which occurred at ~1300, ~900, ~600, and ~1.5 ka; and (4) the terrace formations of the Qingyijiang River might be directly controlled by the weakening of the East Asian summer monsoon. This study suggests that terrace generation might not always be controlled by climatic cycles in different climatic regions, and the mechanism behind terrace formations might be regionally unique.

P-2895

## Chronology of the establishment of Sarthe's alluvial system

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### Abstract

In terms of geomorphology, Quaternary period is characterized in Northern France by the entrenchment of the main alluvial systems. The glacial/interglacial Quaternary climatic cycles of this period induce a variability in the competence of the rivers, and then a balance between erosion and deposition phases. In active uplift tectonic context, it usually results in the establishment of stepped terraces systems. Indeed, each climatic cycle seems allowing the establishment of a terrace deposit that can be protected from the erosion during the next glacial cycle through tectonic reasons (uplift, change of the course...). In parallel to geological and climatic events, Quaternary is also marked by the appearance of the genus Homo. During the Middle Pleistocene, prehistoric men are already present in Western Europe and in the Northern part of France. In sedimentary basin context, evidences of past human occupations have been recognized mainly at the bottom or at the top the fluvial terraces deposits.

The Sarthe river is located in the western France and flows on the edge of both geological formations of the sedimentary Paris basin and the Armorican Massif. This precursory work intended to establish the first chronological framework of the alluvial system of the Middle Sarthe's drainage basin and, by extension, to constraint the ages of the prehistoric human artifacts found on the surface of the terraces. In that aim, the Electron Spin Resonance (ESR) dating method was applied to optically bleached quartz extracted from Quaternary alluvial deposits. Results indicate that the Sarthe hydrographic network is aged of about 1.2 Ma, and that the incision of the valley by the river continued throughout the whole Middle and Late Pleistocene. Most of the fluvial terraces were deposited during the Middle Pleistocene.

Lower Palaeolithic archaeological artifacts of were found on terraces dated between 650 ka and 400 ka, while Middle Palaeolithic ones were recovered at the surface of formations dated between 320 and 200 ka, and Upper Palaeolithic ones on the most recent terrace.

P-2896

## Tributary stream long profile analysis of the Douro River (Portugal): insights into long-term drainage evolution in Western Iberia

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### Abstract

We investigate the projection of the concave-up longitudinal profiles of the upstream sections of Douro River tributaries. This allows quantification of fluvial incision patterns as the trunk river passes through different tectonic blocks. The tributary profiles show two distinct configurations: 1) an upstream relict reach, almost in “equilibrium”, and 2) a lower rejuvenated reach, with an irregular form that relates to adjustment by the Douro River to the Atlantic base level. The relict profile is an almost steady state form, developed under a prolonged period of base level stability when the Douro Cenozoic Basin (DCB) changed from endorheic to exorheic (to the Atlantic). This basin encompassed a significant area of the northern Iberian continental landmass (mainly in Spain) with its western boundary (in Portugal) controlled by the high relief Western Mountains. The switch from sedimentation to erosion of the DCB implies a significant continental scale drainage rearrangement. The subsequent incision stage is recorded in strath terrace staircases with up to 9 levels configured within enlarged meanders and tectonic depressions.

In this work we used unpublished geomorphological maps and related information produced by Ferreira (1978), combined with new DTM model analysis and field surveys along the Douro watershed. These analyses have allowed identification of erosion surfaces and terrace levels, with quantification of their heights above the modern river bed. Regression analysis of gradient vs length and log slope vs log length enabled relict and rejuvenated profiles to be constructed. Projection of the relict profile to the tributary junction with the Douro River used the equilibrium longitudinal profile equation of Goldrick and Bishop (2007).

Results suggest that the tributary profiles contain an ancestral morphology of the Douro River that differs from the current convex morphology. In the “Arribas do Douro” knickzone, incision exceeds 500m, with some ~440m in the vicinity of the Vilarica Fault and > 600m in the downstream areas of the Plateaus and Mountains of Northern Portugal. Older knickpoints are clearly represented in the longitudinal profiles. These correspond to the upper limit incision wave migration from the Atlantic Ocean, reflecting the establishment of connection between the ancestral Douro and the Atlantic coast.

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P-2897

## Determination of the rock uplift in Central Menderes Massif (Aydın Block), Western Turkey; inferences from OSL dating of fluvial terraces

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### Abstract

Western Anatolia is one of the rapidly extending areas on the earth. Menderes Massif in Western Anatolia has been experiencing uplift above the South Aegean arc since the Neogene. However, quantitative dating studies on determine the rock uplift or surface uplift of the Central Menderes Massif has not yet been perform. The primary goal of this study is to determine the rock uplift rate of Aydın Block (central part of the Menderes Massif) by incision rates derived from key river terraces controlled by normal faults through the southern flank of Aydın Block using the OSL dating method. OSL ages of river terraces will help us to understanding the the influence of climate and tectonics on landscape evolution of study area.

Firstly, geomorphic units in southern mountain-front of Aydın Block were in detail mapped using a combination the Red Relief Image Mapping (RRIM) technique, unmanned aerial vehicle, TanDEM-X (12.5 m spatial resolution), D-GPS, and field observation. Firstly, we extracted the river terraces deformed by active normal faults from the three different locations through southern flank of Aydın Block using the with high-resolution (10 cm) DEM. From West to east, these locations are Tabakhane, Kabaklık and Esnek river, respectively. We determined at least the 5 terrace staircase with terrace elevations of  $90 \pm 0.2$  m,  $82 \pm 0.2$  m,  $35 \pm 0.2$  m,  $25 \pm 0.2$  m and  $3 \pm 0.2$  m above the Tabakhane River, the 3 terrace staircase with terrace elevations of  $45 \pm 0.2$  m,  $22 \pm 0.2$  m,  $8 \pm 0.2$  m above the Kabaklık River and the 6 terrace staircase with terrace elevations of  $92 \pm 0.2$  m,  $70 \pm 0.2$  m,  $46 \pm 0.2$  m,  $33 \pm 0.2$  m,  $25 \pm 0.2$  m and  $16 \pm 0.2$  above the Esnek River.

To determine the deposition time from the river terraces using the OSL dating, we chosen the three samples strategy from per river terrace level. We collected the six samples from terrace elevations of  $90 \pm 0.2$  m and  $25 \pm 0.2$  m for Tabakhane river, the six samples from terrace elevations of  $22 \pm 0.2$  m and  $3 \pm 0.2$  m for Kabaklık river and the twelve samples from terrace elevations of  $92 \pm 0.2$  m,  $46 \pm 0.2$  m,  $25 \pm 0.2$  m and  $15 \pm 0.2$  m for Esnek river. Thus, totally 24 OSL samples were collected from fluvial sediments. The preparation of samples for equivalent dose was performed under red light conditions. The luminescence measurements are currently under progress. We aim to present the first results during the congress. This study is supported by TÜBİTAK #116Y077 project and by the Turkish Academy of Sciences within the framework of the Distinguished Young Scientist Award Program (TÜBA-GEBIP-2016)

**Keywords:** River terraces, uplift, OSL dating, Western Anatolia, Menderes Massif, Aydın Block

P-2898

## Quaternary river terrace-climate relationships on the NW Sahara Desert margin (Morocco)

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### Abstract

In this study we explore the role of cyclic Quaternary climate change as a driver for controlling temporal patterns of river terrace development from the south-central High Atlas Mountains of Morocco. This is a low-mid latitude, up to 4km high, dryland mountain setting along the north western margin of the Sahara Desert. We illustrate the cyclic climate relationship using the adjacent Dades and M'Goun Rivers, key non-glaciated catchments (areas = 1500-1200km<sup>2</sup>) that document along-strike variations in orogenic system lithology (strong carbonates vs weak mudrocks) and tectonic configuration (route across the fold-thrust belt, wedge-top basin, thrust front regions). Terraces occur primarily as straths, with erosional bases located at regular 10m altitudinal intervals from ~+2-3m to +80m above the valley floor, and a rare occurrence at 140m (Dades). Terraces are variably distributed along the Dades and M'Goun trunk drainages, being well preserved in the Thrust Front region, but variably preserved within the Wedge-Top Basin and Fold-Thrust Belt regions related to rock strength variations. Individual terrace levels are generally <7m thick, comprising key stratigraphic levels of a basal bedrock erosion surface, overlain by up to 5m of fluvial conglomerate (imbricated rounded cobbles) and variably capped by ~2-5m of fluvial slack water sand-silt or slope conglomerates (angular, poorly sorted gravels). To assess the timing of terrace formation we targeted the one of the most continuous strath terrace levels (~10m above the modern river) from a range of different trunk drainage locations across key orogenic system regions (Thrust Front etc). Results (published and preliminary) reveal that the 10m terrace aggraded between 164-127ka (fluvial conglomerate) and incised between 110-77ka (fluvial sands-silts). This suggests aggradation during the (MIS6) glacial followed by valley floor incision and terrace inundation during the (MIS5) interglacial through to the (MIS4) glacial, implying that terrace formation is potentially tuned to 100ka climate cycles. We compare this chronology and climate relationship to other African Quaternary archives, noting that this emerging chronology is one of the first meaningful insights into climate-related river behaviour on the north western margins of the Sahara Desert. The study illustrates that dryland mountain river terraces possess potential for informing on climate-related landscape development patterns. This is especially significant since most terrace-climate studies with meaningful chronologies and robust climate-fluvial landscape relationships come from moderate-large mid latitude river systems with direct hydrological linkages to the waxing and waning of northern hemisphere glacier / ice sheet systems. As knowledge of terrace formation is primarily based on numerical modelling studies, field examples such as this are essential to test and verify such approaches more robustly.

P-2899

## Lower Paleolithic artifacts preserved on the lower fluvial terraces of Minho River near Melgaço, NW of Iberia: diversity and chronology

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### Abstract

Lower Palaeolithic industries are known in the Lower Minho River, Northwest of Iberia, for about 100 years. The first findings of Acheulean age were collected scattered along the river valley. Since the 1960s, attention was paid to an important Acheulean site of the right bank – Gándaras de Budiño, Galicia, Spain – with controversial chronology. New research has connected such site to the Middle Pleistocene and more recently new important Acheulean sites were discovered in the same river bank.

In the last three years, archaeological work carried out in the left bank of the Minho River (Portugal) has also allowed to (ACHO QUE LEVA UM "TO") the identification of new Palaeolithic sites, generally associated to ancient river deposits, also dating from the Middle Pleistocene. Its characteristic large cutting stone tools include different types of bifaces, most of them made from quartzite pebbles or wide flakes removed from large cores, and cleavers, as well as other artefacts such as cores and flakes, sometimes retouched.

In 2016, 2017 and 2018 multidisciplinary research was carried out at Carvalhas (municipality of Melgaço, Portugal), an archaeological site located in the surface of a river terrace, with the top 20 m above the current river bed. Such research involved the excavation of three different geoarchaeological contexts, the analysis of the local geomorphology and the sedimentary architecture of the terrace, and OSL dating.

Preliminary results suggest that the Acheulean assemblages are connect to an ancient river channel or meander, and to a colluvium/slope deposit, and were produced between c. 255 Ky and c. 335 Ky. Another assemblage, with a significant amount of flakes and associated to a deposit with different features, may date from a later period and be related eventually to the Middle Palaeolithic (no dates available for this context).

In conclusion, the abundance and diversity of the lithic stone tools from Carvalhas attest to the human presence at the NW of Iberian Peninsula during the Middle Pleistocene.

P-2900

## Late Quaternary evolution of fluvial terraces along Tista River in Darjeeling Sikkim Himalayas: Implications to climate and tectonics

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### Abstract

Fluvial terraces are important geomorphic archive preserving information about past fluctuations in climate and tectonics. In tectonically active regions such as Himalayas which are also the drivers of Indian Summer Monsoon (ISM) and were influenced by the past climatic changes. To understand the impact of two processes, different sections of fluvial terraces were studied along the Tista River in the Darjeeling Sikkim Himalayas over a stretch of ~65 km.

An attempt has been made to reconstruct the geomorphic history of the region using Optically Stimulated Luminescence (OSL) dating and geochemistry. Four level of terraces were identified in the region as T4, T3, T2 and T1, in decreasing order of their ages. T3 terrace is nested into T4 and could only be differentiated on the basis of chronology. The upper age limit of T4 is ~72 ka and this period was followed by a glaciation phase. We do not get any deposits during this phase showing that this was a period of no active sedimentation. The T3 has an age range of ~50-30 ka and is regional in nature, whereas all other terraces are fragmentary in space. This time period was also an interglacial phase with similar precipitation conditions as of today. However, the Chemical Index of Alteration (CIA) values indicate that the weathering was not intense during this period indicative of relatively dry condition. The T2 formed during ~24-11 ka which was period of Last Glacial Maxima (LGM) followed by interglacial period and Younger Dryas event. The striking difference between T4, T3 and T2, T1 is its terrace material. The T4 and T3 are composed of laminated sand with few intercalations of cobble-pebble layers whereas, the T2, T1 and present day channel are composed of pebble, cobble and boulder beds with few thin sand units. The river dynamics during formation of T4 and T3 was such that it could only transport sand sized particles while during formation of T2 and T1 it changed drastically. It is important to understand that this change was either induced due to climatic fluctuations or due to the tectonics. We observed in two of the studied sections the T3 terrace was deformed indicating that this deformation event took place after its formation, i.e. 30 ka. This was followed by the formation of T2 terrace, pointing towards a tectonic activity between 30 ka and 24 ka which drastically changed the dynamics of the Tista River. Even the younger terraces viz. T2 and T1, also show warping indicating that the region is tectonically active in present day scenario, posing a serious problem for the local inhabitants. The climate and tectonics are working hand in hand in shaping the geomorphology of the region.

**P-2901**

## **Holocene river terraces and alluvial fans in the Republican River valley: Implications for geoarchaeology in the central Great Plains, USA.**

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Geomorphic and stratigraphic investigations during the late 20<sup>th</sup> century in the Republican River valley proposed a sequence of two distinct Holocene terraces. This differentiation, however, was based on limited age control and is problematic. Here, we present results from a systematic study of different alluvial landforms at 22 localities in the Republican River valley. A suite of over 50 radiocarbon ages determined on soil organic matter provide age control for periods of landscape stability and soil formation.

Holocene alluvial landforms in the river valley include a broad floodplain complex (T-0a, T-0b, T-0c), a single alluvial terrace (T-1), and alluvial fans that mostly grade to the T-1 and T-0c surfaces. Remnants of a late Pleistocene terrace (T-2), mantled by Holocene (Bignell) loess, are also preserved. Holocene alluvial fans also grade to the T-2 surface, indicating that higher geomorphic surfaces have provided local base level control during the Holocene.

Radiocarbon ages from the upper A horizons of buried soils, indicating approximate burial ages, cluster at ca. 10,050-9200, 6800-5800, 4500-4100, 3600-3100, 2200-1700, 1300-900 yr. B.P. The correspondence between these age groups and particular landforms provides important information on the evolution of the Republican River valley and, subsequently, on the temporal and spatial pattern of buried cultural deposits. In particular, age groups 6800-5800, 4500-4100, and 3600-3100 are exclusive to buried soils in the T-1 fill and associated alluvial fans. In contrast, age groups 2200-1700 and 1300-900 yr. B.P. are associated with buried soils in almost all landform types, including the T-1 and T-0c fills as well as fans that grade to the T-2, T-1, and T-0c surfaces.

Stable carbon isotope ( $\delta^{13}\text{C}$ ) analysis of soil organic matter indicates a shift from ~40%  $\text{C}_4$  biomass at ca. 6000 to ~85% at ca. 4500 yr B.P. This increase in  $\text{C}_4$  biomass is interpreted as reflecting a shift to warmer and likely drier conditions during the Altithermal (Holocene Climate Optimum). We propose a scenario where (1) a reduction in  $\text{C}_3$  vegetation after 6000 yr B.P. destabilized the uplands, resulting in an increase in sediment supply and aggradation of the T-1 fill and associated alluvial fans and (2) the establishment of  $\text{C}_4$  vegetation by ca. 4500 yr B.P. stabilized the uplands, resulting in a reduction in sediment supply and subsequent incision and abandonment of the T-1 surface. The proposed timing and nature of landscape change is consistent with regional records from the Central Plains and provides an important model for identifying where specific cultural deposits are likely to be preserved in buried contexts.

P-2902

## Characteristics and geochronology of the Severance Formation: a new mid-through late Wisconsinan lithostratigraphic unit in the Eastern Plains, USA

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### Abstract

Studies of late Quaternary landscape evolution in river valleys of eastern Kansas and Nebraska have identified thick packages of mid- through late-Wisconsinan alluvium beneath terraces and thin to moderately thick accumulations of late-Wisconsinan colluvium preserved along margins of valley floors. Previously, these alluvial and colluvial deposits were referred to as the valley facies of the Gilman Canyon Formation (Mandel and Bettis, 2001), a unit of late-Wisconsinan loess on the adjacent uplands, but subsequently have been defined as a new lithostratigraphic unit, the Severance Formation. Recent investigations have revealed that the Severance Formation consists of two members: an early member that sometimes occurs immediately beneath the Gilman Canyon Formation, and a late member that is beneath a terrace surface or a thin veneer of Peoria Loess. Preliminary OSL ages suggest that the early member aggraded between ca. 50 and 30 ka. Hence, the early member records Marine Isotope Stage 3 (MIS 3) alluvial activity that predates the oldest Gilman Canyon Formation deposits and has potential to provide a window into a virtually unknown period on the Eastern Plains. OSL and radiocarbon ages suggest that the late member aggraded between ca. 30 and 14 ka (MIS 3 and 2); hence, it records valley activity just prior to and during cool and dry conditions that coincide with the accumulation of the Peoria Loess and related eolian sand on upland and high-terrace landscapes. The shift from the relatively warm moist conditions of MIS 3 to relatively cool, dry MIS 2 was accompanied by incision, perhaps mimicking the response of the drainage system across the MIS 4 (relatively cool/moist)/MIS 3 boundary.

Both members of the Severance Formation are oxidized, and the late member typically has two or more paleosols forming a pedocomplex similar to the one developed in the Gillman Canyon Formation. The paleosols tend to have thick, well-expressed Bt horizons with strong brown to yellowish brown matrix colors; prismatic to subangular-blocky structure; iron and manganese oxide stains and nodules; discontinuous clay films and silans; and many to common macropores. Radiocarbon ages determined on total decalcified organic carbon from the paleosols in the Severance comprise two separate clusters: 28-25 ka and 17-15 ka.

P-2903

## Geologic influence on subglacial hydrology and glacier basal motion

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### Abstract

Understanding subglacial systems is essential for making predictions of glacier motion and the contribution of glacier melt to stream runoff in the context of overall glacier response to climate change. Several studies have shown that subglacial hydrology is one of the key controls on basal sliding, but how the ice bed geology influences the subglacial drainage system and therefore the basal sliding, is still poorly understood. The drainage system at the base of a glacier usually consists of two main components with complex interactions: 1) a distributed system of linked cavities and 2) a channelized system that depends on the development of Röthlisberger channels into the basal ice. Both systems are expected to evolve during the melt season in response to variable water flux, effective pressure, and sliding speed. In this study, we use a two-dimensional finite element model to simulate the seasonal evolution of a hydrological system at the base of a glacier. The sliding velocity of the ice is allowed to vary as a function of the contact area between the ice and its bed.

Our computational experiments consider a range of groundwater transmissivities in order to explore the effect of groundwater flow on the seasonal variability of sliding velocity. Using low groundwater transmissivities ( $< 10^{-5} \text{ m}^2 \text{ s}^{-1}$ ), typical of non-carbonate rocks, a subglacial drainage system evolves from an inefficient drainage system in winter with relatively slow sliding, a high contact area, and moderate effective pressure, followed by the spring event with enhanced sliding as the capability of the drainage system is exceeded by the increasing surface melt. In summer, channels gradually develop as the subglacial system adapts to the increased water flux. The development of channels cause cavities to shrink and sliding consequently slows towards the winter level. On the other hand, by applying groundwater transmissivities typical of carbonate rocks ( $> 10^{-5} \text{ m}^2 \text{ s}^{-1}$ ), the water discharge through bedrock prevails over the entire year, leaving the channelized system largely undeveloped. As a result, the sliding velocity remains low and stable throughout a year.

Warm-based glaciers typically exhibit a distinct seasonal variation in sliding velocity, with spring-summer sliding velocities sometimes two or three times faster than winter averages. However, glaciers resting on carbonate rocks, where the meltwater discharge through bedrock accounts for more than 90% of the total meltwater flux, are, at least in some cases known to show reduced seasonality. Our results demonstrate how groundwater flow can effectively remove the seasonal variation of glaciers flowing on carbonate rocks such as well-karstified limestone.

**P-2904**

## **Subglacial seasonal meltwater deposits from a thick Weichselian till sequence, Dösebacka, Sweden**

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Seasonal changes in subglacial hydrology, which affect ice-flow rates, have been inferred from the Greenland ice sheet. The sediment record of this type of event is not known because of the inaccessibility of the bed. Here, we report on a serendipitous sequence of diamicton and sorted sediments at Dösebacka, Sweden, which we interpret as being produced by seasonal development of subglacial meltwater delivered from the surface of the Scandinavian ice sheet during the last glaciation. The sequence consists of 30 m of diamicton with interbeds of sorted material. Though there is some variation, sorted sequences are 5-30 cm thick and are coarsening upward starting with 1-3 cm of clay, followed by silt, sand and pebbly sand. Deformation in the sorted sediment is rare. Five to seven sorted layers are identified and can be correlated across the outcrop. Diamicton beds are 1-5 m thick between the sorted layers. The diamicton is massive and contains a strong fabric, and we interpret the diamicton as subglacial traction till. We interpret the sorted sediment as a sequence deposited by subglacial meltwater and created during increased water pressure at the bed. Initially, increased water pressure produces patches of bed separation that are not connected laterally. In this standing water, clays are deposited. With time, these pockets become better connected, and water velocity increases as indicated by the increase in grain size. We hypothesize that these sequences represent seasonal delivery of meltwater from the surface. Thus, each sorted bed represents a summer and indicates seasonal subglacial drainage evolution. The coarsening upward indicates the evolution of bed-hydrology integration from standing pools to connected systems.

**P-2905**

## **The ability of glaciers to erode limestone beds**

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### **Abstract**

Despite numerous studies and the use of various techniques, quantifying glacial erosion is still challenging. This is due to difficulties accessing the ice-bedrock interface for direct measurements. In addition, the question of representivity of using sediment load of meltwater remains as the detangling of contributions from glacially eroded material from other sediment sources e.g. from gravitational processes is difficult. Furthermore, glacial erosion is dependent many factors like ice thickness, bedrock slope, glacier type (cold based/warm based, plateau glacier/valley glacier) or lithology to mention only a few. Therefore it is not surprising that reported erosion rate values range over many orders of magnitude ( $10^{-3}$  – 10 mm/a). Studies so far focused mainly on glaciers eroding crystalline bedrock. Therefore, this study aims to quantify glacial erosion on a limestone bed to ascertain the influence of lithology. To do so a combined approach of detailed geomorphological mapping of the only recently ice-free glacier forefield combined with cosmogenic nuclide analysis which enables calculating erosion rates, is used. In order to calculate subglacial erosion rates we implement the MECED cosmogenic nuclide MATLAB model developed by Wirsig et al. (2017). The model includes periods of glacier coverage, snow shielding and karst weathering. The study area is the Lapiez de Tsanfleuron (CH). It is with around 10 km<sup>2</sup> one of the biggest karst fields in Switzerland and the highest part of the area is still covered by the Tsanfleuron Glacier. The glacier forefield has a pronounced glacial polish, many different karst features, and a prominent Little Ice Age (LIA) moraine crossing the entire forefield. Samples for erosion rate determination were distributed over the forefield, as well inside and outside of the LIA extent, to detect possible spatial variations of erosion rate values eventually linked to karst features.

Wirsig et al. (2017) Earth Surf. Proc. Land. 42, 1119-1131.

**P-2906**

## **Investigation of large-scale glaciotectonic deformations at the paleo-ice stream bed using multiple geophysical methods, a case study from western Latvia.**

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### **Abstract**

Subglacial processes are usually interpreted from sedimentary sequences exposed in subglacial bedforms that frequently shape paleo-ice stream beds. In Western Latvia, subglacial structures are hidden under almost flat ground surface mainly due to postglacial erosion processes of the Baltic Ice Lake. Along the bluffs of the Baltic seashore in Strante-Ulmale site, outstanding glaciotectonic structures are described (Saks et al., 2012) showing that relatively flat ice stream bed holds unique features characterizing active and passive subglacial glaciotectonic deformations formed beneath a local Apriķi ice tongue. Research comprises the study of the distribution and morphology of glaciotectonic structures, as well as disintegrated Late Pleistocene sedimentary sequence using ground penetrating radar (GPR) and electrical resistivity sounding (ERS).

The thickness of Pleistocene deposits in the coastal area of Western Latvia reaches 70 m. The upper dozens of meters consist of shallow basin clayey, silty and sandy sediments overlain by a defragmented cover of the several-metres-thick Late Weichselian till and topmost marine and aeolian gravels and sands. The sandy sediments are protruded by clayey silt diapirs in places.

To study the diapirs and complicated sedimentary sequence we used GPR Zond 12-e with 300 MHz antenna and the electrical resistivity sounding (ERS) system SYSCAL Pro Switch 72. GPR profiles (32) with a total length of 9 km were recorded. With ERS two profiles with the two-meter spacing between electrodes (72 electrodes in total) and seven profiles with five-meter spacing (54 electrodes) were recorded.

The GPR data show strong reflections from disturbed layering and diapir structures. It is possible to detect the surface of the upper till unit or clayey silt diapirs, as well as sandy sediment sequence up to 10 m below ground surface. The maximum penetration depth of GPR signal is used to visualise the possible distribution of defragmented Pleistocene sandy, silty and till sediments. Combining GPR results with results of geological drilling we show that it is possible to distinguish the areas covered by upper till from diapir structures. Results from ERS greatly coincide with GPR results. Unlike GPR, ERS method allow to detect the thickness of upper till unit and provides deeper look on possible under-till structures up to the depth of 25 m from the ground surface.

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P-2907

## First extensive glaciations of the northern Alpine foreland: Sedimentology of diamicts in the Early Pleistocene Deckenschotter Groups (Northern Switzerland)

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### Abstract

The Höhere and Tiefere Deckenschotter Groups of Northern Switzerland mainly comprise glacial outwash sediments deposited by the first extensive glaciations of the Alps. Only in very few outcrops, however, the gravelly facies is associated with diamictos interpreted as glacial tills (e.g. Heim 1891, Frei 1912, Graf 1993). Despite the importance of these presumed glacial deposits as markers of ice-contact during the Early Pleistocene, they remain relatively poorly studied. We present results from an ongoing project to better constrain the depositional environment of these diamicts at selected key sites using detailed macro- to microscale sedimentology, fabric and geotechnical analyses. Our first results show that the investigated diamicts are of glacigenic origin. They appear, however, to be emplaced in a variety of subglacial to ice-marginal settings giving insights into the subglacial bed conditions, ice-bedrock interaction and paleo-landscape. Our analyses thus help to better constrain the extent and characteristics of glacier advances related to the first extensive glaciations of the Alps.

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**P-2908**

## **Glacial erosion on limestone and relief development in the Alps**

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### **Abstract**

By combining detailed field study and cosmogenic <sup>36</sup>Cl measurements, we look at the striking contrast between subglacial erosion rates measured on gneiss (Wirsig et al. 2017) and on limestone (Steinemann et al. 2019) in the Alps. The fundamental quandary exists: limestone is a rock that is enormously softer than gneiss, thus it should be much easier to erode beneath a sliding glacier. Observations at glaciated karst regions have been contrastingly interpreted as indicating either profound or insignificant glacial erosion. In the latter case the presence of a cold-based glacier is at times invoked.

At the Tsanfleuron glacier site in Switzerland, evidence of glacial erosion is abundant. But the true magnitude (depth removed by the glacier) is difficult to constrain based on observations alone. The obvious appearance of highly polished rock surfaces within the Little Ice Age-glacier footprint belies the likelihood that very little rock was removed during recent glacier advances. The underlying limestone is part of a well-studied karst system (Gremaud et al. 2009). Meltwater running off the glacier surface today is seen to pour into karst shafts within meters of the ice margin. Meltwater beneath the glacier is and was likely immediately and efficiently channeled down into the karst system. Glacier sliding, and thus erosion, is directly linked to the presence of water at the base of a glacier on a hard bed. Loss of water inhibits sliding, erosion slows (Bindschadler 1983).

This suggests that in strongly karstified areas it is the inability of glaciers (and of course rivers) to effectively erode limestone itself that led to the formation of the high limestone plateaus of the Alps over the numerous Quaternary glaciations. As the glaciers cleared away easier to erode overlying (silicate) rocks and eroded down to the massive limestones the plateau character emerged. The low relief of the thus created high-elevation flat surfaces further hampered sliding and a positive feedback developed. On the other hand, clearly some limestone terrains in the Alps are strongly glacially incised. What factors lead to certain areas of limestone being eroded less than their neighbors such that high standing plateaus form? As shown at the Tsanfleuron site, near horizontal, very thick-bedded, weakly fractured, massive limestone bedrock favors this process.

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P-2909

## Fantastic flutes and where to find them: the world's oldest surging glacier land-system

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### Abstract

Fingerprinting ancient surges is often hindered by the poor preservation potential of some common features (e.g. concertina eskers), alongside the absence of any single diagnostic landform of surge-type behaviour. It is necessary therefore to recognise a suite of closely associated landforms to reliably interpret palaeo-surge activity. This land-systems approach has been widely adopted on modern and Pleistocene glacier forefields, but here we demonstrate how it can be applied far deeper in geological time. Using new Unmanned Aerial Vehicle (UAV) imagery, we present the first palaeogeomorphological map of an Ordovician (443 million year old) surging glacier land-system: the oldest example recorded to the authors' knowledge. Three sets of cross-cutting landforms crop out over an area of  $\sim 1 \text{ km}^2$  in the Western Cape Province of South Africa, interpreted to represent three stages of a complete surge cycle. Firstly, highly elongate ( $>100 \text{ m}$ ) and narrow subglacial flutes reflect streamlining of dilatant sediments during active surging. These are cross-cut and overlapped by low amplitude transverse fold ridges, formed by 'rucking' of the subglacial bed at surge termination as lubricated sliding ceased. Finally, both structures are draped by sinuous sand bodies which represent the fill of a more efficient, channelized drainage system established during post-surge quiescence. We argue that the transverse fold ridges occur in place of the more typical crevasse-squeeze ridges due to locking up of the subglacial bed, either driven by freezing or desaturation. This inhibits bottom-up squeezing of dilatant crevasse fill, and instead promotes buckling of the stiffer, more competent bed. These transverse fold ridges may therefore represent an additional landform type which can be incorporated in the typical surging suite, thus expanding the available toolkit for identifying surges in both the ancient and modern depositional record.



View westward over the 443 million year old surging glacier land-system at Pakhuis Pass, Western Cape Province, South Africa.

**P-2910**

## **Morphological and sedimentological studies of subglacial V-shaped hummocks – formation and significance**

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### **Abstract**

Mapping of glacial landforms in the south Swedish uplands (SSU) using LiDAR-derived digital elevation models (DEM) has revealed a distinct type of hummock landform. The SSU is characterized, in general, by hummocky glacial landforms, often connected to stagnant ice environment during deglaciation. However, distinct V-shaped hummocks occur in places, with an apex generally pointing down ice and with an asymmetric vertical profile along its axis. They are roughly 10-100 meters wide, 5 to 50 m long, and 2-10 meters high.

The V-shaped hummocks occur in close relation to ribbed moraine and, in places, they are draped by eskers and overprinted by flutes, indicating a subglacial genesis. Generally, the landform occurs in fields that in places are elongated parallel to the overall ice-flow direction. We have surveyed all of Sweden for occurrences of these landforms, and this has revealed that they are most frequently occurring north of the Younger Dryas ice margin and in areas deglaciated during Bølling-Allerød. Detailed sedimentological studies in machine-dug excavations at multiple locations were performed and reveal a composition of heterogeneous sandy gravelly diamicton, with angular to sub-angular clasts. Lenses of sorted sediments are interbedded in the diamicton and boulders are common on the surface.

Crosscutting relationships suggest a subglacial origin and their distribution on an ice sheet scale suggest that they were formed during periods of rapid ice retreat. We list and discuss multiple hypotheses that can explain the geomorphological and sedimentological indications to shed light on the formative process. We hypothesize that their genesis is related to changing subglacial hydrologic conditions.

**P-2911**

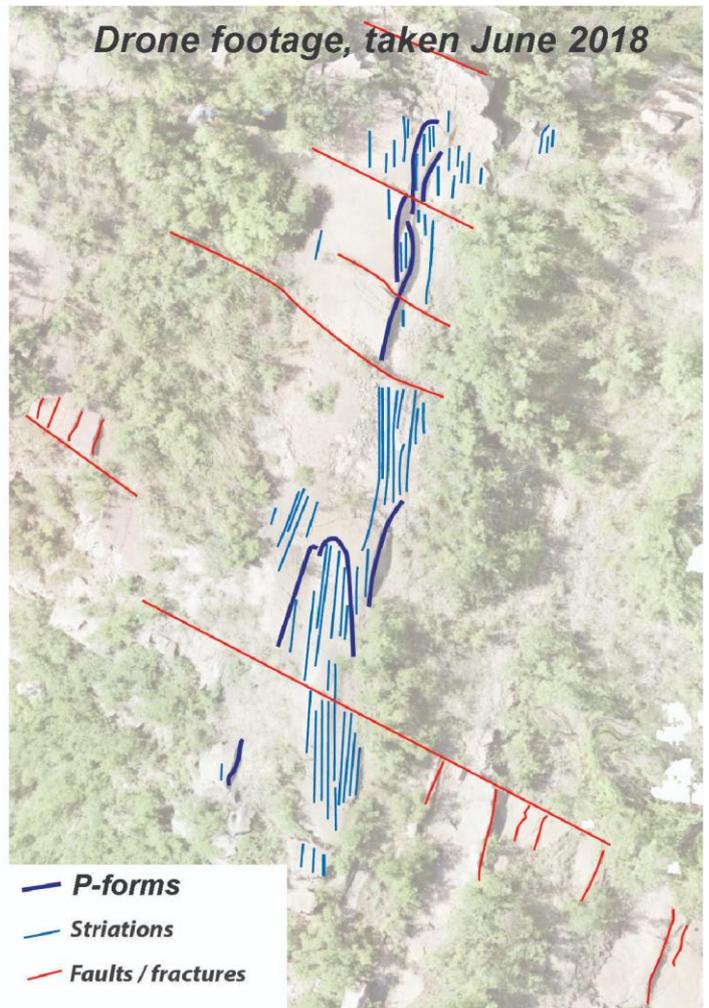
## **A bird's eye view of a Ediacaran-Cambrian subglacial landscapeA**

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### **Abstract**

A spectacular subglacial landscape carved beneath Ediacaran-Cambrian ice masses crops out in the Shimengou area of central China. Despite being known for more than 30 years, no attempts have hitherto been made to map, document, and rigorously interpret this surface which was produced during the Luoquan glaciation. This glaciation occurred when the Shimengou area occupied tropical palaeolatitudes. New imagery from an Unmanned Aerial Vehicle (UAV) reveals a series of scallop-shaped bedforms over a wide (ca. 1 km x 100 m) area of dipping sandstone beds. A classic "p-form" assemblage is mapped and described, including general faceted forms, müschelbrüche, cavetto and spindle forms alongside striations. Some of these features cross-cut small scale orthogonal fractures and faults, the trend of which has been later exploited during subsequent regional tectonism. The small-scale fractures are interpreted as Riedel shears which developed in response to shear by an overriding ice mass. Significant lateral variation in bedform arrangement is interpreted to record complex local flow behaviour. Collectively, interpretation of the p-forms, striations and transverse fractures leads to a story of progressive abrasion, significant ice-bed coupling and stick-slip behaviour. Remarkably, and unlike many Quaternary examples, the pristine surface shows no evidence for meltwater reworking, perhaps pointing to rapid ablation, in spite of the evidence for vast hinterland ice sheets. This raises questions about the representativeness of subglacial structures seen throughout geological time.



Unmanned Aerial Vehicle (UAV) image (left) and interpretation (right).

P-2912

## Subglacial processes and mega-scale glacial lineations in North Lithuania

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### Abstract

The identification of mega-scale subglacial lineations (MSGs), i.e., determination of their morphological, structural and genetic features, is one of geological mapping problems. Confirmations are growing in scientific literature that such subglacial forms as MSGs are related to ice thickness and glacier movement rate (Rose, 1987; Brodzikowski, van Loon, 1991, Stokes et al., 2013; and other). To examine the problem, an area in North Lithuania (districts of Pasvalys and Biržai) has been chosen, there, “drumlinised” morainic surface of the Last Glaciation is fixed with well-expressed mega-scale lineations. The morphometric parameters of MSGs in Lithuania have been determined by cartometric measuring from topographic maps (1:10 000). A digital elevation model (DEM) with 2 m spatial resolution was used for some small areas in North Lithuania. The composition of the Pušalotas and Ruopiškiai MSGs, the thickness and sedimentological characteristics of the depositional units have been determined as well as clast fabrics and samples for anisotropy of magnetic susceptibility (AMS) have been taken from excavated pits. The orientation and dip of the long axes of 50 clasts with elongation ratios of  $\geq 3:2$  have been measured at 2 sites in the MSG using a geological compass applying the method outlined by A. Gaigalas. The petrographic composition of pebbles has been analysed using the following categories: crystalline rocks, sandstone, Devonian dolomite and dolomitized rocks, Ordovician and Silurian limestone, Devonian and Permian limestone and group of other rocks.

The data presented above show great resemblance between the implied MSGs formation type and the mechanism of surge phenomenon. In the case of Mūša–Lėvuo lobe, favourable geological, palaeogeomorphological and hydrological conditions also could be mentioned. Depressions in sub-Quaternary and Grūda–Baltija interstadial surfaces, intense drainage of meltwater and formation of glaciolacustrine basin formed conditions for rapid movement of Mūša–Lėvuo lobe into the area studied. Pebble long-axes and AMS orientation measurements confirm formation of older “loose” till typical for flutings and MSGs during the glacier’s erosion, when basal ice carries over macroclast material to the MSGs crests from the interridge areas in a spiral mode. In order that such process could occur, water should be available at the bedrock and glacier’s basal part as well as shear stress relaxation at the southern margin of the ice stream. The fact that Mūša–Lėvuo lobe moved into the glaciolacustrine basin is confirmed by parallel crests of MSGs becoming lower towards the central part of the basin.

**P-3001**

## **Surface exposure dating of raised shorelines in Finnmark, Norway**

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### **Abstract**

Ice sheet growth and decay profoundly impact global eustatic sea-level and, regionally, isostatic depression and uplift. Raised shorelines, beaches, deltas and wave cut rock platforms are all landforms typically bearing witness of higher relative sea-level stands following a deglaciation, along previously glaciated coasts where the ice sheet have glacio-isostatically depressed Earth's crust. In Scandinavia, the relative sea level history is commonly well studied in areas suitable for application of the isolation basin method. However, large uncertainties remain in many areas, e.g. along most of the arctic coastline of Finnmark, where Norway faces the Barents Sea. Here, we have employed a novel approach to reconstruct the chronology of postglacial shoreline displacement. We use terrestrial in-situ cosmogenic nuclide (TCN) dating directly on boulders and cobble found on the raised landforms (deltas and beach ridges).

We have targeted and dated deglaciation moraines, juxtaposed to raised shorelines, beaches and deltas and sampled for; i) n=25 rock samples from erratic boulders on top of moraines, ii) n=16 sediment samples from depth profiles in delta deposits, and iii) n=46 flat (<5 cm thick) cobbles from raised beaches, and measured the concentration of <sup>36</sup>Cl and <sup>10</sup>Be in these samples. Overall, initial results show that the northern coast of Finnmark was deglaciated at 14-15 ka, and that the ice sheet withdrew to the inner fjord areas where prominent moraines were built during the Younger Dryas chronozone. The ages obtained on raised beaches and deltas representing marine limit generally reflect the deglaciation ages, Some ages were obtained from levels below marine limit; these represent later relative sea levels and our goal is to use the data collectively to reconstruct rates of relative sea level change through different periods, especially during the Lateglacial for which other chronological data (e.g. from isolation basins) do not exist. Our first results are promising, especially for flat cobbles on raised beach ridges, which yielded the most consistent results so far. Some of the TCN dates are, however, ambiguous, reflecting limitations with TCN field sampling and dating precision.

**P-3002**

## **Coastal zone landscapes of the archipelago Novaya Zemlya and bird colonies**

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The position of the archipelago Novaya Zemlya contributed to the development in its coastal zone of unusually abundant and diverse life for these latitudes: the largest colonies of seabirds in the Russian Arctic.

Seabirds feed on fish and zooplankton, their excrement enriches coastal waters with nutrients. The metabolic cycle of seabirds is not a local phenomenon, but a regional cycle of great importance for the functioning of the marine ecosystem as a whole.

For occurrence of the bird's colony on the sea coast the combination of a number of natural conditions is necessary, the most important among which is the existence of sufficient forage base, a specific relief of the sea coast, hydrodynamic conditions of nearshore marine waters.

Almost all rookeries of the archipelago Novaya Zemlya are located on the Barents Sea coast. On the Eastern side of the rookeries were observed only in the North-East end of the North Island, and the most south is in the cape Bismarck.

The basis of the rookeries is nesting *Uria lomvia*. We estimate the total number of the main bird species in the bird colonies of Novaya Zemlya as close to 2 million individuals.

During the breeding season colonial seabirds of the Novaya Zemlya consume at least 54 409 tons of fish and zooplankton. The calculations carried out for each of the bird colonies of Novaya Zemlya have shown that as a result of the birds' activity 33 380 tons of excrement are produced during the breeding season.

The total amount of phosphorus dissolved in sea water near the coast of Novaya Zemlya will be more than 20 tons, and nitrogen – almost 54 tons. The calculations show that the total area of aquatory enriched with nutrients for Novaya Zemlya is 1226 km<sup>2</sup> with a water layer thickness about 25 meters.

The coastal waters of the Oransky Islands, where there are bird colonies, numbering about 60 thousands birds, clearly have marks of eutrophication – rocky limestone bench, surrounding the westernmost of the Large Oransky Islands, to a depth of 3-5 m overgrown with filamentous algae (covered about 60%). The presence of bird colonies initiates an increased flow of nutrients into the aquatic ecosystem, which contributes to the increase of its primary production. The increased content of organic matter in the suspension is evidenced by the high content of organic carbon in the bottom sediments – 0,95-1,90%, which corresponds to the content of organic carbon in the rivers mouths of the taiga zone, such as the Severnaya Dvina.

P-3003

## Stability and biodegradability of organic matter in permafrost-affected soils of coastal Yamal region, Russian Arctic

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### Abstract

Knowledge of permafrost soils in polar regions has advanced significantly in recent decades, despite the remoteness and inaccessibility of most of the region and the sampling limitations posed by the severe environment. This has led to significantly substantial increasing of estimates of the amount of organic carbon (OC) stored in permafrost-affected soils and improved understanding of how pedogenic processes unique to permafrost environments built enormous OC stocks during the Quaternary. Chemical composition of SOC determines its decomposability and may affect soil organic matter stabilization rate (Beyer 1995; Ejarque, Abakumov, 2015). This is quite important for understanding variability in SOC pools and stabilization rate in context of changes in plant cover or climate (Rossi et al. 2016). Moreover, <sup>13</sup>C nuclear magnetic resonance spectroscopy, which provides detailed information on diversity of structural composition of humic acids and SOM, may also be used to study the SOM dynamics under decomposition and humification processes (Kogel-Knabner, 1997; Zech et al., 1997). This study is aimed to characterize molecular composition of the humic acids, isolated from various permafrost-affected soils of coastal Yamal region and to assess the potential vulnerability of soils organic matter in context of possible mineralization processes. Organic carbon stocks for studied area were  $7.85 \pm 2.24 \text{ kg m}^{-2}$  (for 0-10 cm layer),  $14.97 \pm 5.53 \text{ kg m}^{-2}$  (for 0-30 cm),  $23.99 \pm 8.00 \text{ kg m}^{-2}$  (for 0-100 cm). Results of solid-state <sup>13</sup>C-NMR spectrometry showed low amounts of aromatic components in studied soils. All studied humic powders are characterized by predominance of aliphatic structures, and also carbohydrates, polysaccharides, ethers and amino acids. High content of aliphatic fragments in studied humic acids shows their similarity to fulvic acids. Low level of aromaticity reflects the accumulation in soil of lowly decomposed organic matter due to cold temperatures. Our results provide further evidence of high vulnerability and sensitivity of permafrost-affected soils organic matter to Arctic warming. Consequently, these soils may play a crucial role in global carbon balance under effects of climate warming. This study was supported by the grant of Saint Petersburg State University "Urbanized ecosystems of the Russian Arctic: dynamics, state and sustainable development" and the Government of the Yamalo-Nenets Autonomous District.

P-3004

## Multiproxy records from the Laptev Sea shelf, Siberian Arctic: implications for reconstructing land-sea interactions and palaeoenvironmental changes since the mid-Holocene

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### Abstract

Here we present multiproxy records from the inner Laptev Sea shelf. The sediment cores were recovered from two sites to the north and northeast of the Lena River Delta and at 27 m and 21 m water depths, respectively. High-resolution records of the distribution of various ecological groups of microfossils were established, including terrestrial (pollen and spores), marine (cysts of dinoflagellates, benthic and planktic foraminifera, ostracods) and freshwater (colonial chlorophycean algae). Together with benthic foraminiferal  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  records this allows for a detailed reconstruction of the regional palaeoenvironmental changes since 6.0 ka.

Two major factors are responsible for the observed environmental variability: progressive shelf flooding and coastline retreat due to thermoabrasion, and climatically-induced river runoff fluctuations (fluvial events). The latter are represented in the records by (1) increases in sedimentation rates; (2) high influx of terrestrial pollen, spores, freshwater green algae, wood and plant remains; (3) elevated percentages of far-distant, river-transported pollen of conifers vs local tundra shrub pollen; (4) negative  $\delta^{13}\text{C}$  excursions and some radiocarbon age reversals due to the introduction of old carbon with dissolved inorganic carbon (DIC) of river water. Coeval positive  $\delta^{18}\text{O}$  excursions and increasing representation of river-distal species among benthics, including rare planktic foraminifers, point to a presence of a reversed (north to south) bottom current activity along the submarine paleovalleys on the shelf. The most pronounced fluvial events were recorded at 5.3-5.9, 1.5 and <0.5 ka. As reflected in the pollen records, the oldest fluvial event coincides in time with the final phase of mid-Holocene regional climate warming. Although the rather brief fluvial event at 1.5 ka is recorded at both localities, it is more prominent at the northeastern site, thus, probably marking a diversion of the main Lena River outflow towards this direction. The most distinct major change, however, is noted at this site during last 500 years. A trend to extremely negative benthic  $\delta^{13}\text{C}$  values is seen which could be a result of light DIC composition of the bottom waters, perhaps due to re-mineralization of organic matter produced by phytoplankton in response to increased outflow of nutrient-rich Lena river water. We therefore conclude that this unprecedented change in  $\delta^{13}\text{C}$  provides further evidence for a principal diversion of the main Lena River outflow which since then occurs towards the east.

**P-3005**

## **Distribution of recent and buried ice scours on the shelf of the East Siberian Sea**

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### **Abstract**

In August - September 2018 Russian Geological Research Institute (VSEGEI) together with Russian Marine Positioning and Survey Company (ROMONA) carried out 2100 km of acoustic-seismic ("SleeveGUN" and EdgeTech model CHIRP 3300HM), side-scan sonar (CM-2, C-MAX) and multibeam (R2Sonic 2024) profiling in the East Siberian Sea onboard RV "Ivan Kireev".

Numerous ice scours were fixed within the whole investigated area from the De Longa Strait to Kolyma Gulf. Several types of single and multiple ice scours can be distinguished. The width of the ice scours varies over a wide range from a few meters to 100 meters and more. The relative depth of scours usually does not exceed 1–1.5 m, but can reach 3 m. Some of them are characterized by "fresh" appearance with well-developed berms (ridges). The height of ridges achieves 1 m. Sometimes the scours are covered by bottom sediments.

The map of the ice scouring distribution in percentage of seafloor disturbance was compiled for the investigated area of the East Siberian Sea. The density of recent ice scouring traces, especially in the coastal area shallows, achieves 100% of bottom surface. Some ice scours within the open sea including the area of plaeovalleys were traced up to 50 m sea depth. The minimal disturbance of the seafloor by ice scouring was fixed in the De Longa Strait to the south of Vrangal Island.

It is possible to assume that scours are formed by rampant ice masses (toross) and grounded ice hummocks because no any icebergs are formed within the investigated area. The high degree of processing of the recent bottom surface by ice suggests that under the conditions of the East Siberian Sea, ice scouring, at least throughout the Holocene, was one of the leading underwater geological processes moving huge volumes of sedimentary matter. The acoustic seismic records showed that sediments processed by ice are revealed up to 12 m depth of subsurface geological section. Thus, it is possible to distinguish and map widely distributed Late Pleistocene - Holocene sedimentary strata with totally disturbed stratigraphic boundaries.

P-3006

## Records of long-term coastal evolution in the southern Laptev Sea: An interdisciplinary study of two Holocene lagoon/beach-ridge systems

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### Abstract

The geomorphological record of coastal sedimentary systems, such as lagoons, beach ridges, barriers, chenier plains and spits, may provide useful insight into the local spatiotemporal development of landforms and the processes involved in their formation. In Arctic environments, the delivery of wave energy and sediment is intimately linked with the duration and extent of the sea-ice cover and the study of coastal sedimentary systems thus may allow inferences on the long-term climate forcing of the marine environment at a larger scale.

Two coupled lagoon/beach-ridge systems located in Buor Khaya Bay (southern Laptev Sea) are investigated. They present valuable records of coastal evolution in an area dominated by presently retreating permafrost shorelines and thus have the potential to shed light on the forcing of coastal change over Holocene timescales. The study aims at providing a full appraisal of the modern spatial properties of the two systems by combining the investigation of surface and subsurface properties of the lagoon environment by ship-borne ground penetrating radar, underwater video and side-scan sonar surveys with the study of the beach ridge deposits by remotely-sensed data, elevation surveying, absolute dating and extensive field work. Both systems were previously undescribed in detail and were surveyed during an expedition in summer 2018.

Our data show that the initial formation of barriers separating the lagoons from the open marine environment has occurred prior to the establishment of a similar-to-modern relative sea level at approx. 6.5 – 6.0 kyr BP. The beach-ridge systems are composed of coarse material and rapidly prograded until c. 3.0 kyr BP. Since then, the system developed at a much lower rate, punctuated by periods of stability, concurrent with the timing of changes in late Holocene climate conditions. The elevation of the beach ridges is 3-4 m above present mean sea level throughout the entire sequence, suggesting a development driven by storm wave forcing from an NE sector under a stable Holocene relative sea level. The bottom sediment of the freshwater lagoons is composed of marine gravel, exposed bedrock and sand sheets and is mostly barren. The lagoons are c. 20 m deep and are thus several meters deeper than the open water of Buor Khaya Bay. Frost polygons were observed in the shallow waters in proximity to the lagoon shoreline. These new observations and their paleoenvironmental implications contribute to an improved baseline understanding of the modern properties and the past responsiveness of Arctic coastal systems to changes in natural forcing.

**P-3007**

## **Coastal dynamics of the accumulative Intsy cape (Zimniy coast of the White sea).**

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The research is based on field survey in 2016, with the involvement of satellite images 1984-2017 and topographic maps 1833-1999. Part of the White sea named The Gorlo is a water area with very active hydrodynamics, where Northern and Western waves are superimposed on high speeds of tidal currents. The Holocene accumulative terrace of Intsy cape occupies 12 km of the shore between the eroded areas; its width exceeds 3 km. Climate and sea level changes cause erosion of previously formed accumulative coast.



Fig.1. The location of study area.

The sea terrace includes remnants of the moraine ridges up to 25 m high, one of which is located the Intsy lighthouse, built in 1900. At the time of construction, the distance from the lighthouse to the coast was more than 250 m and the moraine hill was not eroded by the sea. Our research has established: The average rate of retreat of the coastal ledge, cut out in the moraine hillside, for 185 years was 2.4 m/year. With the same speed the ledge has receded also in 2009-2016. For these 7 years the area of the hill has decreased by 14.5%, annual losses due to erosion and landslides are estimated at 0.32 ha. If the rate of destruction of the shore remains the same, the lighthouse of Intsy will be destroyed in 25 years.

On the surface of the terrace up to 3 m high above sea level there are several generations of palaeo coastal ramparts marking the stage of extension of the shore. At this time of the 12 km of the terrace, only about 3.5 km remain stable, the rest are eroding. The retreat of the shore increases the deflation of sand on the littoral and the beach. The exposed sand is accumulated in the depth of the terrace forming vast massifs of dunes up to 12 m high. The main conclusion of the study is that in this area, due to changes in lithodynamic factors, the accumulation that prevailed during the Holocene was replaced by erosion of the shore.

P-3008

## A study of tide-driven sediment transport in the Jujincheon(river) and estuary on the west coast of the Korean peninsula

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### Abstract

Jujincheon is a small river that flows into the Gomso Bay in Buan city on the west coast of the Korean peninsula. Salinity, grain-size distribution of suspended sediment, and diatoms in surface water samples were analyzed from the estuary of Jujincheon to the upper river in the order of Yongsan Bridge, Banam Bridge and Hoam Bridge, during one tide cycle (12 hours). The water level of the river was measured using a global positioning system (GPS). The change in river regurgitation at Yongsan bridge and high salinity was measured when the sea level in Gomso Bay was higher than the river level due to the change of tide. The backward flow of the river was also observed at Banam Bridge and Hoam Bridge, which are located upstream from the Yongsan Bridge. The change in the water level at Banam Bridge and Hoam Bridge at high tide was similar or slightly higher than the tidal surface level; however, the salinity level did not change. After analyzing the particle size in the suspended sediment, it was clear that sand particles dominated in the downstream water and silt particles dominated in the upstream water. In addition, marine diatoms, such as *Paralia sulcata*, appeared which confirms that suspended sediment is transported by the seawater.

Based on these results, the transportation of sediment can be explained by tide changes in Gomso Bay. During low tide, the water level in the river is higher than the sea level, and the sediment is transported from the upper river to Gomso Bay by the river flow. On the contrary, during high tide, the sea level is higher than the river, and the seawater flows upstream from the estuary to the upper river. In this case, it is clear that the outflow of fresh water mixes with the estuarine environments and the marine sediments are deposited upstream. These results provide important data for interpreting how sediments were deposited in estuarine environments in the past. Even if there is little evidence that sea water would have affected sediment deposits in estuary environments in the past, it could indicate changes in sea level, including the tidal effect in estuaries where estuarine deposits occur.

Marine sediment is an indicator of changing sea levels and tides, especially in estuarine environments that are formed by rivers with low flow discharge, such as the Jujincheon river. In an estuarine environment where sediment from the sea is transported to a tidal limit or high tide level, very little evidence of marine sediment is observed due to the sedimentation associated with sea level changes. This could be interpreted as a result of sea level changes.

**P-3009**

## **Mid-Holocene sea-level highstand in the Malay Peninsula**

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### **Abstract**

In order to better understand the postglacial ice melting history, this study has investigated an estuarine wetland on the east coast of Peninsular Malaysia. From this tectonically relatively stable far-field site, a number of sea-level index points were collected from mangrove sediments. Based on these index points, the relative sea-level history between 7000 and 2000 cal. a BP was reconstructed. The result shows that the relative sea level reached the present height around 7000 cal. a BP, continued to rise to c. 2.0 m by about 4000 cal. a BP; and fell back onto the present height by about 2000 cal. a BP. This result has filled the gap of mangrove-based sea-level data for the Peninsula. The rise of relative sea level at a rate of 0.67 mm/a between 7000 and 4000 cal. a BP provides supporting evidence for the assumption of a continuous ice melting in this time period. The sea-level highstand of c. 2.0 m around 4000 cal. a BP suggests that the amount of glacial isostatic adjustment is significantly lower than previously assumed.

**P-3010**

## **Bioerosion notch reveals decimetre scale sea level variability during MIS 5 (Sur, Sultanate of Oman)**

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### **Abstract**

Coastal notches are cliff incisions that form primarily through a combination of bioerosion and abrasion and function as sea-level indicator since their apex aligns with Mean Sea Level (MSL) during formation. Our study area in Sur Lagoon at the northeastern coastline of Oman shows two coastal notches, one abrasional and one bioerosional. Both notches formed during the global sea-level highstand of Marine Isotopic Stage 5 (MIS 5) and are now located around 3.5 m above MSL. While the abrasion notch is less distinct, the bioerosion notch is very well preserved and shows body and trace fossils of a variety of organisms. Biological indicators adapt to sea-level variations with their distribution. Sea-level research often focusses on sea-level indicators emerging during stable conditions or on indicators roughly representing distinct climate periods. The combination of stable (coastal notches) and quickly corresponding sea level indicators (biological indicators) improves the information of sea-level changes before or after the stable sea level. These methods support the investigation of highly interesting periods like MIS 5.

With this study we aim to reconstruct short-term fluctuations in sea level during MIS 5 based on the shape and organisms of the bioerosion notch and thereby better understand the Quaternary sea-level history of the Omani coastline.

During fieldwork all occurrences of the notches were mapped around Sur Lagoon. The notch shape and distribution of the organisms were measured for each outcrop. Most common organisms are boring mussels, sponges, oysters, worms, and barnacles.

The interpretation of this field-data shows that the combination of a bioerosion notch and biological indicators can be used to determine sea-level development during MIS 5. Broadened and conflicting zonation provide evidence for a more complex sea-level history than simply one stable high stand. Proof of a sea-level rise of several decimetres after the notch formation and a subsequently dropping sea level was found.

P-3011

## High-latitude, coarse-grained beach ridges as archives of Holocene sea-level change

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### Abstract

Progradational beach- and foredune- ridge systems hold the potential to serve as archives of changes in sea level, storm frequency, climate, source and rate of sediment supply, as well as the coastal system's response to these changes across timescales. Here, we present records of millennial-scale Holocene sea-level change derived from two high-latitude, coarse-clastic beach-ridge plains, based on RTK-GPS mapping and geochronology. Internal beach-ridge structures are mapped at both sites using ground-penetrating radar to allow for characterization of beach-ridge indicative meanings based on the modern beach and foredune-ridge systems. At Bjornpynten, Svalbard 11 new radiocarbon dates derived from juvenile specimens of *Astarte borealis* shallowly buried within raised, gravel-dominated beach ridges across a ca. 1000 m wide plain reveal a period of rapid (ca. 9.0 mm/yr) sea-level fall of ca. 20 m from 11 to 9 ka. This resulted in reworking of pebble- to cobble- sized clasts alongshore to form seaward-dipping (~12–18°) beach ridges that are <50 cm in amplitude and spaced at 10–20 m. Decelerated sea-level fall between 9000 and 2000 years ago to 3.5 mm/yr resulted in slowed progradation (from 16.5 to 7.3 m per 100 years) and decreased ridge spacing to ~5-10 m. Together, these data confirm earlier reconstructions of Arctic sea level, and in particular the rapid sea-level fall following collapse of a major ice dome centered southeast of Kong Karls Land. In contrast, the mixed sand-and-gravel beach- and foredune- ridge plain of Miquelon-Langlade, France (50 km south of Newfoundland) records a period of slowly rising sea level in the North Atlantic during the last 2500 years. Development of this plain was through longshore delivery of coarse sediment sourced from erosion of proximal glacial deposits (moraines). Optically stimulated luminescence dating of the well-defined contact between coarse-grained, wave-built facies and overlying aeolian deposits is used to document a net sea-level rise of 2.4 m in three distinct periods: (1) an increase between 2400 and 1500 years at an average rate of + 1.3 mm/yr; (2) relatively stable or slowly rising relative sea level 1400-700 years; and (3) a rise of ca. 0.7 m during the past 700 years at a rate of + 1.1 mm/yr. These changes in sea-level rise are reflected in the development of the plain itself: periods of slower rise (0.2 up to 1.3 mm/yr) correlate to faster progradation. These data not only allow for the first sea-level reconstruction for the Saint-Pierre-et-Miquelon archipelago but also reveals further details of relative sea-level change in a region (Newfoundland) characterized by substantial variation reflecting its late Pleistocene ice-marginal position. Together, these two studies demonstrate the utility of Holocene (or earlier), progradational beach-ridge plains in archiving past changes in sea level, and associated coastal system response.

**P-3012**

## **Drastic Shore Line changes along Tamil Nadu Coast, India. Does it indicate the Sea Level changes?**

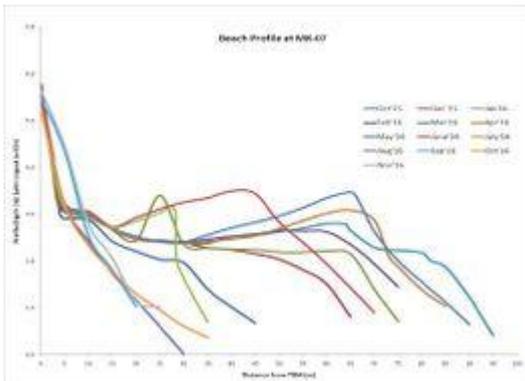
Selvaraj Settu

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As a part of Sustainable Shore Line Management (SSM) project, conducted by National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Beach Profiling was carried out at 60 locations along the coastal stretch between Poovar and Tuticorin, Tamilnadu Coast, India to monitor the behavior of coastal processes and shore line changes, for the period of 13 continuous months. The beach profiles show the rhythmic erosion and accretion pattern along the study area. In few locations, erosion is drastically active, and sea water inundation is prevalent. The general wave action is highly active and several meters of land has been inundated by sea water. Many roads and buildings are collapsed and washed out by the sea waves. In some places 50 – 75 meters of land has been encroached by sea water. This phenomenon of aggressive erosion corroborates the process of sea level changes taking place along Tamil Nadu coast. Many preventive structures like sea walls and groins have also been developed in such locations, but of no use. In fact the situation has been aggravated by these structures.

In a few locations accretion process is dominated, where beach area is prograded for several meters towards sea. Such abnormal behavior of the sea waves are recorded through beach profiles in the study area. Geotechnical and sedimentological researches have been initiated to find the causes.

**Key Words:** Beach Profiling, Erosion, Accretion, Sea level Changes.



**P-3013**

## **Holocene uplift rates in Korea**

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### **Abstract**

The most common method for estimating the uplift rate is to measure the height of the coastal terrace. Coastal terraces are basically formed at the position of sea level. In the Korean peninsula, the heights of sea level and coastal terrace during the Holocene are uncertain and it is difficult to estimate the uplift rate. The current controversy over the presence of the mid-Holocene sea-level highstand is due to the fact that sea-level data and interpretations vary slightly depending on the researchers. Although it is known that the coastal terraces are rising about 0.1-0.3 mm annually, there are disagreements among the researchers on age-dating of the coastal terraces, recognizing the coastal terrace surface, and evaluating the impacts of local fault activities. The purpose of this study is to investigate the regional differences in uplift rates based on the height of sea level and coastal terraces during the Holocene. Comprehensively, coastal terrace and sea level data show that Gangwon and Jeolla provinces coasts are stable after at least the beginning of the Holocene. Gyeongsang area showed a considerable uplift after the mid-Holocene. This spatial pattern seems to be related to the regional tectonic structures of the Korean peninsula (Gyeonggi massif, Ogcheon belt, Yeongnam massif, Gyeongsang basin, etc.), and the faults between the massifs. The trend of Moho depths estimated from the seismic explorations and the gravity anomalies estimated from the gravity survey generally coincide with the tectonic structures. Therefore, the uplift rate varies depending on the characteristics of the massifs, such as the degree of response to the tectonic stress and the crustal thickness. It can be determined that this pattern has caused confusion in restoring the Holocene sea level changes.

**P-3014**

## **Holocene sea-level changes in SE Asia**

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### **Abstract**

The project “Holocene sea-level changes in Southeast Asia” aims to investigate which areas in SE Asia are highly vulnerable to ongoing and future sea-level rise based on paleo relative sea-level (RSL) changes in the Holocene. The first phase was a compilation of a Holocene sea-level database, where existing data from literature was re-analyzed following a standardized protocol. Each data point was classified into one of three different data types: sea level index points, describing samples indicating the position of the paleo sea level as well as marine and terrestrial limiting points, indicating the sea level position above or below the sample origin. In this phase we verified that, for Indonesia, there is only a small amount of data available. Therefore, fieldwork was conducted in the Spermonde Archipelago, south-western Sulawesi, Indonesia, to collect new sea-level data. Results provide ages of 26 fossil microatolls calculated from the radiocarbon analysis, where 16 samples show ages varying between  $5956.5 \pm 83.5$  years before present (a BP) and  $3614.5 \pm 98.5$  a BP. These samples indicate paleo RSL positions from  $-1.59 \text{ m} \pm 0.1 \text{ m}$  up to  $0.46 \text{ m}$ . 9 samples show younger ages ranging from  $236.5 \pm 140$  a BP to  $36.5 \pm 25$  a BP and present paleo RSL positions between  $-1.96 \text{ m} \pm 0.19 \text{ m}$  and  $-0.15 \pm 0.13 \text{ m}$  a BP. One sample turned out to be modern. Finally, combining these RSL positions with Glacio Isostasy Adjustment models (GIA) this project will lead to future sea level predictions of the Spermonde Archipelago and the area of SE Asia and identify which areas are highly endangered by sea-level rise.

**P-3015**

## **Modeling the Impact of Tropical Cyclones on Developed Coastlines Under Future Sea-Level Rise Scenarios**

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### **Abstract**

Global warming and climate change represent a severe hazard for the global population living within low-elevation coastal zones. Coastal communities are already experiencing social and economic impact under current sea-level rise, in the future however, their overall exposure to inundation and erosion will be even greater. These impacts are further magnified under extreme storm conditions, like tropical cyclones. In 2016, Hurricane Matthew skirted the coastline of Palm Beach, Florida. The category 4 storm subjected the area to significant storm surge and powerful wave conditions; leaving a swath of destruction in the storm's wake. In order to provide an insight into coastal change during tropical cyclone events under future sea-level rise scenarios, this study utilizes a coupled 2DH hydrodynamic and morphodynamic XBeach model that is evaluated under two local sea-level projections. Both sea-level rise scenarios are extracted from Kopp et al. (2014) and Kopp et al. (2017), and are applied to a validated hindcast of Hurricane Matthew. The effective doubling of sea-level rise projections under hurricane conditions significantly increases overwash and inundation of the beach. This greater exposure of the entire beach profile to hydrodynamic forces, drives increases in deposition along the backbeach, as well as erosion along the foot of coastal protection structures. Analysis of shoreline hydrodynamics indicate that wave velocities and wave height increase in conjunction with sea-level rise. This experimental structure shows the applicability of XBeach in modeling the impact of future tropical cyclones under changing sea-levels and opens the door for continuing investigations.

**P-3017**

## **Early Holocene sea-level jumps: evidence and open questions from the Adriatic Sea**

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### **Abstract**

Strong efforts have been done by the scientific community to reconstruct the last marine transgression and describe it through geophysical models that could match with the information observed in the field. However, because of the few available data, the eustatic curve is still affected by important uncertainties for the period before 8 ka BP.

Thanks to its gentle slope, the continental shelf of the Northern Adriatic Sea is one of the very few areas in the Mediterranean that preserves a partial record of the sea-level variations occurred between Late Glacial and Early Holocene. These changes are documented by sediments and landforms formed in lagoon and paralic environments, which are strongly susceptible even to subtle variations of the relative sea level.

We analysed the large dataset of CHIRP-Sonar profiles acquired in the Adriatic since 1990 by CNR-ISMAR during a series of oceanographic missions and the database of stratigraphic cores sampled in the off-shore and along the coastal plains of Northern Italy and Istria.

A major issue is represented by the recognition and characterization of the periods of rapid increase of the sea level, which punctuated the Late Glacial and the first part of Holocene. These phases caused the abrupt submersion of large sectors of the former coast and alluvial plain, inducing dramatic environmental changes.

In the study area, a large barrier-island system, which remnants can be found between -38 and -42 m Mean Sea Level (MSL), formed ca. 11-10 ka BP and was rapidly drowned in place soon after. Furthermore, important information about a sea-level jump occurred around 9.5-9.2 ka BP have been recently documented both in the deltaic plain of the Po River and in the submerged shelf at about -30 m MSL. This phase of transgression allowed to the Adriatic Sea to penetrate into the Gulf of Trieste, strongly transforming the area between Istria and the coast of Friuli. Another important phase of submersion is documented between 8.4-8.2 ka BP, when relative sea level in the area was around -15 m MSL.

In the studied area the reconstruction of the sea-level evolution rises a major question, represented by the uncertainties related to the stratigraphic, geomorphological and environmental indexes which could allow the identification and quantification of sea-level jumps. Moreover, considering the lagoon and coastal environments, the decreases of the rate of the relative sea-level rise documented in the stratigraphic record could be the product of eustatic stillstands or, partly, also of the environmental changes induced by the episodic strong increase of the sedimentary input from the continent and the consequent basinward shifting of the coastline.

**P-3018**

## **Reconstructing of Holocene sea level in southwestern Baltic by means of geodynamic constraints and sea-level data**

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### **Abstract**

The evolution of the southwestern Baltic Sea during the Holocene is important to quantify its water exchange with the oceans through the Belt-Sea region. Especially, the timing of the transition from its fresh Ancylus-Lake to its brackish Yoldia-Sea state is of interest as it allows to constrain the glacial-isostatic adjustment (GIA) process in this region. The process is complicated by a number of aspects: the Trans-European Suture Zone representing the transition from the Baltic and East-European Cratons to the Phanerozoic orogens of South-West Europe; the eustatic sea-level rise due to the final melting of the Laurentide ice sheet; and the adjustment process due to the deglaciation of the Fennoscandian ice sheet.

In this study we present a forward modelling approach, where we discuss the impact of lateral heterogeneities in mantle viscosity on the flexural behavior of the GIA process and on the interpretation of geological sea-level data as proxies for Holocene sea-level change. By this, we aim at a better understanding of the timing and amplitude of this last transgression event of the Baltic Sea.

This study contributes to the German climate modeling initiative PalMod and benefited from discussions inside PALSEA 2.

**P-3019**

## **Quantifying 20th century sea-level change in Southeast Asia using coral microatolls**

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### **Abstract**

Regional records of relative sea-level (RSL) change provide vital constraints for future sea-level rise projections. However, in Southeast Asia instrumental records from tide gauges are temporally and spatially limited and contaminated by non-climatic processes. Indeed, there are no records longer than 50 years in the tectonically stable region of Sundaland. Fortunately, coral microatolls provide a proxy for RSL, because of their vertical and age resolution. Coral microatolls record extreme low water levels with a potential resolution of ~3 cm over their multi-decadal lifetimes. In addition, their chronology can be deciphered at an annual resolution.

Here, we collected two living coral microatolls from Mapur Island in Indonesia, ~80 km from Singapore. Singapore is very susceptible to the future impacts of sea-level rise with a third of the island being in a low-elevation coastal zone. We reconstructed 8 sea-level index points from the coral microatolls and compared these to the instrumental records from Singapore and southern Peninsular Malaysia. The two-unponded microatolls provide an RSL history from 1915 and 1982 years to present. The proxy RSL record closely matches published instrumental data from Singapore from 1975 to 2009. The longest living coral microatoll which begun to record sea level in 1915 suggest RSL rose 27 cm in the 20<sup>th</sup> century. The rate of RSL rise increased from 2.5 mm/y in 1915 to 2.9 mm/y in 2016. Our findings indicate that coral microatolls can be used to reconstruct reliable sea-level records. Coral microatolls can be applied as surrogate for instrumental data in other regions of demographic or economic importance determining the rates, mechanisms, and geographic variability of sea-level rise.

**P-3020**

## **Holocene relative sea-level change in Chile**

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### **Abstract**

We present a comprehensive relative sea-level (RSL) database for north, central, and south-central Chile (18.5°S – 43.6°S) using a consistent, systematic, and internationally-comparable approach. Despite its latitudinal extent, the Chilean coastline has not previously received rigorous or systematic attention and details of the RSL history remain largely unremarked. To address this knowledge gap, we re-evaluate the context and age of previously published sea-level indicators, providing 80 index points and 84 marine or terrestrial limiting points that span the period from 11,000 years ago to the present day. We also describe two new limiting points from two sites in the Maule and Bío Bío regions. Our database incorporates a range of different types of sea-level indicator, including tidal marsh sediments, beach ridges, marine deposits and freshwater sediments, dated through radiocarbon and luminescence approaches. We compare the spatiotemporal distribution of sea-level indicators with a suite of glacial isostatic adjustment models and place first-order constraints on the influence of tectonic processes along the coastline. By compiling and comparing the RSL history for 11 different regions, we summarise current knowledge of Chilean RSL, highlight directions for future sea-level research, and provide a resource to assist attempts to understand the distribution of archaeological, palaeoclimatic, and palaeoseismic evidence in the coastal zone.

P-3021

## Late-Holocene sea level evolution in the Rhone delta (western Mediterranean Sea): implications for a sea level rise scenario by 2100

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### Abstract

With an area of over 930 km<sup>2</sup>, the Rhone river mouth (southern France) is forming the western Mediterranean largest river delta. The vast plain comprised between the Mediterranean Sea and the two main arms of the Rhone river includes large brackish lagoons or étangs, separated from the sea by sandbars and encircled by reed-covered marshes. These are in turn surrounded by a large cultivated area. The whole territory, known as Camargue is very sensible to future sea level rise. In fact, most of the Camargue area is lying at less than 1 m above the present mean sea level and 1/3 of the area is composed of marshes and lagoons presently placed at the mean sea-level. In order to assess the impacts of future sea level rise on this key natural area we reconstructed the sea level evolution in the last millennia in order to have a pre-anthropogenic picture of the delta evolution. The formation of Rhone river deltas may be broadly subdivided in two successive stages. The first corresponds to the delta inception scenario tied to the mid-Holocene sea-level stabilisation that occurred ca 7000 years ago. The second corresponds to the actual delta formation over the last 2500 years. In this period, the eustatic input is negligible and the whole relative sea-level variation in the Rhone delta is controlled by negative land-level changes due to isostasy and, in major part, by subsidence associated with the sediment compaction. We quantified these signals using a large set of past sea level indicators available in the area and we superimposed them to available the sea-level projections of 2050 and 2100. In the frame of the SAVEMEDCOASTS project ([www.savemedcoasts.eu](http://www.savemedcoasts.eu)), we used a Lidar (1m/ pixel and 5m/pixel) and analyzed high resolution Digital Terrain and Marine Models of this area, available from <https://data.shom.fr/> (DATA.SHOM.FR - Information géographique maritime et littorale de référence), prone to be flooded by sea level rise in the next decades. From these data we extracted and investigated very high resolution DTMs at 5m/pixel. We used the IPCC projections for RCP4.5 and RCP8.5 climate change scenarios of the expected sea level rise by 2100 for the Mediterranean region, in combination with the trend of VLM from geodetic or geological data, to provide the relative sea level rise projections for 2100 in the Rhone delta. Finally, we produced multitemporal maps of sea level flooding scenarios showing the portion of the Delta that will be majorly affected by future sea level rise.

P-3022

## Sedimentological analyses of paleomangroves reveal Holocene climate and sea-level variations in Oman

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### Abstract

We aim to understand processes of Holocene climate and sealevel variations within the northern Indian Ocean area by giving a spatio-temporal overview on paleomangrove ecosystems. Therefore, we use sediments deposited within paleolagoonal settings associated with mangrove forests as environmental archives. Such archives have the potential to study environmental changes in high resolution. On the one hand sedimentation record is well preserved. On the other hand, mangrove forests are sensitive to changes of both: climate and sea-level. Mangroves are a group of several plant species that are adapted to the intertidal zone and can be found globally between 30° north and south. This intertidal zone marks the transition between the marine and the terrestrial realm and requires plant adaptations regarding salinity and tides, respectively. Changes in precipitation lead to changes in freshwater supply which results in higher or lower soil salinity. Additionally, variations in sealevel result in a change of tidal range and thus to a shift of the intertidal zone. Therefore, these mangrove ecosystems are ideal archives that can be utilised to reconstruct environmental changes. Climate variability within our study area is linked to the Indian Monsoon circulation, an atmospheric system millions of people depend on. We focus on the coastlines of the Arabian Sea in the northern Indian Ocean, specifically the shores of Oman and western India. The recent climate in Oman is arid and there are few mangrove forests. These are made up of only one species, *Avicennia marina*. This species is known to be the most tolerant in terms of environmental conditions. Archaeological and sedimentological evidence suggests that mangroves in Oman were more widespread and also enriched in species at the transition from Early Holocene to Mid Holocene. Hence, either climate conditions were more humid at that time or sea-level was different.

P-3023

## Relative sea-level and morpho-sedimentary evolution during the last eustatic cycle in the Mar Piccolo basin (Taranto, Northern Ionian Sea)

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### Abstract

The Mar Piccolo (Taranto, Southern Italy) is a small semi-enclosed basin with lagoonal features, affected by complex environmental issues. Its cliffs are known in the geological literature as a reference point for the detailed study of the last interglacial sea level fluctuations. On the contrary, post MIS5e deposits were never analyzed in detail, although they are fundamental to understand the present-day morpho-sedimentary processes and anthropic impact. We studied the 60 m thick basin infill using a new very high-resolution data set consisting of a dense grid of sub-bottom profiles, 23 cores, and <sup>14</sup>C datings.

At the base of the succession, at a maximum depth of 59 m below mean sea level, an erosional surface was recognized as a paleovalley basal surface, formed during the last relative sea-level (RSL) fall.

The paleovalley was filled by a thick post-LGM transgressive succession, marked by the presence of peat levels with *Planorbis sp* freshwater gastropods next to lagoonal silts with *C. glaucum*. Peat levels vegetal remains were radio-carbon dated, providing consistent RSL index points for a time span of 8.5 – 11.3 cal ka BP in an area, the northern Ionian Sea, that lacked completely of Holocene sea-level markers. Furthermore, this data can be considered one of the most complete suites of RSL index points for the Mediterranean.

The transgressive succession also contains a tephra level recognized as Pomici di Mercato eruption (8890 cal yr BP) from the Vesuvius area. The tephra provides a further reliable time constraint to our study; it deposited in a marine realm and, therefore, can be considered a marine limiting point (*sensu* Vacchi et al., 2016).

Finally, the sea level rise was identified as the cause of important cliff retreat phenomena, that determined the passage from a fluvial morphology to the present-day sub-circular shape of the basin.

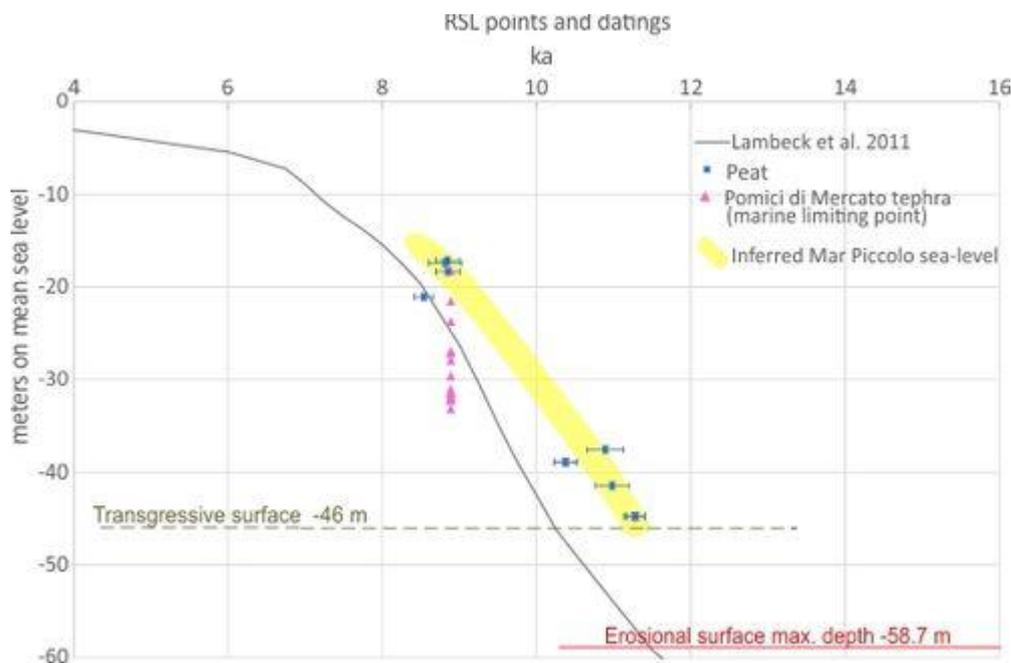


Figure 1. Geochronological constraints and RSL points, plotted together with the Lambeck et al. (2011) RSL curve. Horizontal error bar, represent the  $2\sigma$  error in age; vertical bars represent the error associated to the drilling methods (0.15 m) plus the reference water level range (for peat is the tide range  $\pm 0.3$  m, for *C. glaucum* 0 to -2 m) as in Vacchi et al. (2016)

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P-3024

## Holocene sea-level change and coastal landscape evolution in the southern Gulf of Carpentaria, Australia.

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### Abstract

A Holocene sea-level history for the southern Gulf of Carpentaria has been constructed based on a review of previously published data, combined with data collected for this study from a variety of sea-level proxies. These sea-level proxies include beach ridges, claypans, mangrove swamps, fossilized *in situ* coral reefs, beachrock and aeolinite deposits. Results confirm that rising sea-levels during the last Post-Glacial Marine transgression beached the Arafura Sill ca. 11,700 years ago (-53 m), resulting in a change from lacustrine to a marine environment. Sea levels continued to rise to ca. -30 m by 10,000 years ago. By 7,700 cal. yr BP sea-level reached PMSL and continued to rise an elevation of between 1.5 and 2 m above present mean sea-level by 7,000 years ago. Elevated sea levels resulted in the development of raised coral reefs, beach-rock and aeolinite deposits, and the initiation of chenier plains and beach ridges. Sea-level remained ca. +1.5 m above PMSL during the Holocene highstand, accompanied by distinct phases of beach-ridge and chenier plain development. The highstand was followed by a rapid regression to within  $\pm 0.5$  m of PMSL by ca. 3,500 cal. yr BP. When placed into a wider regional context results from this study show that coastal landscape evolution in the tropical north of Australia was not only dependent on sea-level change but also show a direct correlation with Holocene climate variability. Specifically, the formation and preservation of beach-rock deposits, intertidal successions, beach and chenier ridge systems hold valuable sea-level and Holocene climate proxies that can contribute to the growing research into lower latitude Holocene sea-level and climate histories.

P-3025

## Coastal submergence events identified by fossil diatoms and plant macrofossils at Ukishima-ga-hara adjacent to the Suruga Trough, central Japan

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### Abstract

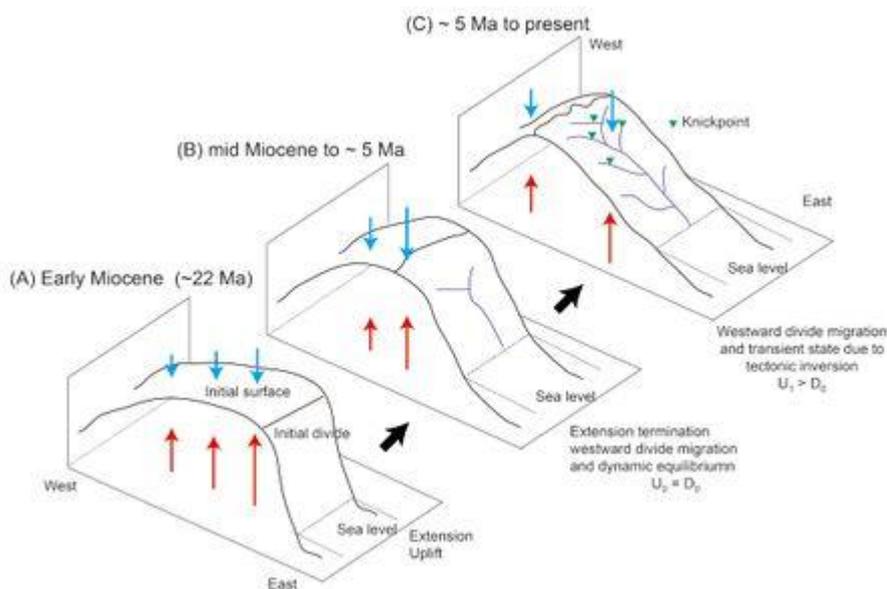
We identified eight episodic submergence events based on paleontological analyses on peaty sediment samples at Ukishima-ga-hara lowland adjacent to the Suruga Trough, central Japan. The submergence events were shown by changes in compositions of diatom assemblages and plant macrofossils although lithostratigraphy has no clear changes in facies. For example, at about 2.3 m and 3.1 m below the ground surface, while aerophilic diatoms (such as *Diadesmis contenta*) dominate underlying peaty layer, freshwater and brackish planktonic taxa (*Aulacoseira* and *Thalassiosira*) abound in overlying layer. Radiocarbon ages of plant macrofossils taken from samples just above and below the event horizons were used to constrained ages of the events. As the results of applying Bayesian estimation of event ages using OxCal program, the youngest one may be correlated with either 1707 or 1498 earthquake. The second one was with either 1361 or 1498 earthquake. The third one covers ages of 1096 and 887 earthquakes. Further older events were correlated with prehistoric tsunami deposits reported by Fujino et al. (2018). These submergence events may be generated with coastal deformation associated with subduction zone earthquake along Suruga Trough and/or active fault earthquake at Fujigawa-kako-fault zone.

P-3026

## Tectono-geomorphic evolution of Taebaek Mountain drainage divide, Cenozoic extensional basin margin, Korean Peninsula

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Schematic model of retreat along the main divide of the TBR. (A) Uplift of the TBR during opening of the East Sea (Sea of Japan). (B) Prior steady-state condition during which the uplift rate ( $U_0$ ) is equal to the denudation rate ( $D_0$ ). (C) Transient state condition during which the uplift rate since the late Quaternary ( $U_1$ ) is higher than the denudation rate ( $D_0$ ) because of tectonic inversion. To follow the increased uplift rate, the denudation rate would increase and the main divide would migrate to the west.

The Taebaek Mountain Range (TBR) initially formed via the extension of a back-arc basin (the East Sea) during the early-Miocene (ca. ~22 Ma), and constitutes a typical escarpment in a passive continental margin since its extensional cessation. The TBR acts as a major watershed divide across which topography rapidly changes; the western side slopes gently while the eastern side is steeper. Compared to the geologic history of the extensional basin based on analysis of the sedimentary basin, the geomorphic history of the margin of the post-extensional basin has been minimally studied because of a lack of terrestrial archives and tools to analyze them. We determined the rate of divide migration of the TBR using various geomorphic and chronologic analysis. The geomorphic analysis of relief, slope, river long profiles, swath profiles, hypsometric index, and  $\chi$  parameters were used to validate a transient topography. The catchment-wide denudation rate (CWDR) using  $^{10}\text{Be}$  was used to quantify the denudation rate of paired basins. Our study documents that CWDRs show the denudation rate of the eastern steep slope is nearly two times higher than that of the western gentle slope. Morphometric results also indicate that catchments on the eastern TBR have captured some of their counterpart catchments on the western TBR. Both results suggest that the retreat process of the main divide of the TBR has accelerated since the regional uplift (tilting or flexure) of the eastern TBR during the late Quaternary and/or since drainage capture occurred. From this moment onward, geomorphic disequilibrium on the current divide of the TBR has continued.



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P-3027

## **Preliminary results of a paleoseismological study of the south Yangsan fault indicate timing and characteristics of recent activity**

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The Yangsan fault, a prominent fault in the southeastern part of the Korean Peninsula, is an NNE tectonic fault of dextral reverse sense. This fault has been known to be active and has recently attracted attention in the peninsula following a shallow-depth (<13 km) earthquake (Mw 5.1) in 2016. This study aimed to investigate a blind extension from known outcrops, the recent activation and average vertical slip-rate of the active fault segment. Following the identification of a fault scarp using aerophotography and LiDAR imagery, an excavation was performed on the wide fluvial terrace in the Eonyang region at the southern end of the fault. The fault scarp is approximately 700 m long with a vertical displacement between the terrace surfaces no bigger than 1.5 m. A trench of 5 m deep, 3.5 m wide and 18 m long, crossing the scarp, showed the existence of an active fault with a the-top-up-to-the-west attitude and reverse fault movement sense. The trench wall is composed of fluvial sediments 2 m and 15 - 20 m thick on the hanging wall and footwall sides, respectively. The age of upper sediment layers was measured as ca. 37,000 - 600 years BP by <sup>14</sup>C and OSL dating. Considering the age, the terrace could be correlated to MIS 3 and is underlain by thick fluvial sediments of MIS 2. The active fault forms a boundary between unconsolidated gravel layers and an intermediate dike and has fault striation (108°/55°) with dip-slip sense. We estimate the last activation occurred around 8,300 years ago with a vertical displacement of about 1.5 m. Preliminary data shows that the vertical displacement rate is 0.18 mm/yr and the accumulated vertical slip-rate is 0.26 - 0.35 mm/yr. The Yangsan fault has been reactivated with the-top-up-to-the-west reverse sense during the Holocene period. This reaffirms that the peninsula is located within the influential range of E-W compression due to the westward subduction of the Pacific Plate, rather than that of the northward subduction of the Philippine Plate.

P-3028

## A 3.7 kyr paleotsunami record in the dynamic coastal lake system of Lake Cucao (Isla de Chiloé, south central Chile)

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### Abstract

In AD 1960, Lake Cucao on the Pacific coast of Isla de Chiloé (south central Chile) was inundated by the tsunami of the Great Chilean Earthquake ( $M_w$  9.5). The coastal lake basin is submerged since the postglacial sea level rise and may have recorded tsunami inundations in its sedimentary record since then. Sub-bottom profiles and side-scan sonar data near the lake outlet show a tidal delta with a crosscutting channel and fields of mega-ripples. Radiocarbon dates on sediment cores allow dating the seismic stratigraphy down to 3.7 kyr and suggest that tidal currents were active at least sporadically in this time frame. In a total of 21 sediment cores (including 9 cores that are up to 8 m long), 15 detrital layers are intercalated within overall organic-rich background sediments. Short-lived radionuclide data suggests that the youngest of these detrital layers corresponds to the AD1960 tsunami. The older detrital layers are interpreted as tsunami deposits with a varying confidence level, which depends on five criteria. There are site-specific criteria, e.g. i) high magnetic susceptibility of the sediment indicating high detrital content, ii) core correlation, iii) acoustic reflector correlation to the sedimentary record (indicating traceability of the detrital layer in the sedimentary record), and general criteria, e.g. iv) presence of mud rip-up clasts and v) age correlation to known paleotsunamis in the area. In this way 8 detrital layers are interpreted as tsunami deposits with a high level of confidence, 5 with a medium level of confidence and 3 with a relatively low level of confidence. The paleotsunami record of Lake Huelde, a mere 2 km north of Lake Cucao, contains 13 tsunami deposits in the same time interval. This study adds a long paleotsunami record on a coastline, where extreme tsunamis occur relatively frequently and where long paleotsunami records are still sparse. This study underlines the many challenges associated to paleotsunami research on coastal lakes and demonstrates how indispensable geophysical mapping and numerous coring sites are in understanding the depositional environment of dynamic coastal lakes for extracting high-quality paleotsunami records.

P-3029

## Sandy event deposits identified at Kogare-ike, Minami-ise Town, facing the Nankai Trough, central Japan

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### Abstract

The Nankai Trough is well known to generate great earthquakes and tsunamis that have impacted western part of Japan. The trough is divided into three segments as Tokai, Tonankai, and Nankai areas from east to west, based on rupture areas of historical great earthquakes. Written records cover earthquake history more than 1100 years and long-term forecast for subduction zone earthquakes along the Nankai Trough is calculated using the historical records. However, they cannot reconstruct giant earthquakes such as the 2011 Tohoku earthquake, which may have recurrence intervals measured in centuries or millennia (Satake and Atwater 2007). Here we used stratigraphic and paleontological investigations at Kogare-ike in Minami-ise Town, eastern part of the Kii Peninsula (near central part of the Nankai Trough), to extend the history of subduction zone earthquakes along the Nankai Trough.

We identified sixteen sandy event deposits interbedded with organic mud in five lake-bottom cores taken at Kogare-ike, Minami-ise Town. The cores were taken using a Russian sampler on a plastic floating boat and then the cores were observed by eyes and computed tomography (CT). The CT images of the cores, of which length of the cores ranges 3.25 to 4.75 m, show sedimentary structures such as sharp lower stratigraphic contacts and parallel laminae. A tephra layer was also recognized in all cores. Candidate of the correlative tephra is either Kikai-Akahoya tephra (K-Ah) of 7.3 cal kyr BP, or Amagi Kawago-daira tephra (Kg) of 3.1 cal kyr BP. This presentation will provide results of radiocarbon dating, identification of tephra, and diatom analysis.

**P-3030**

## **Palaeoearthquake and volcanic influence of Mount Fuji reconstructed from lacustrine sediments of Fuji Five Lakes, central Japan**

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### **Abstract**

Mount Fuji is the largest active volcano in Japan, and its eruption started in ca. 100,000 years ago, as Hoshiyama stage of Fuji volcano, and next eruption stage, Fuji volcano Fujinomiya and Subashiri stage began from ca. 18,000 years ago (Takada et al, 2016). The Fuji Five Lakes, as popularly known Fuji-Goko in Japan, comprise Lake Motosu, Lake Shoji, Lake Sai, Lake Kawaguchi and Lake Yamanaka. They are located at north foot of Mount Fuji and were formed as a result of natural damming by lava flows and pyroclastic flows from Fuji volcano. Previously our investigation collected sediment cores from Lake Mototsu, Kawaguchi and Yamanaka show that they formed before ca 30,000 to 10,000 years ago (Koshimizu and Uchiyama, 2002; Yoshizawa et al, 2004; Koshimizu et al, 2007)

Lacustrine sediments of these lakes are good recorders to reconstruct the volcanic activity and estimate the changes of and impact on the natural environment around Fuji volcano. We deduced that lacustrine sediments in these lakes has the potential to record evidence of earthquake caused by volcanogenic and palaeoearthquakes from Nankai, Sagami Trough and Japan Trench (ex QuakeRecNankai team, 2015). For example, we know that seismic seiche occurred in Lake Sai due to the 2011 earthquake off the Pacific coast of Tōhoku.

We inferred that lacustrine sediment cores from these lakes illustrate the influence of volcanic activity of Fuji volcano on three lakes, which was greatly different in the place of each lake nad boreholl Core from lakeside of Lake Motosu shows significantly understanding for palaeoearthquake shaking due to Nankai, Sagami Trough and Japan Trench, and reconstructing the changes of natural hazards around Fuji Five Lakes.

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**P-3031**

## **Inland fining and inland lightning characteristics of tsunami deposit**

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Inland fining is one of the most commonly observed characteristics of sheet-like distributing tsunami deposit. Thus, this feature is used for identification of a paleo tsunami deposit. Similarly, there are also some reports inferring that inland lightning can be seen in the deposit. In a case where the topography and surface situation is simple, these tendencies are thought to reflect those sand particles carried in the tsunami flow deposit in descending order of their settling velocity. In this study, we examined the combination of inland fining and inland lightning features of the 2011 tsunami deposits left in the coastal forest in Misawa, Aomori Prefecture, Japan. The tsunami heights were 6-10 m above the mean sea level. The beach sand in the coast is characterized by high content of heavy minerals such as magnetite. The tsunami and coastal sand consist of iron sand by 60 % or more by weight. We studied 15 excavation sites at 5 m intervals on an 80 m profile perpendicular to the coast. The maximum deposit thickness is ca. 30 cm and decreases toward the tsunami inundation limit. The average grain size of the tsunami deposits is about 2.2 phi in the first half of the profile and fines inland to be 3 phi. On the other hand, the specific gravity of the deposit decreases inland through the profile. In order to analyze this trend more precisely, the sand was divided into sand iron and the other (here we called non-iron sand) using a magnet. The specific gravity of the iron sands ranges from 3.4 to 3.6 and that of the non-iron sands is constant at 2.7. From the specific gravity and the grain size of the iron sands and the non-iron sands, we calculated the settling velocities of the particles and found that both the iron sands and the non-irons sands were almost the same. It is inferred that both inland fining and inland lightning reflects changes in the characteristics of sand expressed by the settling velocity. This means that sorting seen in sandy tsunami deposit that occurred in a flow may not be expressed by examining only one of the particle size and specific gravity of the sand for the case that the coastal sand consists of minerals with different specific gravity such as quartz and magnetite.

**P-3032**

## **A new multi-millennial record of great earthquake deformation and tsunami inundation in south central Chile**

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### **Abstract**

We present a 2000-year-long record of palaeoearthquake deformation and tsunami inundation from a coastal marsh in northern Isla de Chiloé, south central Chile. The site preserves evidence for at least six episodes of abrupt decimetre- to metre-scale vertical deformation. Applying established palaeoseismic criteria, we interpret the alternating peat and silt stratigraphy as reflecting repeated coseismic deformation and tsunami inundation associated with great to giant ( $M8 - 9+$ ) megathrust earthquakes. A microfossil-based transfer function quantifies the magnitude of deformation at the site during each earthquake, while a radiocarbon chronology enables correlation of evidence at a regional scale. We discuss the implications of this new record and of previously published palaeoearthquake archives in the region for understanding the variability in coseismic fault slip during sequences of multiple great earthquakes.

P-3033

## Relative sea level changes and uplift across northwest Luzon Island, Philippines: Interpreted from late Quaternary emergent coral reef terraces

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### Abstract

We examined the emergent coral reef terraces in northwest Luzon Island, particularly in Badoc Island, Badoc, and Currimao localities in Ilocos Norte, to understand relative sea level (RSL) changes and uplift along the Manila Trench forearc region during the late Quaternary. We mapped and described the late Quaternary coral reef terraces based on their geomorphological characteristics, elevation patterns, and ages and subdivided them into: the upper Pleistocene terraces and the lower Holocene terraces. The Holocene terraces in all three localities are subdivided into three to possibly four terrace steps (TI–TIV in ascending order) with the highest terrace (TIII–TIV) rising up to ~7–9 m above mean sea level (amsl). Fossil coral samples were collected on top of these emergent features and analyzed for U-Th isotopic compositions. Generally, the fossil corals sampled from terraces in Badoc and Currimao reveal ages between ~7000–6000 years before present (BP). Interestingly, we found two sets of coral ages in Badoc Island: mid-Holocene and late Holocene. The mid-Holocene corals range from  $6,871.57 \pm 22$  to  $6,060.87 \pm 31$  years BP and were sampled from the surface of TI with an elevation of 1.9 to 3 m amsl. The late Holocene corals were found at a higher elevation (TIII at 4.9 m amsl) than the mid-Holocene ones and reveal two sets of ages,  $2,727 \pm 13$  years BP and  $945 \pm 5$ – $903 \pm 4$  years BP. Based on the geomorphic data, we infer that during the mid-Holocene, around 6.8 kyr BP, ~3 m of rapid uplift occurred in northwest Luzon to account for the vertical separation of terraces TI and TII in Currimao site. A subsequent episode of RSL fall occurred at 6 kyr BP, based on dated coral samples, causing the emergence of the lowest terraces in the study sites. Meanwhile, the young coral ages derived could potentially mark significant events along the northwest Luzon region during the late Holocene. The very young corals possibly represent the timing of an extreme wave event ~1000 years BP that could have emplaced coral boulders on top of the 4.9 m amsl terrace surface. We also observed apparent tilting of Badoc Island further suggesting that offshore reverse faults could be potential causative faults. This study highlights the importance of studying emergent coral reef terraces to understand RSL changes and attendant coastal hazards along northwest Luzon and the Manila Trench forearc region.

P-3034

## Rethinking the 1737 Chilean earthquake: sedimentary versus historical evidence for a tsunami

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### Abstract

We present new evidence from a tidal marsh site at Chaihuín, south-central Chile, for a tsunami in 1737, which is not documented in historical records, and calls for a re-evaluation of the proposed rupture mechanism. Four great ruptures (M8+) of the Valdivia segment of the Chilean megathrust have occurred in the last 450 years (Cisternas et al., 2005). Historical records document devastating tsunamis accompanied earthquakes in 1575, 1837 and 1960 CE, but there is no record of tsunami inundation in 1737. Previously, without any evidence for a tsunami in 1737, a narrow and deep megathrust rupture was proposed with maximum slip of a few metres. However, multiple core transects from Chaihuín reveal three laterally extensive sand sheets, the middle of which is consistent in age with this previously unrecorded tsunami in 1737. We present sedimentological and microfossil analyses which suggest the three sand sheets are of marine origin and accompanied by abrupt land-level change; the latter being crucial for ruling out deposition by other extreme wave events including storms and far-field tsunamis. Diatom assemblages also suggest abrupt subsidence of several decimetres occurred in 1737, rather than the coastal uplift that would be expected with a deep and narrow rupture. We therefore suggest that instead slip occurred at intermediate depths in 1737, resulting in coastal subsidence, offshore uplift and the generation of a locally significant tsunami. Improving understanding of this rupture is crucial in the assessment of the supercycle that probably commenced in 1575 and culminated with the M9.5 1960 earthquake.

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P-3035

## New Bayesian quantitative paleoenvironmental reconstructions of AD 1700 coastal subsidence along the northern margin of the Cascadia subduction zone

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### Abstract

Coastal estuaries adjacent to the Cascadia subduction zone (CSZ) archive evidence of large megathrust earthquakes over the last 7,000 years. The most recent of these events occurred in AD 1700 with coseismic subsidence ranging from 0.2–0.8 m. Prehistoric great CSZ earthquake evidence is recorded in saltmarsh stratigraphy containing abruptly buried high marsh and upland forest sediments overlain by intertidal muds and occasional landward tapering tsunami deposits. Foraminifera within these sediment sequences are used to estimate the former elevation of stratigraphic marsh horizons because they are sensitive to the duration and frequency of tidal exposure, making them excellent indicators of relative sea-level change. Analysis of fossil foraminiferal assemblages provides an estimate of coastal subsidence along the CSZ by comparing pre- and post-seismic paleo-marsh elevations by way of a transfer function that quantifies the relationship between species distribution and elevation. Quantitative high-resolution AD 1700 earthquake coseismic subsidence estimates in the central CSZ have enabled the development of 3D earthquake dislocation models that map slip patch segmentation and geometry. However, along the northern margin from Washington to Vancouver Island, BC, such estimates are lacking. Previous use of a microfossil-based transfer function on Vancouver Island produced a subsidence estimate of  $0.71 \pm 0.3$  m for the AD 1700 earthquake. To increase the precision of paleommarsh elevation estimates using a recently derived Bayesian transfer function, consisting of 393 regional samples, inconsistencies with prior taxonomy must be rectified. New subsidence estimates will be produced for three sites on Vancouver Island at Tofino, Ucluelet, and Port Alberni. Coseismic subsidence is expected to be larger than previously estimated at Tofino and Ucluelet based on their proximity to the deformation front. Roughly 60 km inland, and further from the deformation front, estimates at Port Alberni will help to inform the downdip limit of deformation.

The use of a Bayesian transfer function allows for the incorporation of informative priors, such as lithologic context, with the purpose of reducing uncertainties and increasing the precision of paleommarsh elevation estimates. We assess the utility of a BC-specific bulk sediment geochemical database ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , C:N, and total organic carbon) of 43 modern samples as informative priors to further constrain the paleoelevational range of fossil samples. Ideally, geochemical priors could replace lithologic priors as the former are statistically derived and could further refine the precision of coseismic subsidence estimates.

**P-3036**

## **Tectonic movements associated with megathrust earthquakes inferred from diatom assemblages in Tokachi coast, Hokkaido, Japan**

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### **Abstract**

Geological records have suggested that tsunamigenic megathrust earthquakes occurred twice in the last millennium, in the 17th (Event-1) and 12-13th (Event-2) century, off Hokkaido along the Kuril Trench. We conducted a survey in the Tokachi area where precise paleo-environmental studies have not been performed. We set a 3.5 km profile from the coast to inland to trace the two tsunami deposits using a 1-m-long geo-slicer, and in total 17 core samples were obtained along the profile and 8 of them were used for diatom analysis to estimate the vertical crustal movements associated with megathrust earthquakes.

As a result, tsunami deposits associated with Event-1 and Event-2 were traced inland up to 1.8 km and 1.2 km, respectively. These tsunami deposits showed thinning and fining inland trends. Commonly observed trends in the changes of diatom assemblages are a gradual decrease of freshwater species and an increase of freshwater-brackish species prior to the event depositions, and the opposite trends after them. These are suggesting a repeated occurrence of earthquake accompanying both large tsunami and significant crustal deformation such as inter-seismic subsidence and post-seismic (including co-seismic) uplift in this area. The amounts of uplift were estimated from the multiple core analyses. They are ca. 2.3 m and less than 1.0 m, respectively. The uplift amount for Event-1 is obviously larger than that have been reported for a megathrust earthquake occurred in the 17th century in eastern Hokkaido (130-200 km east from our sites). Thus, it is important to study the tectonic movements associated with megathrust earthquakes in many sites along the Pacific coast of Hokkaido, for the better understanding of earthquakes and tsunami hazards in Hokkaido.

**P-3037**

## **New database of active faults of Eurasia**

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### **Abstract**

Active faults are those that demonstrate records of tectonic movements in the Late Pleistocene and Holocene. The authors have finished compiling of new database of active faults of Eurasia (NDAF) in 2019. The NDAF accumulates the data of many researchers in a uniform format and includes more than 20,000 objects (faults, fault zones, and associated structural forms) that can be shown in scale 1:500,000. The NDAF contains justifying and estimated attributes of each object. The justifying attributes are: the object's name, morphology, kinematics, magnitudes of displacement for different periods of time, displacement rates estimated from the amplitudes, age of the latest records of activity, data on seismicity and paleoseismicity, sources of information, and other obtained data on the faults. The estimated attributes are represented by a system of indexes reflecting the fault kinematics according to the structural geology classification, three ranks of the Late Quaternary movement rates and four degrees of reliability of identifying the structures as active ones. With reference to the indexes, the objects can be compared with each other and correlated with any other digitized information in any GIS software. The NDAF format allows addition of new information, as well as update and revision.

Principles, methods and tasks of using the NDAF computer processing for neotectonic and geodynamic tasks are discussed. As the examples, some results of this processing are represented. The comparative analysis of active faults of different tectonic provinces of the Caucasus-Anatolian segment of the Alpine-Himalayan Mobile Belt gives a possibility to revise the Late Cenozoic kinematics of the provinces. For the whole central Alpine-Himalayan Belt, variations of directions of axes and values of lateral lengthening and shortening are calculated for estimation of peculiarities of tectonic flow of the upper crust. The distribution of shear deformation is calculated for estimation of parameters of rotation of crustal blocks. The NDAF and results of its processing are important for seismic hazard assessment.

The study was financed by the Russian Science Foundation, Project No. 17-17-01073.

P-3038

## Understanding the depositional record of the Storegga Tsunami in Scotland, UK.

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### Abstract

Perhaps the largest natural catastrophe affecting the UK over the last 11,000 years was the tsunami caused by the Storegga landslip on the continental shelf-edge to the north-west of Norway. A wide variety of sites with tsunami deposits relating to this event have been reported over a 600 km stretch of the North and North-east Scottish coastline (e.g. Smith et al 2010). Local wave run up is thought to have been in the order of 7 m (max 11 m) causing inundation many kilometres inland in places. There is renewed interest in this event due to it occurring at a similar time as the 8.2 ka cold climate event and the sea-level rise which flooded Doggerland in the North Sea. Extensive regional radiocarbon dating of pre-existing and sediments deposited subsequent to the event have determined this event took place circa  $8100 \pm 100$  Cal BP (Dawson et al 2011). However, accurate dating using radiocarbon is challenging as underlying strata were eroded and reworked organic material may have been brought in with the tsunami or following it. No direct dates of the tsunami deposit in Scotland have been published.

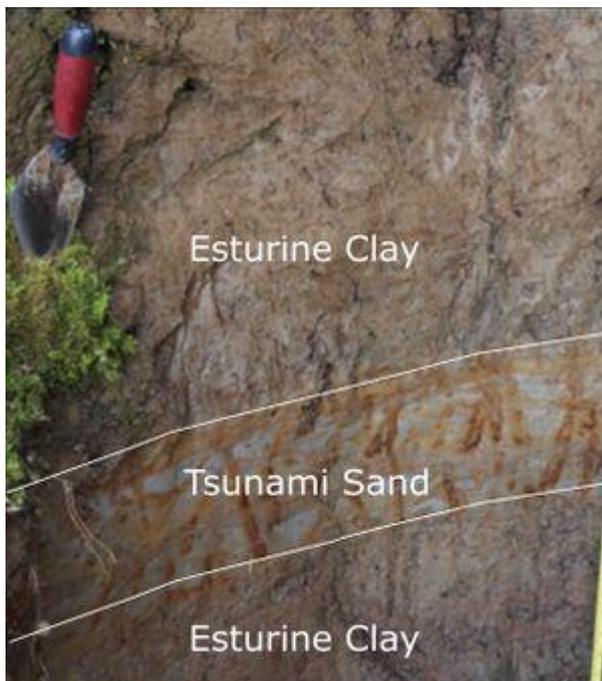


Figure 1: The Storegga Tsunami sandy deposit in the Montrose Basin, Scotland.

Work presented here has focussed on the tsunami sediments found in the Montrose basin north of Dundee (Figure 1). It aimed to develop luminescence dating techniques to directly and precisely date the tsunami sediments. Luminescence, geochemical and sedimentological measurements from a series of 13 sub-sample through the deposit were used to understand the source of sediment transported and number of waves impacting on the coast.



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Smith, D.E, Davies, M.H., Brooks, C.L., Mighall, T.M., Dawson, S., Rea, B.R., Jordan, J.T., Holloway, L.K. (2010). Holocene relative sea levels and related prehistoric activity in the Forth lowland, Scotland, United Kingdom. *Quaternary Science Reviews* 29, 2382-2410.

P-3039

## Tracing tsunami signatures of at the Gulf of Kyparissia using Direct Push in situ sensing techniques combined with geophysical studies

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### Abstract

The western Peloponnese was repeatedly hit by major tsunami impacts during historical times as reported by historical accounts and recorded in earthquake and tsunami catalogues. Geological signatures of past tsunami impacts have also been found in many coastal geological archives. During the past years, abundant geomorphological and sedimentary evidence of repeated Holocene tsunami landfall was found between Cape Katakolo and the city of Kyparissia. Moreover, neotectonic studies revealed strong crust uplift along regional faults with amounts of uplift between 13 m and 30 m since the mid-Holocene. This study focuses on the potential of direct push in situ sensing techniques to detect tsunami sediments along the Gulf of Kyparissia. Direct push measurements were conducted on the landward shores of the Kaiafa Lagoon and the former Mouria Lagoon from which sedimentary and microfaunal evidence for tsunami landfall are already known. Direct push methods helped to decipher in situ high-resolution stratigraphic records of allochthonous sand sheets that are used to document different kinds of sedimentological and geomorphological characteristics of high-energy inundation, such as abrupt increases in grain size, integration of muddy rip-up clasts and fining upward sequences which are representative of different tsunami inundation pulses. These investigations were completed by sediment coring as a base for local calibration of geophysical direct push parameters. Surface-based electrical resistivity tomography and seismic data with highly resolved vertical direct push datasets and sediment core data were all coupled in order to improve the quality of the geophysical models. Details of this methodological approach, new in palaeotsunami research, are presented and discussed, especially with respect to the question how the obtained results may help to facilitate tracing tsunami signatures in the sedimentary record and deciphering geomorphological characteristics of past tsunami inundation. Using direct push techniques and based on sedimentary data, sedimentary signatures of two young tsunami impacts that hit the Kaiafa Lagoon were detected. Radiocarbon age control allowed the identification of these tsunami layers as candidates for the AD 551 and AD 1303 earthquake and tsunami events. For these events, there is reliable historical data on major damage on infrastructure in western Greece and on the Peloponnese. At the former Mouria Lagoon, corroborating tsunami traces were found; however, in this case it is difficult to decide whether these signatures were caused by the AD 551 or the AD 1303 event.

P-3040

## Multi-proxy study in Augusta Bay (Eastern Sicily, Italy) expands understanding of offshore tsunami deposits

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### Abstract

Tsunami deposits are important archives for understanding tsunami histories and dynamics. While most research has focused on onshore preserved remains, offshore deposits have received less attention, although may offer a higher potential in terms of preservation and spatial coverage.

In 2009, during a coring campaign with the Italian Navy *Magnaghi*, four 1 m long gravity cores (MG cores) were sampled from the northern part of Augusta Bay, along a transect in 60 -110 m water depth, in the same area where a core (MS06) was collected in 2007, about 2.3 km offshore Augusta at a water depth of 72 m (Smedile et al., 2011). Core MS06 consisted of a 6.7 m long sequence that included 12 anomalous intervals interpreted as the primary effect of tsunami backwash waves in the last 4500 years. In this study (Smedile et al., 2019), tsunami deposits were identified, based on sedimentology and displaced benthic foraminifera (as for core MS06) reinforced by ITRAX X-ray fluorescence (XRF) data. Two erosional surfaces (L1 and L2) were recognized coupled with grain size increase, abundant *Posidonia oceanica* seagrass remains and a significant amount of *Nubecularia lucifuga*, an epiphytic sessile benthic foraminifera considered to be transported from the inner shelf. Relative maxima of Ti/Ca and Ti/Sr, coinciding with peaks in organic content (Mo inc/coh) suggest terrestrial run-off. Units L1 and L2 were attributed to two distinct historical tsunamis (AD 1542 and AD 1693) by indirect age-estimation methods using <sup>210</sup>Pb profiles and the comparison of Volume Magnetic Susceptibility data between MG and MS06 cores. One most recent bioturbated horizon (Bh), despite not matching the above listed interpretative features, recorded an important palaeoenvironmental change that might correspond to the AD 1908 tsunami.

Amongst all the techniques applied, sedimentology and micropalaeontology (displaced benthic foraminifera) remained the most informative, corroborated by the XRF results. Comparison of multiple cores collected at different depths along the shelf provided important insights about the dynamics of tsunami backwash and its imprint in the offshore stratigraphic sequence not easily gained from a single core. This work adds to previous studies in highlighting the growing potential of offshore investigations for reconstructing the palaeotsunami record of critical relevance to test tsunami hazard models and scenarios.

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**P-3041**

## **Tsunamis and tsunami deposits along the eastern margin of the Japan Sea**

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### **Abstract**

The research of tsunami deposits along the eastern margin of the Japan Sea region have been increasing after the 2011 off the Pacific coast of Tohoku Earthquake and tsunami. The distribution of the several wave source fault of the tsunami in the Sea of Japan are clarified, but the activity history of each fault is unclear. An investigation into tsunami sediment in each area is important to elucidate a tsunami history. The aim of this review is to enhance this record based on tsunami deposits reported from coastal area of Hokkaido to Toyama, northeast Japan, and draws their characteristics and spatio-temporal distribution. Most of the tsunami deposits were recognized in peaty and marshy deposits distributed at swales of coastal dunes, flood plains, and small valley plains. On the other hand, some gravelly deposits of possible tsunami origin were recognized on top of low marine terraces and slope-talus. Large number of tsunami sand layers were also identified in lagoonal deposits at Sado Island, Niigata and Okushiri Island, southwestern Hokkaido.

Although several historical tsunamis of the 19–18th centuries are known in this region, there are few localities of tsunami deposits correlatable to such records. On the other hand, tsunami deposits indicate four tsunami events during 15–9th centuries despite of the insufficient historical record of tsunamis older than the 18th centuries. The distribution of deposits of these four events are as follows: 14th century, Aomori to northern Yamagata; 12th century, southwestern Hokkaido; 11th century Sado (Niigata) to southern Yamagata; 9th century, Yamagata to Aomori. These events are also well recorded in deep-sea Japan Basin as seismo-turbidites. Most of the tsunami deposits older than 9th century have been identified only in remote islands, Okushiri, Tobishima, Sado and several coastal lagoon. This review will be useful for future studies to clarify images of paleo-tsunami events along the eastern margin of the Japan Sea.

P-3042

## Identification and characterization of tsunami deposits based on historical documents and field data in the peri-alpine Lake Lucerne, Switzerland

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### Abstract

Historical documents report that fjord-like, perialpine Lake Lucerne in Central Switzerland hosted two devastating tsunamis in the 17th century, which both were caused by subaquatic mass movements. The chronicle of the local city clerk describes a tsunami in Lake Lucerne in the year 1601 after a strong magnitude 5.9 earthquake nearby that caused several casualties. Alluvial plains surrounding the lake were flooded by half a kilometre from the shore, with run-up heights of up to 4 m. Additionally, it is stated that the lake outlet, the river Reuss, dried up and flooded repeatedly within the first hours after the earthquake, an oscillating movement that lasted for several days with a declining amplitude. On the basis of this chronicle and another documented tsunami event in the year 1687, caused by a spontaneous delta collapse, with similar run-up heights, several limnogeological studies have been conducted on Lake Lucerne during the last decades using the lake as analogue model for marine mass-movement processes and slide-induced tsunami phenomena. These studies documented that several episodes of sublacustrine mass-movements occurred during the last 15'000 years in Lake Lucerne, with some of them exceeding the volumes of the 1601 event. These findings led to the hypothesis of repetitive occurrence of tsunami events in Lake Lucerne during the post-glacial epoch.

This study focuses on the characterization and identification of tsunami deposits in a lacustrine setting based on historical documents and field work. At the lake shore prone to be inundated during a tsunami event, sediment cores were recovered in mostly shore-perpendicular transects. On the basis of the recovered sediment cores, we identify sedimentary signatures related to the tsunami processes using petrophysical sediment analysis encompassing density, magnetic, X-ray imaging scans, lithological analysis as well as geochemical element measurements using an ITRAX XRF core-scanner. Results indicate that the concepts to identify marine tsunami deposits need to be modified to a certain degree in order to be applicable in lacustrine settings. Despite the challenging recovery of these very heterogeneous sedimentary successions, the artificial shoreline changes, and the limited sediment-availability in the foreshore area, several candidates for potential tsunami deposit have been observed and were lithologically characterized. Radiocarbon dating will relate these detrital deposits in organic-rich background sediments to known and unknown tsunami events, thus completing the tsunami event catalogue for an area with a currently densely populated and vulnerable lake shores.

P-3043

## Use of passive remote sensing to assess cyclone impacts on coastal features to aid understanding of the submerged archaeological record.

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### Abstract

In looking at the potential for preservation of submerged prehistoric cultural sites over millennial timescales, it is important to also factor in episodic and short-term change over decadal and possibly annual timescales. In NW Australia one of the key drivers of marine and coastal geomorphological change is cyclones (Larcombe et al. 2018). This study explores the use of historical aerial photos and time-series satellite imagery to help identify 1) cyclone-specific coastal change, 2) abrupt and longer-term geomorphological change from other physical drivers, and 3) archaeological feature assessment, shell mounds specifically. Comparison can be made visually but also empirically using changes in surface reflectance revealed by the high spectral resolution of earth observation satellites (e.g. Figure 1). Initial results in the Dampier Archipelago region indicate an overall strong resilience in the majority of shell mounds over decadal timescales in what is arguably already a largely eroded environment. However, there is evidence for significant coastal change at discrete and localised scales. These regional and local-scale differences relate in part to the frequency and associated effects of cyclones (e.g. near-shore coastal and bathymetric features (e.g. mangroves, reefs, etc.) and the nature of the archaeological sites themselves (e.g. location, morphology, etc.). By combining our understanding of current archaeological sites with past coastal morphology and processes, we can better predict the locality and likely preservation potential of submerged cultural sites in this region and ultimately test these predictions using ground-truthing.

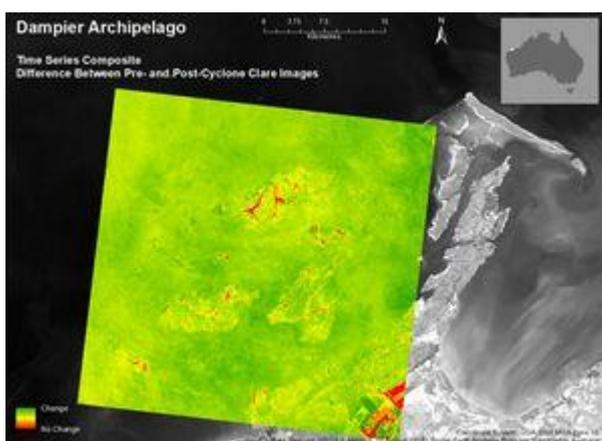


Figure 1 Differences between pre- and post- cyclone Clare composites.

P-3044

## Tsunami threats facing Fiji's capital city (Suva) from submarine landslides, as reassessed from Holocene and recent reef-boulder deposits

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### Abstract

Wave transported coastal boulders are one of the proxies that improve our understanding of cyclones and tsunami hazards for predicting future hazard impacts. While many boulder fields formed in modern storm and tsunami events have been analysed in detail for providing analogues for interpreting earlier counterparts, there remains a lack of research on boulders results from landslide tsunamis. Here we present the characteristics of a reef-top boulder field created by a local submarine landslide tsunami (the 1953 Suva tsunami) for the first time. Our examination of large reef-derived boulders near Suva City, Fiji, revealed that the 1953 tsunami flow velocity was over 9 m/s at the reef edge. While prior research has demonstrated the head-ward retreat of Suva Canyon in response to the repeated occurrence of earthquakes in the past, our results suggest the lingering vulnerability of this Fijian coastline to high-energy waves generated both in the presence (tsunami) and absence (storm) of submarine failures and/or earthquakes as subsequent storms appear to have remobilised some boulders. The boulder distribution confirms that the shorter-period-than-normal tsunami waves generated by submarine landslides would create a boulder field resembling typical storm boulder fields due to relatively short transport distances. This boulder field can be used as a reference set in identifying possible prehistorical local submarine landslide tsunami occurrences elsewhere and it will be particularly useful for tropical Pacific island coasts where submarine slope failures are relatively common and past hazards are not well documented.

P-3045

## Selective representation of sediment sources in tsunami deposits from the Shetland Islands (UK)

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### Abstract

Tsunami deposits provide information on inundation hazard and recurrence patterns. Their composition is mainly a function of the site-specific coastal sediment system and the tsunami's physical characteristics. However, tsunami deposits often have a low preservation potential and experience significant post-depositional changes, the magnitude of which is poorly understood and mostly depending on the complex geographic setting. Here, we compare a tsunami sand dated to c. 1500 yrs BP (Bondevik et al., 2005) from the Shetland Islands (UK) with its local sediment source (intertidal, shallow subtidal) and discuss possible reasons for the discrepancies noted. Inside the fjord of Dury Voe, the tsunami deposit is exposed in coastal peat sections. It has a thickness of 3–5 cm at the shore and was traced for c. 400 m inland, where it becomes discontinuous and reduces its thickness to <2 cm. Seven sections of the tsunami deposit were sampled using short push cores. Twelve modern surface samples were taken in the bay from the local intertidal area down to a water depth of 42.5 m. Samples were subjected to grain size and foraminiferal analyses; XRD and geochemical analyses are in progress. First results indicate large discrepancies between the composition of the tsunami sand and the local shallow subtidal and intertidal sediment source, which can be assumed to have not changed notably over the last 1500 years due to a quasi-stable sea level (Bondevik et al., 2005). The modern samples are very poorly (very shallow subtidal) to poorly (intertidal) and moderately (deeper subtidal) sorted. Siliciclastic sands dominate, accompanied by mud and shell debris in the subtidal. Foraminiferal concentrations range from low/moderate (intertidal) to high (subtidal), while diversity ranges from two taxa in the intertidal (*Miliammina fusca*, *Elphidium williamsoni*) to almost 60 in the deepest samples (dominated by *Cibicides lobatulus*, *Egerella scabra*). The tsunami deposit, however, is restricted to fine and medium sand, while mud and any foraminifera or other skeletal grains are absent. Differences in grain size can be explained by hydraulic sorting of the heterogeneous source sediment, which is also evident from landward fining (Bondevik et al., 2005). The absence of foraminifera is likely related to chemical dissolution in the acidic environment created by the blanket peat bog, while any sedimentary structures associated with tsunami deposition may have been removed by intense post-depositional bioturbation. Thus, it has to be considered that tsunami deposits may only represent specific sediment fractions from the source area as a function of (i) hydraulics of tsunami inundation and (ii) selective resistivity towards post-depositional degradation.

Bondevik, S., Mangerud, J., Dawson, S., Dawson, A., Lohne, Ø., 2005. Evidence for three North Sea tsunamis at the Shetland Islands between 8000 and 1500 years ago. *Quat. Sci. Rev.* 24, 1757–1775.

**P-3046**

## **A multi-proxy approach to examine terrestrial and aquatic environmental change resulting from palaeo-hurricane events.**

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### **Abstract**

Hurricanes are one of the most hazardous natural events to occur regularly around the world and it is suggested that these large scale weather events are set to increase due to global warming and climate change. As official hurricane records date only as far back as the 1850's, a further palaeo-record is required to analyse the frequency and intensity of hurricanes. Palaeotempestology is the study of hurricane events during the Holocene by a multitude of geological proxies. Using a multi-proxy approach, this study analyses Holocene hurricane frequency and intensity, and assesses environmental change caused by these large scale events at Gulf Shores, Alabama, USA.

A 6 m lake core (MLC1) was collected in May 2018 from Middle Lake, Alabama. Evidence of hurricane events are represented by sand layers in lake and marsh sediment cores, where beach debris has been transported inland by storm surges and wind. Initially, the core was visually inspected for these sand layers. Following visual inspection, the core was processed through an ITRAX for elemental analysis. ITRAX XRF data is presented with specific ratios such as Si/Ti, K/Ti and Ca/Si.

Organic matter content (LOI) and particle size has been calculated for MLC1 at 1 cm resolution. MLC1 shows a decline in organic matter content and an increase in particle size at visible sand layers. Two large sand layers identified between 199- 211 cm, suggest large scale hurricane events.

Preliminary results from diatom and pollen analysis will be presented. Diatoms are excellent indicators of environmental change due to their sensitivity to features such as temperature and salinity. However, because the field of palaeotempestology is still developing, there are minimal studies that use diatoms to infer environmental change resulting from hurricanes. This study examines the aquatic environmental change as a result of hurricane events inferring from diatoms analysis. Furthermore, pollen analysis is used to assess the terrestrial impacts associated with hurricane events, examining the change in vegetation and/or the recovery time for species to reach pre-event conditions.

Identification of hurricane frequency and intensity as well as the environmental impacts (both terrestrial and aquatic) in palaeo records are essential to understanding hurricanes today. These data also has the potential to be fed into future climate forecast models.

**P-3047**

## **The off-shore Lisbon 1755 tsunami sediments**

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### **Abstract**

The RV Meteor M152 expedition mapped and sampled two transects perpendicular to the south coast of the Algarve, off Portugal, in water depths from 60 to 800 meters. The special focus was on the areas to the east of Portimão and the west of Sagres/Martinhal transects, close to the famous Martinhal, Boca do Rio and Salgados AD 1755 onshore sedimentary imprints. This part of the coast was heavily affected by tsunami inundation exactly 263 years ago on All Saints Day 1755 following a strong earthquake offshore. Shortly after the earthquake a tsunami hit the coastlines. It was one of the most consequential and impressive natural hazards ever reported destroying the Portuguese capital and many villages were destroyed, Faro was sheltered by sandbanks, whereas in Lagos the waves overtopped the city walls.

Deposits of the Lisbon 1755 tsunami have been well studied along the southern Portuguese coast, but the impact of backwash, the retreating flood into the sea has not been well understood and studied. To date, very scarce information on backwash deposits is available from other areas, so this is unknown terrain, especially in these water depths.

We focus on the following scientific questions: Do we find variations in thickness and sediment composition, distribution and preservation of the tsunami layer? What effects on benthic life after tsunami deposition can be observed? Can we develop a tool for the identification of historic and prehistoric tsunami deposits on the inner shelf? Can we detect predecessor events along the Algarve coast, and obtain information about timing, frequency and magnitude of these natural hazards thus extending the time-window of observation?

We collected pre- and post-tsunami deposits (the background sedimentation) along the transects for comparison, e.g. of the benthic life and its resilience. Other proxies such as geochemistry and physical properties are analyzed as well. Radiocarbon and OSL dating methods are used for establishing a geochronological framework and to estimate ages of preceding events identified macroscopically in the sediment cores. Overall, the lithostratigraphic column can be characterized as a silty-dominated sequence, likely reaching the Younger Dryas. More importantly, we detected a gravelly high-energy layer at a depth of approx. 16-25 cm depth in many cores, characterized by an erosive base, shell debris and well-rounded extra-clasts of fluvial origin. A surprising finding was a second medium to coarse sand layer at depths of around 150-180 cm with clear indications of a high-energy depositional environment (e.g. sharp erosional base, mineralogical diversified composition, macrofossil diversity, etc.). Both of the layers are found within cores of the two transects; they are preliminarily interpreted as two events, the upper is regarded as deposits of the 1755 event, whereas the lower dates younger than 4000 yrs BP.

**P-3048**

## **Extreme ocean waves events reconstructed from a stalagmite in the coastal zone of central Chile**

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### **Abstract**

Changes in climatic conditions or seismic events can lead to the generation of extreme sea waves directly affecting coastal areas. This study explores the use of stalagmites to record extreme coastal conditions with the aim to better understand these events and their periodicity. This work applies a multi-proxy study on a speleothem from a coastal cave developed in schists under a Miocene marine terrace in Central Chile, a very unusual context. An innovative approach is applied combining macro and microscopic visual properties (thin slides), geochemical analysis (through high resolution non-destructive and destructive methods), U/Th dating and optical color/reflectivity properties.

The results of this work show continuous growth of a speleothem between 450 year Before Common Era and 650 year Common Era constrained by 11 U/Th dates. Along the stalagmite, the frequent dark laminas identified by their reflectivity and the concentration in Fe are associated to detrital material incorporated during extreme flood events into the cavern (tsunamis or large storms). Apart from these dark layers, the stalagmite is divided into several domains with a different geochemical composition. The highest values of Sr are found along the darkest sections of the stalagmite, probably indicating drier conditions, while Mg values are associated to sea spray. Preliminary results from frequency analyses on color and reflectivity data point to solar forcing as a likely mechanism to account for the observed variations.

This work concludes that stalagmites from coastal caves have the potential to record the paleo-evolution of extreme ocean waves and, once the calibration of such events against the instrumental record is carried out, will surely be of great interest for policies on coastal management.

P-3049

## Boulder transport along the coast of Eastern Samar (Philippines) – Implications for Holocene extreme-wave events

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### Abstract

The Eastern Visayas region in the Philippines is significantly exposed to high-energy marine inundation events. It gets regularly hit by some of the strongest tropical cyclones on Earth, recently by Typhoon Haiyan (2013) or Typhoon Hagupit (2014), causing extreme waves at the coastline. The region is also closely located to the Philippine Trench and experienced several tsunamis in the historical past, therefore flooding through extreme-wave events represents a strong hazard to the coastal population.

As there is not much known about frequency-magnitude relationships or maximum magnitudes of coastal flooding events over larger timescales, geological archives such as subaerial boulder deposits can derive information on occurrence patterns of extreme-wave events over centennial to millennial scale. To understand the mechanisms of boulder transport and the underlying extreme-wave events, we study a large boulder field in San Policarpo, Eastern Samar. A multi-temporal analysis of satellite images is conducted to quantify recent boulder movement during the typhoons Haiyan and Hagupit. In a systematic geomorphic mapping campaign, we recorded location, size, shape, morphological features and also lengths and orientation of the main axes of 269 boulder with a-axes between 1.5 m and 10.7 m to estimate spatial extent, height, velocity and direction of flow during extreme-wave events. The boulder field was also mapped by an unmanned aerial vehicle (UAV) to create structure-from-motion (SfM) models to improve inverse modelling of transport flows of recent and past events. A poorly developed exponential fining landward of the clasts and their landward distribution way beyond the limit proposed for storm boulders in literature suggest the occurrence of very strong events such as tsunamis or infra-gravity waves in the past. The latter were associated with Typhoon Haiyan elsewhere in Eastern Samar and locally shifted some of the largest boulders ever documented for storms. In order to date possible events, samples of post-depositional, secondary calcite flowstones and pre-depositional coral were taken for U-Th and <sup>14</sup>C dating.

**P-3050**

## **Can sediment source signals be used to reconstruct paleotsunami?**

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### **Abstract**

Tsunami deposit can be eroded and transported from both marine and terrestrial environment. An interesting question will be how sediment source information can be applied to reconstruct paleotsunami events or assess tsunami hazard. In this contribution, we employ a state-of-the-art tsunami sediment transport model, GeoClaw-STIRCHE, to carry a parameter study. In this parameter study, we change the onshore slope, the initial wave amplitude, and the grain size in the sediment source to study the marine-terrestrial signals in the tsunami deposit. We define the normalized location where the marine sediment becomes easily recognizable (> 5%) to characterize the distribution of the marine sediments. Meanwhile, the normalized location can be used as a quantitative tool to estimate maximum inundation from the spatial distribution of tsunami deposits. Based on the parameter study, both the initial wave amplitude and the grain size in the sediment source significantly influence the percentage of marine sediment in the tsunami deposit. Our method successfully estimates the offshore wave amplitudes for the 2010 Chile tsunami in Las Cañadas area. Based on the data from Goff et al., 2015 and our parameter study, the normalized wave amplitude ranges from 0.03 to 0.04, which is consistent with simulation results from GeoClaw.

**P-3051**

## **Spatial distributions of the 2011 Tohoku-oki tsunami deposits, Odaka area, Fukushima, Japan**

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### **Abstract**

Spatial distributions of the 2011 Tohoku-oki tsunami deposits, Odaka area, Fukushima, Japan was reconstructed based on a field survey, facies descriptions, bed thickness, magnetic susceptibility, anisotropy of magnetic susceptibility (magnetic fabric), grain size distribution, and topographical data. The behavior of the tsunami reconstructed in this study was summarized as follows;

- (1) In the Odaka area, two tsunamis struck from the northeast and east. The water collided with the embankments of the prefectural road 260 and the Odaka River, and joined at the western part of the area. The head part of the tsunami eroded the soil in the rice paddy fields and the eroded mud clasts were taken in by the tsunami waters. As a result of this, the mud content increased in the fluid inland.
- (2) The integrated tsunami inflow at western part changed direction and started to outflow toward the northeastern mouth of the river. This outflow caused accumulation of the muddy fraction along the embankments, and resulted in lower mud content in the fluid toward the downstream area.
- (3) In the northern part of the area, tsunami deposits included abundant coarse materials with artificial tsunami debris derived from the residential area located toward the east of the study area.

P-3052

## Micromorphological analysis on the Storegga and the AD 1755 tsunami deposits: compositional determination and definition of inundation phases

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### Abstract

In this work preliminary data based in high-resolution micromorphological observations of sandy tsunami deposits of the AD 1755 tsunami and the Storegga tsunami deposit are presented. Through an analysis of the vertical compositional variations it is possible to attempt to recognize different phases, synchronous with the inundation, and its associated sedimentological signature.

At Boca do Rio (Portugal), the sandy deposit associated with the tsunami has been found to consist of quartz, feldspars, micas, pyroxenes, amphiboles, plant fragments, shell fragments and mud balls. Samples taken from the tsunami deposit show an overwhelming prevalence of quartz, plant fragments and feldspars ( $\pm 90\%$  of the sample).

In the Boca do Rio tsunami deposit, it was possible to identify 3 inundation phases and correlate them with the synchronous event that affected near-by Salgados and its 3 major inundation phases (established using textural and geochemical data). The initial phase presents the wider compositional diversity (reflecting several sedimentary environments crossed by the tsunami waves). In contrast, the second phase exhibits a quartz dominance which translates a narrower (coastal) source area. Finally, phase three presents more micas which reflect the waning of tsunami inundation. We interpreted the initial phase comprising a strong erosive component on the dune, which leads to a dissipation of transport competence into the alluvial plain, leading to lower expression (thickness) in the geological record. The second phase, with thicker depositional signature, is characterized by lower compositional richness. Such stratigraphic expression is a result of the partial removal of the dune, facilitating the sediment transport competence, extension and duration of the inundation. Finally, in the third phase there is less sediment available and less energy capacity. In this final phase synchronous with the tsunami inundation, it is possible to observe an increase in the proportion of micas corresponding to a period of greater calming and slower flow velocity.

Investigation of the Storegga deposit reveal that the tsunami unit is mainly composed of quartz, micas, plant fragments and amphiboles. In terms of inundation phases, only two were identified. An initial one presenting larger compositional diversity and higher concentration of sediments (arrangement/packing), while the other phases seem to be a return to pre-event conditions (recovery phase) and is characterized by the large presence of micas, poor packing and lack of rip-up clasts.

This ongoing innovative study contributes to a greater understanding of the tsunami-related hydro-morphodynamic processes and offers the potential to better define inundation phases in historical and pre-historical tsunami events.

### Acknowledgements

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**P-3053**

## **The unknown event deposit – a predecessor to the AD 1755 tsunami?**

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### **Abstract**

The Portuguese coastline was severely struck by the AD 1755 Lisbon tsunami, which has been documented in many historical accounts and confirmed by geological evidence at numerous sites. But had there been a preceding event? To date, the focus has always been on the deposits of the Lisbon tsunami. The same holds true for our research at the well-studied site of Boca do Rio, a N-S oriented flood plain at the western Algarve, Portugal, with a well-preserved sedimentary record of the AD 1755 Lisbon tsunami. Two transects, one parallel, the other perpendicular to the coastline were studied, comprising 7 sediment cores with depths up to 4.5 m. All of them clearly show tsunami deposits originating from the AD 1755 event that had effected the coasts of the southern Iberian Peninsula, including those of the Gulf of Cádiz and the Algarve. In one core, however, a distinct second event layer was found about 30 cm below the known tsunamite. This layer, which had never been described before, and the AD 1755 tsunamite were analysed in a multi-proxy approach, including granulometry, micropalaeontology, and geochemistry. As for the chronology the <sup>14</sup>C and OSL dating techniques were applied. Based on a synopsis of the results and the calculated age estimate (1004 ± 26 cal BP, AD 985-1148; <sup>14</sup>C), the lower event layer may preliminarily be classified as a storm deposit (tempestite), since it roughly fits to a period of increased storminess during the 4<sup>th</sup> – 8<sup>th</sup> centuries (Dark Ages Cold Period). However, the interpretation as a potential predecessor of the AD 1755 tsunami cannot be excluded as yet, based on the location of the deposit (too far inland for a storm), and the contained deep water foraminifera. Additional studies, e.g., mapping the event layer's onshore distribution and comparing it with the offshore record (cf. Reicherter et al.'s talk about the METEOR 152 research cruise) need to be conducted to make a final decision about the deposit's origin.

**P-3054**

## **Organic geochemical signature of deposits by the 2011 Tohoku-oki tsunami (Northern Japan)**

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### **Abstract**

The 2011 Tohoku-oki tsunami caused massive damages along the coastal areas of the main island of Japan. The tsunami, triggered by the 9.1  $M_w$  Tohoku-oki earthquake, overtopped the coastal defense wall with waves of 6-10 m height along the shores of the Aomori Prefecture in Northern Japan. The interaction of tsunami and earthquake caused devastating damages, leading to the release of pollutants in the nearfield environment, and the deposition of tsunami-derived sand up to 550 m inland. The released pollutants associated as biological and anthropogenic markers give the tsunami deposit an unique geochemical signature, that is detectable and distinguishable from sediments deposited prior and following the 2011 tsunami. Along with the sedimentary record of the tsunami, the use of organic geochemical indicators can provide a better understanding of the extend and processes, such as the backwash, of the inundation by the 2011 Tohoku-oki tsunami.

At the field sites, a small fishing port and an industrial park, well-preserved, sandy tsunami deposits present a thickness of up to 18 cm with sedimentary features, such as fining upward sequences, mud caps and rip-up clasts. Further, observation show that the coastal forest stopped indicators of an inundation such as barrels, which were deposited in backwash position. Based on the release of pollutants, due to the destruction of the industrial park, and the deposition of barrels with possible leakage, these sediments are suited for organic geochemical analysis. Preliminary results show a strong increase of anthropogenic (i.e., PAHs, pesticides) and a variation of biological markers (i.e., fatty acids, ketones) close to the industrial park and the small harbor. The release of pollutants can be helpful to identify "invisible" tsunami layers, as the tsunami eroded the upper soil (composed of peat, wood and plants). These eroded materials float on top of the inundating water and deposited beyond the limit of visible tsunami deposits.

At a distance of 300-350 m from the shoreline a thin organic- and peat-rich layer starts to emerge on top of the tsunami sand, which thickens inland as the sand thins out. This layer is interpreted as the continuation of the tsunami deposit beyond the point of coarse sediment transport. This is supported by a tsunami-transported plastic particle that was deposited within this peaty, "invisible" tsunami layer.

P-3056

## The record of tsunamis on arid coasts: examples from the southern Atacama Desert (Chile)

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### Abstract

Studies focused on identifying, dating and describing tsunami deposits in the geological record during the Late Holocene are very scarce on arid coasts. Their low preservation potential in this context partially justifies this circumstance because they can be reworked by winds or eroded by flash-floods. In addition, the absence along this type of coast of environmental settings that favour their preservation in the sedimentary record, such as coastal wetlands or lagoons, hinders the identification and study of these sandy deposits. Coarser deposits (like boulders) have a higher preservation potential as they are less likely to be transported after the event. Consequently, the hyperarid and active tsunamigenic coast of the Atacama Desert can be considered a suitable area for the study of so far undescribed coarse clast record of palaeotsunamis. The southern Atacama Desert coast (26° - 27°) is characterized by the presence of rocky cliffs of variable height that are interrupted by fluvial mouths and small bays with sandy beaches. In this context, the appearance of boulder fields at heights that vary between +2.5 and +20 m a.s.l. constitute the most probable record of recent tsunamigenic events with epicentres near the Atacama coasts. Two types of record can be differentiated: 1) cliff-top boulder deposits; and 2) isolated boulders and boulder fields in beaches and littoral plains. This different record can be explained by means of the height wave, the coarse-grain sediment availability and the geomorphologic configuration of the coast. In this way, tsunamis with wave heights lower than the cliffs or those that impact low gradient beaches have generated extensive boulder fields in the intertidal and supratidal zones, between -0.5 m to +9 m a.s.l. In other cases, large, several tens of cubic meters, isolated fragments of low-lying cliffs formed in marine terraces have been eroded and mobilized towards the sea. Most likely these examples record the effects of the 1922 Atacama tsunami, which reached wave heights up to 9 and 6 m in the cities of Chañaral and Caldera, respectively. On the other hand, isolated boulders and boulder fields appear between +10 m and +20 m forming classic examples of cliff-top deposits. These deposits, eroded from the cliff edge of the marine terraces and transported tens of meters inland, record large tsunami waves of more than 20 m in height and have been associated with a major tsunamigenic event that occurred at the beginning of the 15th century. The correct identification and dating of these tsunami coarse-grained deposits is the most effective tool to develop a catalogue of Late Holocene tsunamis on the hyperarid and steep coasts of the southern Atacama Desert.

**P-3057**

## **Ground-penetrating radar (GPR) investigation of Storegga slide tsunami deposits**

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### **Abstract**

Ground-penetrating radar (GPR) is a portable geophysical survey system that provides almost continuous images of the shallow subsurface. Reflections on GPR profiles are produced by changes in the dielectric properties of the soil which are largely controlled by the electromagnetic properties of the materials and the water content. In the Shetland Islands the tsunamigenic sand layers are commonly overlain by, and sometimes interbedded with, peat. Peat has a velocity of around  $0.035\text{mns}^{-1}$  (Comas et al., 2005, Kettridge et al., 2008, Proulx-McInnes et al., 2013.), while sand layers saturated with fresh water typically have velocities of  $0.09\text{-}0.13\text{ mns}^{-1}$  (Baker et al., 2007), although they are typically around  $0.055\text{-}0.06\text{ mns}^{-1}$  (Reynolds 1997).

The mean dielectric constant for peat is  $63\epsilon$  (Parry et al., 2014) and between 25 and  $30\epsilon$  for wet sand (Reynolds, 1997). It is the dielectric constant that is used to differ between materials in the gprMax modelling program. Modelling can be used to predict how the response from the peat layers will differ from that of the sand and therefore predict the potential response from the GPR system will be.

We have used a Pulse Ekko GPR system with a range of antennas to image the deposits of the Storegga slide tsunami deposits on the East coast of Scotland and on the Shetland Islands. The results of the GPR surveys are shown here and compared with the predictions from modelling.

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P-3058

### **Emergent Sea-Level Indicators, Coastal Boulders, and Washover Deposits as Evidence of Coastal Tectonics and Extreme Wave Events in the Philippines**

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#### **Abstract**

As we recognize the Philippine archipelago as a tectonically active region surrounded by subduction zones and a country frequented by strong typhoons yearly, coastal communities remain at risk, hence an improved understanding of coastal hazards and their impacts is essential. Over the past years, we have been studying geological and geomorphological features to understand how tectonic processes and their accompanying hazards may affect Philippine coastlines and coastal communities. Along the coasts of Luzon, Cebu, and Mindanao islands facing subduction zones (e.g., Manila Trench, Philippine Trench) or other potentially active offshore upper plate faults, emergent coral reef terraces and their implications for long-term tectonic deformation and prehistoric relative sea level changes were studied. Coseismic uplift of the coast following major earthquakes in central Philippines in 2012 (Mb6.9 Negros earthquake) and 2013 (Mw7.2 Bohol earthquake) further demonstrated one of the possible mechanisms in the emergence of sea level indicators. We have also investigated the origin and emplacement of moderate to large coastal boulders atop emergent coral reef platforms along the coasts of northwest Luzon. Initial hydrodynamic calculations and numerical modeling infer the occurrence of a prehistoric extreme wave event which affected the eastern South China Sea region. We also studied the coastal areas in Zamboanga del Sur to understand and characterize washover sediments from tsunamis as a number of tsunamigenic earthquakes have occurred along the Cotabato Trench. All these geologic and geomorphic data are significant in refining fault rupture models and hazard scenarios, while also important in constraining long-term deformation and relative sea level changes in this tectonically active block of the Southeast Asian region.

P-3059

## Tsunami boulder transport simulated in a numerical two-phase mass flow model and flume experiments – a combined approach

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### Abstract

Numerical models simulating the transport of coastal boulders by tsunamis provide pivotal information regarding physical characteristics of the hydraulic event. However, model results need to be validated, due to the complex and sensitive transport mechanics, e.g. by physical experiments, in order to generate reliable implications for tsunami hazard evaluation. Current numerical models only simulate the behavior of idealized boulder shapes like cuboids, spheres or prisms and do not account for sedimentary load in the tsunami wave, which might substantially influence transport dynamics and distance. Therefore, we propose a novel approach, based on the immersed boundary technique in combination with the general two-phase mass flow model of Pudasaini (2012), for simulating an arbitrary shaped boulder interacting with a sediment-laden flow. In corresponding flume experiments, we observe a dominating influence of boulder shape not only in terms of the transport distance but also on a standardized and repeatable boulder behavior. Experiments were conducted for subaerial, partially submerged and submerged conditions utilizing idealized (cuboids) and complex boulder shapes, the latter resembling a previously studied wave-transported boulder from the island of Bonaire (Engel and May, 2012). Transport patterns were analysed by video processing. Test runs were repeated until the results showed a normal distribution for boulder-transport distance. While under partially submerged conditions, the cubic boulder required  $\geq 37$  runs to obtain normally distributed results, the complex boulder required  $\geq 16$  and the flat one at least nine. In general, median transport distances of the cuboid boulder were significantly higher compared to the complex and flat ones. Thus, the need for numerical boulder-transport models accounting for non-idealized boulder shapes is obvious. By applying an immersed boundary approach, the arbitrary shaped boulder is implemented as a highly resolved point cloud in Lagrangian coordinates. The developed algorithm detects the boulder shape, a convex hull with allowance of concave segments, and its orientation to the Cartesian grid of the main program with every computational time step. Subsequently, the velocities of the fluid and solid phases at every boundary node are interpolated and recalculated from influencing grid cells outside the boulder, while the velocity inside the boulder remains zero. Boulder transport is not determined by submergence-depending threshold functions but by a dynamical formulation that is generally valid. Results of the physical experiments will be presented focusing on the model sensitivity and the behavior of different boulder shapes. Furthermore, the functionality of the numerical model and its performance is demonstrated by comparing the numerical results with those of the experiments.

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P-3060

## The sedimentary imprint of the CE 1936 tsunami event in Lake Lovatnet, western Norway

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### Abstract

Several historical rock fall events between CE 1905 and 1950 have caused devastating tsunamis in Lake Lovatnet, western Norway, claiming a total of 174 human lives. Based on detailed sedimentological and geophysical surveys of the sedimentary infill in Lovatnet, we present a 2200 year long reconstruction of mass wasting events in the lake, with particular focus on the largest recorded historical tsunami that occurred in CE 1936. This particular event was caused by a 1 million m<sup>3</sup> rock fall from the Ramnefjell Mt., located in the SE end of the lake. The resulting tsunami wave had a maximum run-up of about 70 m, and a hydrodynamical model indicates that the wave propagated along the entire 8 km length of the narrow (1-1.5 km) lake within about 12 minutes.

We mapped the lake bathymetry with a 125 kHz interferometric side-scan sonar, whereas the sub-surface was imaged using a single-channel high-resolution Geoacoustic 3.5 kHz pinger unit. The seismic stratigraphy reveals several mass transport deposits (MTDs) with thickness of up to 2 m in the deepest part of the lake (134 m), i.e. in the basin proximal to the Ramnefjell rock fall area. A piston core (420 cm) and a shorter gravity core (89 cm) were retrieved in the NW shallower lake sector (89 m water depth), about 6 km distal to the CE 1936 rock fall area. The cores were subjected to a multi-proxy analysis, which included lithostratigraphical logging, radiographic and optical imaging, and magnetic susceptibility- and X-ray fluorescence (XRF) scanning. A chronology was established for the cores using a combination of radiocarbon dates (n=4) and measurements of <sup>210</sup>Pb and <sup>137</sup>Cs-activity. Based on the <sup>137</sup>Cs chronology we dated a prominent 33.5 cm thick, complex MTD, to have been deposited between CE 1938 and CE 1924, which we interpret as a result of the CE 1936 tsunami event. The MTD features an erosive lower boundary, and is characterized by several types of sedimentary facies commonly associated with tsunami deposits. This includes a 10 cm normally graded unit at the base consisting of very fine gravel to medium sand, overlain by an 'organic conglomerate' and a silty layer rich in plant macrofossils, with a mud cap on top. Another potential tsunami deposit is seen around 2000 cal a BP, whereas the remaining 65 event layers are probably the result of snow-avalanches entering the lake and smaller, local sliding events within the lake.

**P-3061**

## **Sedimentary record of historical storm surges along Gulf of Gdańsk, SE Baltic Sea**

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### **Abstract**

Baltic Sea is commonly viewed as a region with a low frequency of coastal hazards like tsunamis or extreme storm surges. However, historical archives indicate that during the past millennium several catastrophic storm surges resulted in coastal floods and related casualties. However, the sedimentary record of them is poorly known. Consequently, several locations along southern Baltic Sea coasts were investigated in order to find past storm surge deposits within coastal peatlands and recognize their sedimentary features, which could be used in further studies extending the storm surges history.

Based on digital spatial data (satellite and aerial images, digital elevation models) several key locations were selected for detail field work. After the preliminary geomorphological investigation, cores and surface samples were collected and subjected to grain size, heavy minerals, diatom, and loss on ignition analyses. The age of sediments was estimated with <sup>137</sup>Cs, <sup>210</sup>Pb, and <sup>14</sup>C methods.

Two types of event deposits were identified. They were interpreted to be storm sediments formed under inundation regime and breaching regime, respectively. The deposits formed under inundation regime were marked by sharp, erosive lower boundary, massive structure and presence of rip-up clasts, while sands formed under breaching regime consisted of low-angle planar cross-stratification sands and intercalations of finer sediments of massive structure.

Grain size distributions in storm surge sediments were mainly unimodal, moderately well sorted, fine skewed, and mesokurtic. Mineral composition was dominated by the light mineral fraction (85-99%). In heavy mineral fraction increase content of very dense minerals of rounded shape (e.g. garnets, zircon, staurolite) was observed. Diatoms were found only in one core. Comparison of storm surge sediments with deposits from adjacent sedimentary environments (dune, beach, nearshore, river) showed the possibility of distinguishing them from each other applying the listed above methods.

Dating results compiled with historical archives showed that deposition of sediments occurred during the storms in 1872 and in the period of 1898-1914. Several geological evidences also suggest the record of storms from 1497, 1625 and 1825. The results showed that only the most extreme events (mainly from XIX century) were capable to leave the geological record. Notably, none of the historical storm during past 100-year period formed a distinguishable sedimentary layer. These findings clearly show that hazard assessment models and storm return period predictions, which are based on instrumental measurements from past decades, should also involve geological evidence. The strongest storms from the past century may not be an adequate example of the worst case scenario event.

**P-3062**

## **Luminescence analyses as a novel proxy for tsunamigenic stratigraphies**

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### **Abstract**

Optically Stimulated Luminescence (OSL), now a well established chronological method, provides a direct age estimate of the last exposure of commonly occurring mineral grains to daylight. The uniqueness of this trapped charged technique is its intrinsic relation to transport mechanisms and depositional processes forming a sedimentary deposit. The extraordinary sensitivity of this signal to environmental conditions allows to differentiate degrees of sedimentary chaos: sediments incompletely bleached at burial or transported by highly turbulent regimes, such as tsunami or storms, thus the applicability of the OSL signal as a sedimentary proxy.

Recent work along Southern Portugal has revealed a complex coastal stratigraphic sequence evidencing multiple potential palaeotsunami and palaeostorm events. This rugged coast of the Central Algarve has witness severe shoreline erosion over the last 300 years, nonetheless small embayments such as the infilled coastal lagoon of Almargem have demonstrated to be good event entrapment basins, allowing preservation of complex sedimentary facies.

A series of large trenches dug along two N-S cross-shore profiles were excavated with their long axis both parallel and perpendicular to shore to potentialise the geometries of the different sedimentary units and structures, increasing visualization and stratigraphic correlation. The trench walls with most significant visual stratigraphic differences were sampled throughout their entire profiles. Individual small to micro (10 to 1 g) bulk samples were collected from different laminae for Portable OSL Reader (POSL) analyses, small 3 to 5 cm-diameter PVC tubes were inserted in key layers for OSL dating and Single Grain Over-Dispersion (SG-OD) OSL analyses, and multiple box-cores were retrieved throughout the trench walls for all the various other analyses (detailed sedimentology, mineralogy, petrophysics, bio-stratigraphy).

So far, our research has revealed at least one massive bioclastic-rich layer and multiple heavy mineral laminae associated to extreme marine incursions. Diverse luminescence analyses were undertaken not only to establish chronologies of such events (OSL dating) but also as sedimentological characterisers: a) transport and depositional variations between individual storm-laid and tsunamigenic layers are being identified by means of SG-OD analyses; while b) luminescence profiles created from the measurement of small to micro bulk samples (e.g., individual lamina) using POSL have been useful to interpret changes in stratigraphic patterns, defining the continuity of deposition.

The luminescence analyses on the multiple storm and tsunamigenic layers are detecting the variations imposed by their mechanism of formation, concurring with the other analyses done so far. Despite its massive character, the bioclastic-rich layer is most likely linked to the 1755 Lisbon Earthquake and Tsunami Event while the multiple heavy mineral laminae are most probably the result of successive storm washover events. The presence of numerous layers of different origins in such a small enclosed area makes this a challenging tsunami vs storm study site.

**P-3063**

## **Tsunami events in sedimentary archives from the costal lagoons (Laguna Cuyutlán and Laguna Chacala, Colima, Western Mexico).**

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### **Abstract**

South west coastal Mexico is located in the interaction between the Rivera plate, the Jalisco block and the Cocos plate. Six different high magnitude earthquakes ( $M_w > 7.0$ ) have been documented since 1837 AD including the  $M_w$  8.2 earthquake of 1932 AD in Jalisco. These low frequency but severely damaging natural phenomena in the geological records of lagoons can be in detail through the paleoenvironmental analysis of cores from coastal lagoons. Based in a multiproxy analysis (mineralogy, magnetical susceptibility, ostracods, diatoms and geochemistry) from four cores from laguna Chacala and Laguna Coyutlán, Colima were identified three exceptional events linked to the tectonic activity of these plates.

Indicators of marine invasion includes abrupt erosive contacts that initiate with mixed coarse sand with clay sediments and an increase in the material swept along by an oceanic incursion; mixing of marine diatoms with fresh water diatoms, large fragments of charcoal and presence of Ti, Fe, and Na are. Afterwards the lagoon experimented a process of evaporation halite and carbonates possibly formed in situ and trapped in the lagoon after salinity increased due to a marine incursion. The earliest tsunami we recorded dated between  $517 \pm 87$  and  $518 \pm 88$  AD,  $879 \pm 103$  followed by a second tsunami dated at  $879 \pm 103$  AD. The latest is contemporary with the 1816 AD earthquake that flooded the saltpans of San Pantaleón.

The event effects distributed along over 50 km of the coastline of the state of Colima with waves of over 15 m in height that reached distances of over 2.5 km inside the continent.

It is observe a 361 to 468 years recurrence of tsunamis events.

Documentation of the past records of tsunamis helps in identification of the recurrence intervals in regions with higher population.

P-3064

## Boulder deposits on the southeastern coast of Cyprus and their relation with paleotsunami events of the Eastern Mediterranean

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### Abstract

Cyprus has a long record of tsunami waves, as noted by archaeological and geological records. Large boulder deposits have been noted in southeastern and western part of the Island. In the area of Cape Greco (southeastern Cyprus) large boulders have been noted, however, no detailed geomorphological research exists so far and the related high energy event remains undated. In this context, we focused at Cape Greco Peninsula at the southeastern coast of Cyprus, in order to record in detail large boulders deposits. The accumulation of the boulders along the uplifted coastline (3m amsl) was recorded. The boulders are fragments of a layer of an upper Pleistocene aeolianite, which is overlaying unconformably a lower Pleistocene calcarenite. Dimensions and spatial distribution of 272 small, medium and large boulders were documented. The precise distance of the boulders deposition from the coastline was recorded by field measurements and remote sensing with the use of GNSS, Drone mapping and GIS technics.

Several large boulders weighting more than ~30 metric tons were located up to 60m inland. Geomorphologic mapping and morphometric measurements, along with the presence of marine organisms suggests that some of the boulders were removed from their original intertidal zone and were transported inland by the force of large waves. Samples of *Vermetus* sp. were collected from the displaced boulders in order to date the extreme event. In this work, we report and compare preliminary results from the application of widely accepted hydrodynamic equations (e.g. Pignatelli et al., 2009), in order to determine the extreme event that caused their transport inland. We further attempt a correlation of the event with already known tsunami events from Eastern Mediterranean, based on the estimated wave heights and the radiocarbon dating of marine gastropods (*Vermetus* sp.).

### Keywords

Tsunami, Coastal geomorphology, Boulders, Cyprus

### References

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P-3201

## Phytolith analysis for differentiating between broomcorn millet (*Panicum miliaceum*) and its weed/feral type (*Panicum ruderale*)

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### Abstract

Domestication of broomcorn millet is one of the most significant events in prehistoric East Asia, which provided enough food for explosive growth of Neolithic population and the transition into complex socialites. However, to date, the process of broomcorn millet domestication is still unknown, particularly due to the lack of clear diagnostic feature to distinguishing between the millet and its wild related grasses from archaeological residuals. Here we examine the percentage of silicified epidermal long cell undulated patterns in the glume and palea from the inflorescence bracts in 21 modern of broomcorn millet and 12 of its weed/feral type *Panicum ruderale* collected cross north China. Our results show that the percentage of  $\eta$ III patterns in the domesticated broomcorn millet ( $23.0\% \pm 5.9\%$ ) ( $n=63$ ) is about 10% higher than in *P. ruderale* ( $10.8\% \pm 5.8\%$ ) ( $n=36$ ), with the quartiles of 17.2%-28.3% and 5.1%-15.5%, respectively. The increase of  $\eta$ III pattern percentage has a significant correlation with the decrease of ratio Length/Width of grains. The results statistically suggest that the direct wild ancestor of *P. miliaceum* could possibly has lower  $\eta$ III type in the lemma and palea, providing us a potential method to trace the domestication process of broomcorn millet, and will contributing to the methodology which can be applied to distinguish other cereal crops and wild grasses.

P-3202

## New methods and progress in research on the origins and evolution of prehistoric agriculture in China

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### Abstract

China is one of the main global centers of origin of agriculture. Foxtail millet (*Setaria italica*), common millet (*Panicum miliaceum*), and rice (*Oryza sativa*) were the first crops to be domesticated in China. There remain many uncertainties and controversies in our current understanding of the chronology, locations, and plant types at the origins and the process of evolution of prehistoric millet and rice farming, and their relationships with climate change and human adaptation. This review summarizes the research progress made by Chinese scientists over the last decade on the origins and evolution of prehistoric agriculture. It highlights novel techniques and methods for identifying early crop remains, including plant macrofossils (carbonized seeds, spikelets), microfossils (phytoliths, calciphytoliths, starch, pollen), and biomarkers; new evidence on the origins, development, and spread of early agriculture; and research related to climate and environmental changes. Further, we pinpoint and discuss existing challenges and potential opportunities for further in-depth investigation of the origins and evolution of agriculture and the adaption of human activities to climate change.

**P-3203**

## **A multi-proxy record from the North Pacific coast of Canada suggests possible human occupation by 13,000 cal yr BP**

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### **Abstract**

Kilgii Gwaay is a Late Pleistocene-early Holocene archaeological wet site located in the intertidal zone of a small island (6 ha) on the North Pacific coast of Canada. The site includes one of the oldest known shell middens in western North America and provides evidence of early marine adaptation. Cultural deposits include hearth features and thousands of lithic, bone and wood artifacts, with human occupation dating from 10,800 to 10,600 cal yr BP, when relative sea level was 1-3 m lower than at present. The site became exposed in the late Holocene and is currently only accessible at low tide.

We conducted multi-proxy paleoenvironmental analyses (magnetic susceptibility, pollen, charcoal, macrofossils) on paleopond sediments at Kilgii Gwaay that were submerged and capped by marine deposits about 10,600 cal yr BP, as relative sea level rose. Pollen analysis indicates establishment of herb-shrub tundra by 14,500 cal yr BP. Pine-dominated communities were present by 13,800 cal yr BP and then replaced by spruce forest about 13,250 cal yr BP. Salmonberry seeds indicate availability of this important food resource starting 13,500 cal yr BP. Macroscopic charcoal is abundant during the period of confirmed human occupation; however, intermittent increases in charcoal begin following establishment of spruce forest, well below the known occupation horizon. Forest fires are infrequent in this wet hypermaritime setting with fires absent from some areas of the outer coast for the entire Holocene. Thus, the charcoal record from Kilgii Gwaay pond serves as a potential proxy for human occupation, suggesting human presence as early as 13,000 cal yr BP, approximately 2000 years earlier than documented by AMS-dated cultural deposits and artifacts.

The earliest direct archaeological evidence for human occupation in the region dates to 12,600 cal yr BP. Human occupation of ancient shorelines near Kilgii Gwaay at 13,000 cal yr BP is therefore plausible and would make such a site one of the oldest archaeological sites on the North Pacific coast of North America. The record at Kilgii Gwaay provides indirect support for the hypothesized coastal migration route into the Americas at the end of the last glacial maximum and highlights the utility of multi-proxy analyses of non-cultural deposits at archaeological sites.

P-3204

## Waves of colonization and the Sea of Moyle: Linking population history, resilience and landscape change on islands using modern palaeoecology

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### Abstract

Small islands present environmental archaeologists with the opportunity to study the sustainability and resilience of complex socioecological systems over time. This project is investigating the changing landscapes, environment and population of 6 small islands around the Sea of Moyle over the last three millennia. Today the area is seen as a remote border zone between Scotland and Ireland. In the past this was not the case and the Sea of Moyle was at times a coherent and central geographic region crossed by sea voyagers and linked by culture and kinship. The islands (Rathlin, Tory, Iona, Islay, Gigha & Colonsay) all saw the establishment of early Christian communities, were within the Dalriada over-Kingdom in the 6<sup>th</sup> to early 7<sup>th</sup>C, were subject to early Viking Raids and then formed part of the Scandinavian Suðreyjar, or "Southern Isles". The later Medieval and post Medieval history of the islands is more complex and divergent but all six islands saw major, if not remarkable changes in population over the last 300 years. Cores from lakes on each island will be analysed using sedaDNA metabarcoding and lipid biomarkers, particularly faecal stanols and bile acids. Along with some traditional proxies, <sup>14</sup>C AMS dating and tephrochronology the results will be used to examine changes in island ecology and particularly the history of domesticates. This will be combined with landscape archaeological surveys around the sites and soil DNA studies of relic field systems. The project will be the first to explicitly compare archaeological proxies from islands in the same region with archaeological and historical data using sedaDNA and lipid biomarkers in a controlled archaeological setting.

P-3205

## Late Pleistocene environmental background of human occupation of the Dazhushan site in Shandong Peninsula, coastal north China

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### Abstract

Coastal archaeological sites, recording the evolution history of coastal environment and preserving the behavioral information of earlier human ancestors, are an ideal carrier to explore some academic issues such as the utilization of marine resources, the strategy of marine adaptation, and the route of coastal migration during the late Pleistocene. However, little information concerning the time and process of early human occupation has come to light in coastal areas of China. Here, we report on the chronology, archeology and paleoenvironmental reconstruction of the Pleistocene Dazhushan site on the east coast of the Shandong Peninsula in north China, which is the first Paleolithic site with stratigraphic information in Qingdao. In this study, we reconstructed the history of environmental changes in the area, with pollen, magnetic susceptibility, and optically stimulated luminescence (OSL) dating. Our preliminary results are as follows: 1) Dazhushan site appeared in the late Pleistocene, and its absolute burial age of archaeological remains is 65.7-52.9 ka, which corresponds to late MIS4 to early MIS3. Meanwhile, archeology evidence indicates that prehistoric humans employed a flake technology; 2) multiple evidences show that human activities which occupied by terrestrial herbivores increased significantly in the early stage of MIS3, and the region was an inland area dominated by a mixed broadleaved forest and grassland environment, despite locating on the current coastal area of the northern China. In general, the climate trend is indicative of a good correlation with the regional context; 3) rapidly warming climate and stable living environment provided an appropriate ecological background to survive in the early stage of MIS3. Subsequently, however, as temperatures fell and coastline retreated, the massive reductions of archaeological remains may indicate the weakening of human activities or migrations to other areas. The fluctuation of the intensity of human occupation in different period shows that the survival strategy of early human had been profoundly influenced by the variable living environment. Finally, based on the collected topographic and geomorphic data of the coastal region in the eastern China, and considering the striking advance and retreat of sea level in late Pleistocene, we conducted a deeper discussion on the relationship between the migration and adaptation of prehistoric humans and the geomorphological evolution of coastal environment.

P-3206

## Reconstructing Mid-Holocene paleoenvironments in the vicinity of the submerged pile-dwelling in Zambratija Bay (Istria, Croatia)

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### Abstract

A unique characteristic of post-LGM marine transgression reconstructions is the use of submerged archaeological RSL indicators, such as shell middens, coastal buildings, or traces of human occupation. In the rare cases when underwater archaeological research takes place on those sites, it involves diving and excavation, both of which represent a stressful risk for the archaeologists and the investors. The high likelihood of a negative archaeological result, regardless of the promising preliminary surveys, most often means that archaeological research is considered unreliable or unnecessary. This can change by applying interdisciplinary research methods, where environmental data can also answer archaeological research questions. A geoarchaeological submerged case study in Zambratija Bay, Croatia, demonstrates alternative ways to use seabed core environmental data, by using multiproxy analysis of a nearby sediment core (sedimentological, mineralogical, geochemical and palinological analyses). Preliminary archaeological, geophysical investigations and analysis of dated cores revealed that the site, today submerged three metres under the Adriatic Sea, is a 6,000-year-old freshwater pile-dwelling built on the outer edges of a karstic sinkhole. Seven cores taken on site revealed that the submerged sinkhole contains marine, brackish, organic and lacustrine sedimentary sequences. Holocene marine transgression is evident by marine carbonate sediments containing marine shells, covering terrestrial grey and brown clay sediments. These clayey sediments show succession from highly magnetic sediments containing pyrrhotite minerals, formed under marine influence through karstic underground. One-meter thick organic sediments are composed of peaty sediments with high TOC (15-30 %) and N (1.1-2.8 %) and compact fine-grained peat with high P, Fe and Mo, as well as significant amounts of vivianite. These organic sediments are characterised by lower values of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  implying freshwater environment. Occurrences of vivianite are still visible in underlying brown clay freshwater pond sediments, containing much more siliciclastic material compared to above organic sediments. Vivianite is a mineral that occurs on various Quaternary, postglacial and modern aquatic systems worldwide, which includes marine, freshwater and terrestrial waterlogged soils. It is known to appear on archaeological sites in teeth and bones on waterlogged bodies, and anthropologically influenced muddy wastewater layers settings with higher P levels, which implies that its occurrence might indirectly mirror a human impact on aquatic environments.

P-3207

## Chemotaxonomic patterns of vegetation and soils along altitudinal transects of the Bale Mountains, Ethiopia. Implication for paleovegetation reconstructions.

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### Abstract

*Erica* is a dominant vegetation type in many Subafro–alpine ecosystems such as the Bale Mountains in Ethiopia. However, the past extent of *Erica* is not well known and climate versus anthropogenic influence on altitudinal shifts are difficult to assign unambiguously especially during the Holocene. The main objective of the present study is to chemotaxonomically characterize the dominant plant species occurring in the Bale Mountains using lignin phenols and *n*–alkane biomarkers and to examine the potential of those biomarkers for reconstructing vegetation history. Fresh plant material, organic layer and mineral topsoil samples were collected along a northern and a southwestern altitudinal transect (4134–3870 and 4377–2550 m a.s.l. respectively). Lignin–derived vanillyl, syringyl and cinnamyl phenols were analyzed using the cupric oxide oxidation method; leaf wax–derived *n*–alkanes were extracted and purified using soxhlet and aminopropyl columns. Individual lignin phenols and *n*–alkanes were separated by gas–chromatography and detected by mass spectrometry and flame ionization detection, respectively.

We found that the relative contribution of vanillyl, syringyl, and cinnamyl phenols allow us to chemotaxonomically distinguish contemporary plant species of the Bale Mountains. Particularly, *Erica* is characterized by relatively high cinnamyl contributions of >40%. However, litter degradation strongly decreases the lignin phenol concentrations and completely changes the lignin phenol patterns. Relative cinnamyl contributions in soils under *Erica* were <40%, while soils having developed under Poaceae (*Festuca abyssinica*) exhibited relative cinnamyl contributions of > 40%.

Similarly, long-chain *n*–alkanes allowed differentiating between *Erica* versus *Festuca abyssinica* and *Alchemilla* based on lower C31/C29 ratios. However, also this characteristic plant pattern was lost due to degradation in the respective O–layers and A<sub>h</sub>–horizons. In conclusion, neither lignin phenols nor *n*–alkane biomarkers allow developing unambiguous proxies for reconstructing the past extent of *Erica* on the Sanetti Plateau, Bale Mountains, Ethiopia.

**Key Words:** Chemotaxonomy, biomarkers, molecular proxies, humification, soil organic matter, pedogenesis, Sanetti Plateau, *Erica* and *Festuca abyssinica*

P-3208

## Direct push sensing in wetland (geo)archaeology – Minimal-invasive investigations of archaeological and sedimentological issues

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### Abstract

Buried archaeological sites in wetlands provide important information about pre-historic and historic buildings as well as archives for landscape and environment development. High groundwater table and unstable sediments complicate excavations. Alternatively used vibra-corings suffer from imprecise depth accuracy caused by high compaction rates of the sediments.

In this study, we apply and integrate minimal-invasive direct push sensing on cross sections in a multi-methodical approach to get high resolution and depth-accurate data from a buried Early Medieval canal. We used the technique to clarify the geometry and the fillings of the canal. Furthermore, we want to clarify accompanying structures in the subsurface and the landscape development at the site.

Direct push sensing implies a set of tools for underground investigations by pushing steel rods with different probes into the unconsolidated sediments driven by a flexible vehicle. Thus, different probes allow the characterisation of various parameters *in situ*, e.g. electrical conductivity or colour, for a cost- and time-effective site investigation. Recorded data provide a high depth-accuracy and a resolution in the cm-scale. In the forecast, we detect linear anomalies with SQUID magnetic survey. For the ground truth and sampling we used classical vibra-corings.

The *Fossa Carolina* is the first attempt to bridge the Central European watershed between the Rhine-Main- and the Danube-Catchment. The building was initiated in 792/793 AD by Charlemagne with a length of approx. 3 km near Treuchtlingen in S-Germany.

Our data clearly indicate the Carolingian floodplain surface, probable remnants of Carolingian construction works, the Carolingian trench, buried dams, post-Carolingian trench fillings and the onset of flood loam deposition in the 15 century.

Furthermore, we provide an additional example for direct push sensing in the surrounding of the *Fossa Carolina* to clarify artificial water supply. However, Radiocarbon datings and a fossil half-bog top soil indicate active and passive phases in landscape development during the Holocene and negate an artificial water inlet.

Finally, our approach provides an alternative for (geo)archaeological excavations. The results show detailed features of buried historic constructions with less labour and time effort. The data is also suitable for stratigraphical interpretation and the reconstruction of the landscape development.



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P-3209

## Palmitone as a species-specific biomarker for the crop plant taro (*Colocasia esculenta* Schott.) on remote Pacific islands

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### Abstract

The ecosystems of remote Pacific islands were dramatically transformed following the arrival of humans within the last ~3000 years, as the new settlers required technological innovations and environmental modifications to maintain their populations. These modifications included the introduction of numerous exotic species, including the important crop *Colocasia esculenta* Schott. (taro) and the development of water gardens suitable for its cultivation. Reconstructing the history of *C. esculenta* use in the Pacific has been challenging because of the non-specificity of its starch granules and its limited pollen production during periods of intense cultivation. Here, we assess a lipid biomarker approach to trace *C. esculenta* cultivation in the past. We characterized the neutral lipid compositions of leaf samples from common cultivars and widespread indigenous species from the archipelago of Vanuatu by gas chromatography – mass spectrometry (GC–MS). The compound palmitone (16-hentriacontanone) was a major leaf wax constituent in *C. esculenta* cultivar samples (mean concentration of  $402 \pm 63 \mu\text{g/g}$  (dry wt.)) and was only detected in one other species, the ornamental tree *Cananga odorata* ( $175 \mu\text{g/g}$  (dry wt.)). The structure of palmitone is favorable for its long-term stability, and we demonstrate its preservation potential in a ~1000 year sedimentary record from Vesalea Lake on Espiritu Santo, Vanuatu, where *C. esculenta* is grown today. Palmitone concentrations in this core fluctuated up to  $4.1 \mu\text{g/g}$  (dry wt.). Our results indicate that in appropriate environmental contexts, sedimentary palmitone concentrations can be used to reconstruct *C. esculenta* cultivation and to provide insights about past horticultural innovations in Remote Oceania.

P-3210

## Late Glacial and Holocene landscape evolution of the Sanetti Plateau, Bale Mountains (Ethiopia), deduced from biogeochemical properties of lacustrine sediments

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### Abstract

The Bale Mountains are one of the three extensively glaciated higher elevation areas in Ethiopia during last glacial maximum. After deglaciation, several small depressions on the Sanetti Plateau turned into shallow lakes. Today, some of these lakes dry out seasonally due to the alternation between monsoonal precipitation in summer and dry north-easterlies in winter. With this study we aim at contributing to the reconstruction of the Late Glacial and Holocene environmental history (including particularly sedimentation, fire and vegetation reconstruction) of the Bale Mountains using a multi proxy approach.

We investigated partly laminated lake sediments at high-resolution from a catchment located at an altitude of 4115 m asl on the Sanetti Plateau. Stable isotopes, alkanes, black carbon (fire proxy) in combination with pollen were used to infer environmental dynamics. Radiocarbon ages show that the depression became ice free around 18 cal. ka BP. The sedimentation rate was 24.57 yr/cm for the laminated lower part of the profile (255 to 70 cm) and 186 yr/cm for upper 70 cm. Total organic carbon (TOC) concentration reaches almost 7% between 16 to 18 cal. ka BP, whereas low TOC values ( $\leq 1\%$ ) typically dominate in the younger upper part ( $\leq 12$  cal. ka BP). More positive  $\delta^{13}\text{C}$  values in the lower part of the sediments (-20 to -14‰) might indicate expansion of C4 grasses. However, the influence of other process such as methanogenesis and (semi-)aquatic plants using the bicarbonate metabolism cannot be excluded. By contrast, more negative  $\delta^{13}\text{C}$  values during Late Glacial-Holocene transition and during the Late Holocene indicate increasing input of terrestrial C3 plants. Low  $\delta^{15}\text{N}$  values during deglaciation show that the N cycle was relatively closed probably due to cold temperature at that time. Low odd-over-even predominances (OEP) of *n*-alkane lipid biomarkers as well as low TOC/N ratios corroborate the interpretation of highly degraded organic material building up the upper 70 cm. High concentration of black carbon (BC) recorded between 15.5 and 13.8 cal. ka BP is in agreement with high *Erica* pollen concentration at 13.7 cal. ka BP which likely reflects periodical burning of *Erica* during this time period.

**P-3211**

## **Resource partitioning and interspecific interactions among Pleistocene large herbivore species: a tooth wear approach**

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### **Abstract**

Niche and resource partitioning are key concepts for the understanding of interactions among species and to explain (paleo)biodiversity. It is known that differentiation of ecological niches reduces competition and promotes co-existence between species. Among the proxies used to reconstruct paleodiets in fossil large mammals, tooth mesowear and microwear are ideal to study niche partitioning because the two proxies reflect the dietary traits at the time of death i.e. the diet that each species had when they occurred in the same area. This topic will be discussed on selected examples from archaeological and paleontological localities across Europe (Germany, UK, France and Spain): Steinheim and Swanscombe (MIS11), Joint Mitnor Cave (MIS 5e), Portel-Ouest (MIS 4), and Jou Puerta and Kent's Cavern (MIS 3). The combination of mesowear and microwear provides a powerful tool for examining dietary flexibility and resource partitioning at different temporal scales. Mesowear provides a dietary signal integrated over several months at least, and allows us to contrast more eurytopic species (e.g. *Megaloceros giganteus*, ranging from grazing to browse-dominated mixed-feeding) to more stenotopic (e.g. *Capreolus capreolus*, always browsing). Dental microwear provides an independent proxy that records relatively short-term diet. For stenotopic species (e.g. the browser *Capreolus capreolus* or the grazer *Coelodonta antiquitatis*) the two proxies tend to match. For other species, however, there is sometime discrepancy between meso- and microwear signals that often difficult to interpret but always clearly informative about the diet at the time of death.

**P-3212**

## **Magnetostratigraphy of the Miocene mammalian fauna in the Lanzhou Basin, Northeast Tibetan Plateau: implications for mammal migration**

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### **Abstract**

The fluvio-lacustrine sequence in the Lanzhou Basin, located at the northeastern margin of the Tibetan Plateau, is a rich source of Cenozoic mammalian fossils, critical to our understanding of the terrestrial Asian mammal and environmental evolution. While the Oligocene, Early Miocene and Late Miocene mammalian faunas have been dated with magnetostratigraphy, the numerical age of the Quantougou (QTG) Fauna remain controversial. The accurate age of the QTG Fauna is crucial to understand the mammal and environmental evolution in the Eurasia, because the Myocricetodontinae in the QTG Fauna were regarded as the Earliest appearance of this subfamily in East Asia. Here, we present a high-resolution magnetostratigraphic dating of the Miocene mammal assemblages from a 280-m thick fluvio-lacustrine section in the Lanzhou Basin located at the northeastern margin of the Tibetan Plateau (China). The section is suggested to span from polarity chron C5Cn.2r to chron C5n.2n, i.e. ranging from ca 16.5 to 10 Ma (except for a sedimentary hiatus between ca 15-13.5 Ma). This magnetostratigraphy provides new numerical ages for the QTG mammalian fauna (12.5-12.0 Ma) and enables precise correlation of the QTG fauna to the European Land Mammal Age and North American Land Mammal Ages. Consequently, the appearance of Myocricetodontinae in East Asia is much later than that of Indian Subcontinent (19-16 Ma), which provides new evidence for the Indian Subcontinent origin for the Myocricetodontinae. Further, the Paleogene-Quaternary paleoenvironment evolution of the Lanzhou Basin is summarized based on the mammalian fossils excavated in this basin.

**P-3213**

## **Non-pollen palynomorphs webpage and database**

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### **Abstract**

Non-pollen palynomorphs (NPP) represent a large group of microscopic remains found in palynological slides besides pollen and spores. They are represented by algal remains, fungal spores, resting stages and eggs of invertebrates, allowing a deeper understanding of biotic interactions in the Quaternary palynological records. Starting in the 1970s with studies by Bas van Geel and colleagues, large numbers of new described types are published every year. In order to get an overview to the wide world of these “extra fossils” in pollen slides, we created a webpage with a database aiming to gather information about NPP, structuring it by nomenclature and where possible taxonomy and help by identification: <http://nonpollenpalynomorphs.tsu.ru/>. It is developed with PHP and MySQL. The database contains illustrations, original descriptions and ecological information about the NPP. A search function allows easier identification of the palynomorphs.

P-3214

## Exploring plasticity in herbivore dietary ecology in late Pleistocene France using isotope zooarchaeology

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### Abstract

The isotope analyses of archaeo-faunal assemblages has significant, but largely unrealised, potential for gaining new palaeoecological insights into the long-term adaptability and resilience of mid- and large-sized herbivores. This is particularly the case for certain species, such as reindeer (*Rangifer*), which are intermediate feeders and can also exploit food resources with characteristic isotope ratios (i.e. lichens) that most herbivores cannot when other plants are scarce due to environmental conditions or competition.

Here, we present a targeted diachronic study of herbivore dietary ecology from the late Middle and Upper Palaeolithic archaeological site of Les Cottés using the stable carbon and nitrogen isotope analysis of bone collagen. Spanning a 10,000-year period from the late Mousterian to early Aurignacian, the abundant remains of diverse fauna from this well-dated site represent an excellent opportunity to investigate and characterise herbivore dietary ecology in late Pleistocene France. Data reveal niche partitioning amongst the late Pleistocene herbivore communities of Les Cottés, with *Rangifer* exhibiting consistently elevated  $\delta^{13}\text{C}$  values relative to horses and bovids, which is likely a consequence of lichen consumption. However, data from *Rangifer* (and to an extent *Bos/Bison*) deviate from the shifting isotopic 'baseline' of exclusively-grazing species to varying extents, highlighting plasticity in the behaviour of these intermediate-feeding genera through time. The implications for future studies are explored.

P-3215

## Disappearance of *Globigerinoides fistulosus* was caused by hydrological changes in surface water at ~1.74 Ma in the tropical Pacific

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### Abstract

Planktonic foraminifera *Globigerinoides fistulosus*, considered to be a morphotype of the terminal ontogenetic stage of *Globigerinoides sacculifer*, originated at 2.9 Ma and disappeared at 1.74 Ma in the tropical oceans. Relationship between the disappearance of *G. fistulosus* and the thermo-hydrological conditions of surface water over the period of 1.789 – 1.728 Ma were studied using ODP Hole 1115B (ODP Leg 180, 151°34'E, 9°14'S, water depth 1149 m) at the southern periphery of western Pacific warm pool (WPWP).

Kummer and sac morphotypes of the *G. sacculifer* complex appeared in all the six size fractions of >250 μm to >600 μm, but the *fistulosus* form occurred only in the size fractions >355 μm, suggesting it is indeed the terminal stage of *G. sacculifer*. The δ<sup>13</sup>C increased from 0.3 to 2.7‰ in the *G. sacculifer* morphological complex with increasing test sizes, indicating a deeper dwelling depth for the final ontogenetic stage, *G. fistulosus*. The δ<sup>18</sup>O increased slightly by ~0.2‰, suggesting also a deeper habitat for *G. fistulosus*. Mg/Ca (as a sea-water temperature proxy) of foraminifera shells increased slightly with increasing sizes too, but within the same size fraction the Mg/Ca of *G. fistulosus* were less than other forms' by at least 0.2 mmol/mol, implying a cooler (deeper) water environment in which the chambers were formed in the late ontogenetic stages.

The *fistulosus* morphotype disappeared between 1.742 and 1.737 Ma when the temperature gradient between the surface and subsurface waters increased suddenly from 3.5-6.0 °C (as indicated by Mg/Ca of *G. ruber*, and *Neoglobigerinoides dutertrei*). Before the disappearance of *G. fistulosus* the upper 100 meter of the water column has a less temperature gradient and a quick drop of temperature in 100- 150 m. At about 1.74 Ma the upper 150 meter waters were less stratified, the vertical temperature profile shows a gradual decreasing trend towards the deeper part. Consequently, the temperature at ~100 m depth became cooler and the former habitat condition of *G. fistulosus* vanished. At the same time, the specimens in the larger size fractions (>425 μm) of *G. sacculifer* decreased significantly. We interpreted that in order to keep the same buoyancy, individuals in the *G. sacculifer* complex had to decrease their Reynold's number and therefore their test sizes. The morphological expression of the *G. sacculifer* complex turned into a paedomorphosis direction and the ontogenetic final stage shown as *G. fistulosus* disappeared forever.

P-3216

## Regional and continental extinction of Pleistocene mega-herbivores in Australia, and its ecological effects.

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### Abstract

In Australia many species of large vertebrates went extinct in the late Quaternary. These extinctions resulted in the disappearance from the continent of many large herbivores, including all species above a body mass of about 40 kg and all large browsers. Pleistocene megafaunal extinction in Australia resembled similar extinctions in other parts of the world; as in those other cases, its cause and ecological consequences are controversial. We clarify the timing of extinction of large herbivores across Australia, and investigate its ecological effects, by combining data from dated fossils and several regional records of change in dung fungi.

Fossils and dung fungi provide independent lines of evidence on mega-herbivore extinction, which agree in indicating extinction between 42 and 40 ka. This is shown for the whole southern half of the continent using fossil data, and for specific localities—in the north-east, south-east, south-west and north-west of Australia—by dung fungi. These data provide powerful evidence for synchronised continent-wide extinction of mega-herbivores, which can now be dated with quite high precision. The loss of mega-herbivores was unrelated to climate events, which had varying patterns in those regions; it is possible that it was caused by human impact.

We go on to use new time-series analyses of dung-fungus records along with other palaeoecological proxies to investigate variation in the ecological dynamics of extinction in different regions and to test for differences in the association between extinction and changes in vegetation and fire across the continent. These analyses show that the tempo of mega-herbivore decline was similar in different places, involving relatively abrupt reductions in populations of large herbivores, which extended over periods of one to two thousand years. However, association of extinction with dynamics of vegetation and fire varied among regions. This variation supports the hypothesis that in more productive environments the decline of large-herbivores triggered large increases in the density and biomass of vegetation, which led to increased biomass burning. In environments with low primary productivity, the responses of vegetation to relaxation of herbivory were constrained by abiotic factors, and change in fire was reduced or absent. Evidence for this preliminary hypothesis will be explored.

**P-3217**

## **Insights into Mediterranean aridity during the Late Pleistocene using mammalian tooth crown height of large herbivores**

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The Late Pleistocene was characterised by abrupt shifts in climate in Europe, driven by a range of forcing factors. Evidence of the spread of semi-arid environments is highlighted by the westward migrations of arid adapted mammals. However, relating these faunal migrations to the wider unstable climatic regime is hampered by a current lack of quantitative precipitation estimates at a representative spatial scale and within a robust dating framework. Recent work on both modern herbivores and Neogene fossils has revealed the utility of large herbivore hypsodonty (tooth crown height) as a method of quantifying past and present precipitation. In order to improve the reliability of this method for quantifying present and past environmental variables, a new, geographically extensive and species diverse modern training set using well-provenanced museum specimens has been created. The first application of this new understanding to fossil measurements from Late Pleistocene sites across the Mediterranean is presented here.

Measurements were taken from a number of well-dated sites: Abric Romani (Spain; 40-70 kyr BP), Teixoneres (Spain; 14-100 kyr BP), Le Portel-Ouest (France; MIS 5-3), Grotta del Romito (Italy; c. 24-14 kyr), Qafzeh (Israel; 93 kyr and 31-25 kyr) and Tabun (Israel; c. 300-50 kyr). Here, we show how the mean hypsodonty index of the mammal communities throughout sequences at these sites varies through time, potentially reflecting local or regional aridity patterns. Comparisons are made with pre-existing palaeoenvironmental information from these sites to validate what is seen in the hypsodonty index changes, as well as seeing if abrupt changes in palaeoenvironmental and palaeoclimatic proxies are reflected in our measurements. It appears that at several of these sites changes in mean hypsodonty index are contemporaneous with landscape evolution from open to more forested conditions, suggesting that the hypsodonty indices may indeed reflect aridity patterns.

Existing independent high-resolution chronologies from these sites are used to deliver a robust chronology of hypsodonty-inferred aridity at local and regional scales through the Late Pleistocene. This permits us to assess not only the potential controls of abrupt climate changes on aridity at different spatial and temporal scales but also the effects of these changes upon the palaeoecology, faunal migration and hominins of the Mediterranean.

P-3218

## Cross-trophic assemblage dynamics at the Rancho La Brea Tar Pits

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### Abstract

Inferring interactions among species within past communities is complex, and requires understanding how such dynamics are structured by environmental change and community context, as well as the process of fossil deposition. We explore niche dynamics, species interactions, and community structure with multi-trophic paleo food webs through time and along climatic gradients, using fossil mammal and vegetation data from the Rancho La Brea (RLB) tar pits in Los Angeles, CA. We first determine community composition and deposition time of both the small mammal and plant assemblages recovered from multiple asphaltic deposits at RLB. We then assess variation in relative abundances among small mammals and plants through time, and use isotopes to infer changes in dietary niche breadth of several focal taxa (ground squirrel *Otospermophilus beecheyi* and rabbits (genus *Sylvilagus*)). Finally, we integrate mammalian and plant data and simulations to build a preliminary model of the consumer-resource interactions that structure the community.

The fossil deposits date to between ~30 <sup>14</sup>C ky BP and >49 <sup>14</sup>C ky BP and capture typical southern California late Quaternary small mammal fauna and flora. Preliminary dates indicate 1) there are some small offsets in the ages of fossils deposited across different taxa within a deposit, but 2) the age distributions of different taxa within a single deposit overlap to a large extent, indicating the potential for the sampled taxa to interact ecologically. Relative abundances among taxa differed substantially between deposits, indicating a dynamic environment over the 20,000 year sampling period. Further, the isotopic niche breadth of both squirrels and rabbits was narrower in the younger deposits and  $\delta^{15}\text{N}$  became increasingly positive through time in both ground squirrels and rabbits. These isotopic changes potentially signal dietary changes associated with increasing aridification. We are now exploring which consumer-resource interactions most strongly structured the community through time using, in part, a newly developed foraging profitability model to infer herbivore-plant interactions.

**P-3219**

## **An automated system for recognition and picking of foraminifera using convolutional neural networks**

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Paleoclimatic reconstructions at high resolution or at high precision require to process respectively a large number of samples or replicates. In paleoceanography, the main proxy and chronostratigraphic indicator are foraminifera. They are used for geochemical and faunal assemblages' ecological reconstructions. Yet, the protocol used to extract and recognize the foraminifera has not changed since the mid-18<sup>th</sup> century : manual picking using a brush with a stereomicroscope. However, recent progresses in image processing, and image recognition have paved the way for automated procedures to classify natural objects such as foraminifera.

Here we will present the results we achieve by developing an automaton, the MiSo (Microfossil Sorter) automaton, to automatically pick microfossils from the sediment coarse fraction. This automated system is fully operational and works 24/7 at CEREGE. In this study, we will detail the basic workflow of the automaton and its ability to cope with the large morphological and structural variability of particles encountered in real marginal to deep-sea sediments. We use convolutional neural networks adapted and trained on deep sea sediment samples to classify the coarse sediment particles, including planktonic and benthic foraminifera.

As a test case, we will compare paleoceanographic records generated by a micropaleontologist with the ones generated by our automaton: relative abundance, fragmentation rate, biometrical changes. We have studied two deep sea cores from the equatorial Pacific ocean to document past hydrographic changes in the late Quaternary, and and at high resolution since the last deglaciation. Using the automaton, we processed more than 250,000 foraminifera, the largest image dataset to date. We will show the accuracy of recognition (typically around 85 to 95% depending of the morphoclasses), the morphoclass size probability density function and compare it to multi-proxy (micropaleontological and geochemical) records. Last, we will outline the applications we envision for this automated picking machine.

**P-3220**

## **Understanding changes in British palaeobiodiversity through the collagen fingerprinting of Late Pleistocene bone fragments**

Michael Buckley

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Ancient faunal remains offer zooarchaeologists and palaeobiologists valuable insights into past ecosystems, particularly with respect to human-driven vs climate-driven impacts. With improved retrieval techniques, excavations can now uncover assemblages that number in the thousands of specimens, and in many cases hundreds of thousands of skeletal remains. However, more often than not, only a relatively small fraction of these are utilised for palaeoecological interpretation. This could largely be due to the highly fragmentary nature of the remains, particularly if predators such as humans or hyaenas were one of the original accumulators, or simply due to lacking widespread expertise for less well-studied taxa, such as microfaunal remains. To harness the full potential of these faunal archives of the past, biomolecular approaches could be utilised, whether this is through DNA, protein, or lipid based studies, each of which have advantages and disadvantages with regards taxonomic resolution and preservation potential of the biomolecule. Here proteins are considered of great potential because they are able to retrieve species information and survive for much greater lengths of time than DNA, in some cases for several millions of years at least. This presentation highlights the application of a recently developed method of species-level identification using collagen fingerprinting, also known as Zooarchaeology by Mass Spectrometry (or ZooMS) to the study of over 13,000 bone fragments from Pin Hole Cave (Derbyshire, UK). This cave assemblage is thought to span three phases of human occupation during the Late Pleistocene and is from within the Creswell Crags magnesian limestone gorge, home to Europe's most northerly prehistoric cave art. The results from the biomolecular species identification analyses not only indicated a range of fauna typical of this period, dominated by fragmentary reindeer remains, but also highlighted the potential for improved taphonomic understanding through comparison of morphologically-identifiable remains with overly fragmented remains. Additionally, decay measurements within the collagen fingerprints were able to be used to identify intrusions in the assemblage, such as pig and sheep, offering information beyond species identification alone. In addition to previously published analyses of megafaunal and microfaunal mammal remains, this presentation also highlights the taxonomic resolution across all vertebrate classes, including birds, reptiles, amphibians and fish, and their application to improving our understanding of vertebrate palaeobiodiversity during the Pleistocene.

**P-3221**

## **Insects, postglacial colonisation and refugia in northern Norway**

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### **Abstract**

Although northern Norway is a geographically important region to investigate, palaeoecological studies of Quaternary insect data are limited. A variety of different questions, including immigration of the biota at the end of the last glaciation, evidence for refugia, environmental change and human impact can be answered using the fossil record. This study will investigate climatic and environmental conditions during the Lateglacial and Holocene in northern Norway using fossil insects. A number of sites have been investigated in order to test the possibility of insect survival in refugia during the LGM and whether human presence and impact can be inferred from the fossil insect assemblages.

On northern Andøya, the northernmost island in the Vesterålen group, a lake core which spans from 22 ka to 10 ka BP was taken from Øvre Æråsvatnet for pollen, plant macrofossil and aDNA. This is currently being assessed for beetles and chironomid remains, which have been extracted from these samples to obtain information about insect faunas and climate change in the context of other research from northern Norway.

In terms of Holocene climate and environmental change, fossil insect results from a peat section excavated from the Hollabåttjønnen bog, Tønsnes, provide new information which has been compared to existing pollen and molecular biomarkers studies from the site. The overall findings show that the earlier samples are dominated by heathland associated species indicating a dry environment, and the date and temperature reconstructions place this within the Holocene Thermal Maximum. Change, either edaphic, climatic or a combination of both, led to bog development which persisted through most of the mid-late Holocene. Trees were present throughout the Holocene, as species such as *Deporaus betulae* found largely on tree birch but also on alder, occurred in most samples. Temperature reconstructions from this beetle assemblage will be utilised to understand climate change during this period. Pitfall traps were used to sample the modern insect faunas at the site, and an almost entirely different fauna was recorded, suggesting that a more recent shift has occurred, as a result of human impact in the area.

**P-3222**

**An interdisciplinary approach to climate change studies in southern Colorado using wetlands, geomorphology, soils, forestry, and social science.**

Jared Beeton

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Multi-proxy paleoenvironmental research has been conducted for over a decade in the semi-arid mountains of southern Colorado, USA. We have used pollen analysis, soil science, forestry, and radiometric techniques to study modern and paleo wetlands, previously glaciated environments, mountain river systems, paleontological sites, archeological sites, and alluvial fans. Here, we synthesize these data to better understand how environments have changed from the late Pleistocene through the Holocene and offer a unique solution to forest management in a warming and drying climate. A radiocarbon and optically stimulated luminescence controlled study of two paleo wetlands shows pollen species and groundwater levels fluctuating between cooler, wetter environments and warmer, drier conditions through the late Quaternary with a modern warm and dry signal. Temporally controlled data from moraines, kames, glacial outwash deposits, and fluvial terrace sediments also suggest a cooler and wetter Younger Dryas and a fluctuating Holocene climate. Further, temporally controlled soil and sediment data from four archaeological and paleontological sites suggest a similar climate pattern along with the presence of higher water tables and additional surface streams in the late Pleistocene and into the early Holocene compared with today. Forestry data from the Rio Grande and San Juan National Forests provide a strong modern signal of warming and drying through the accelerated presence of pine/spruce beetle outbreaks. As forests become warmer and drier, forest managers are promoting the removal of many beetle-kill spruce trees. A unique solution lies in using these trees for guitars. Ongoing natural and social science research examines management of North American spruce forests for guitar tone woods and experiences of luthiers, manufacturers, harvesters, and players. Our hope is to promote beetle-kill spruce while reducing harvest pressure on living forests. A synthesis of these environmental studies suggests two major conclusions: 1) A multi-proxy approach to paleoenvironmental research can help draw connections between paleo and modern climate change. Specifically, our study of paleo wetlands and fluctuating water tables ties the late-Pleistocene and Holocene geomorphic story to current environmental changes, while our study of beetle-kill forests ties the modern wetland pollen data to a concrete, highly visible example of the modern signal. 2) Throughout the late Quaternary and into the 21<sup>st</sup> century, when temperatures warm in southern Colorado it gets drier, and when temperatures cool it gets wetter. This has major implications for future climate change in the already semi-arid southwest USA.

**P-3223**

## **Disentangling the influences of climate and human management on fire in the Yosemite region of California, U.S.A.**

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### **Abstract**

Recent large fires have sparked great interest in the drivers and controls of fire in the western U.S.A. Understanding the relative influences of climate change and human management has great societal importance as fires in these ecosystems gain increasing prominence in political and public discourse. Lake sediment records offer paleoenvironmental context with which we can assess the magnitude of observed burning and infer fire-climate relationships on centennial and millennial time scales. We present a charcoal-based fire reconstruction from Swamp Lake, Yosemite National Park, spanning the last 1,400 years, anchored by a high-resolution, varve-based chronology. We compared recent changes in charcoal accumulation to historical records of area burned in order to determine the spatial footprint of three size fractions of charcoal to reconstruct fire history within 25 km (charcoal > 250  $\mu\text{m}$ ), 35 km (charcoal > 150  $\mu\text{m}$ ), and 150 km (charcoal 63-150  $\mu\text{m}$ ) of Swamp Lake. We also compare our reconstruction with detailed paleoclimate, archaeological, and historical datasets to dissect relationships between fire, climate, and human activities. Fire activity in this region was generally correlated across local and regional scales, and climate (temperature and aridity) was the dominant control on fire activity throughout the record. A warmer and drier climate resulted in increased burning, which does not bode well for the region in light of the warmer and drier conditions predicted for the western U.S.A. in the future. However, we also observe time periods in which fire activity at different spatial scales do not correlate. These time intervals coincide with periods of pronounced human influence upon the environment, during which humans strongly influenced local fire activity while climate remained the predominant control of regional fire. Thus, climate acts as a top-down control while human management acts as a bottom-up control on fire. Despite the societal impacts of recent fires, burning in the last 50 years, partly influenced by fire suppression efforts and their legacy, was low relative to the last millennium. Taken together, these results indicate that, without active management, burning in this region is likely to be more spatially extensive and frequent in the future.

P-3224

## Landslides, geomorphic evolution and geoscience outreach in Colca Valley, Peru.

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### Abstract

Colca Valley, one of Peru's top tourist destinations, comprises deep canyons with multiple terraces. Tectonism, volcanism and landslides have formed this stunning landscape, but also pose major hazards. A cooperative research venture – between Simon Fraser University's Centre for Natural Hazards Research, the Peruvian Geological Survey (INGEMMET) and Université Clermont Auvergne – is investigating the Maca and Lari landslides and related aspects of the geomorphic evolution of Colca Valley. Knowledge being gained through this collaboration is fundamental to effective hazard and risk management, supports geoscience outreach to local communities and will possibly be incorporated into existing Geopark displays.

We conducted a field-based textural, structural and stratigraphic study of Quaternary deposits to reconstruct the valley's geomorphological evolution. We combined mangentostratigraphy, cosmogenic dating, tephrochronology, optically stimulated luminescence dating (OSL), and radiocarbon dating to constrain the age and spatial relation of debris avalanches, lava flows and lacustrine sediments. The valley contains at least three levels of lake sediments spanning ~1.1 Ma that record impoundments by landslides or lava flows from the nearby Hualca Hualca stratovolcano. We gave particular attention to the stratigraphy of the active landslides affecting the towns of Maca and Lari. Both are large, hummocky rock avalanches deposited onto the middle and lowest lake terraces, respectively. Both have reactivated as complex failures due to undercutting of underlying lake sediments by Río Colca. Recent deformation involves the entire sequence and affects the towns. A 5.3 M earthquake on August 14, 2016 killed four people and exacerbated movement on both failures. Multicomponent monitoring by INGEMMET indicates increased movement correlates with high rainfall and seismic events.

Both rock avalanche deposits contain multiple sedimentary facies, indicating variable emplacement rheology. Lari debris includes large rip-ups of lacustrine sediments and may have been deposited in a paleolake. Lake and distal fan sediments blanket much of the landside, producing a more subdued topography than Maca. The Maca landslide is ~8000-9000 cal years old based on radiocarbon analysis and <sup>10</sup>Be on feldspar. Lari is older; cosmogenic, OSL and radiocarbon samples were collected in May 2018 to better refine its age. Sediments directly above and below both landslides are normally magnetized. Preliminary magnetostratigraphy of lacustrine sediments and associated volcanic rocks infilling Colca Valley record an N-R-N polarity sequence, indicating that infill began by at least the Jaramillo subchron (1.072-0.988 Ma).



The high landslide hazard of Colca Valley has a multitemporal dimension. Rapid tectonic uplift, consequent deep canyon incision, and subsequent active volcanism led to very large landslides that produced lakes and their deposits. Fluvial incision and undercutting of these sediments drives modern instability that directly affects the valley's communities. A better understanding of past mass movements and their relation with the paleo-environment is helping understanding current and future hazards.

P-3225

## The Colônia crater: A scientific deep drilling project in the Atlantic forest, Brazil.

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### Abstract

The Colônia crater is one of the best natural laboratories to test vegetation and climate dynamics through the quaternary in South America. Particularly, the intriguing geological origin of the basin which is thought to be formed by a meteorite impact has allowed having a continuous sedimentary infill that until now is known to have 300 meters depth. In this context, the crater is an excellent site for coring long sedimentary records. In addition to that, the Colônia basin is also a key site to research the long-term processes that have affected the landscape in the past, due to its location between the southernmost influence of the South American Summer Monsoon (SASM) and the northernmost limits of polar air advection. In this regard, and based on previous studies, a scientific deep drilling project was built with the aim of understanding the long-term biotic and abiotic processes that have occurred in the Crater. A new sedimentary record was recovered at Colônia, Southeastern Brazil. The new sediment archive includes a lake and a bog deposit accumulated during several glacial-interglacial cycles in the basin of Colônia. A total of 115 meters of overlapping sediment cores were drilled from three closely-spaced holes. Here we will present the first results from multi-sensor core logging, sediment description, chronology, and multi-proxy analyses. The chronological frame includes radiocarbon, Optically-Stimulated Luminescence (OSL), paleomagnetism and <sup>10</sup>Be dating, which led to an approximate age of 1.7 million yr BP. The multi-proxy data includes X-ray fluorescence spectrometry (XRF), pollen, diatoms and biomarker analyses. The results provide clear signatures for alternating glacial-interglacial sediment facies in phase with global changes of the early Quaternary.

P-3226

## Modelling the evolution of Brazil's Atlantic Forest through the Quaternary in high spatial, temporal and taxonomic resolution.

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### Abstract

Brazil's Atlantic Forest is a global biodiversity hotspot with a precarious present and uncertain future. 20<sup>th</sup>-Century habitat changes decimated the different forest types in the south of the biome, as well as its highland grasslands which have occupied the high elevations since the last glacial period. With the coming decades set to bring warming temperatures and disrupted rainfall regimes, 21<sup>st</sup>-Century climate change presents a further threat to the biome's survival. Understanding how the southern Atlantic Forest has responded to previous changes in conditions may help forecast the biome's dynamics into the future, but its past is unclear.

A number of fossil pollen studies have examined ecotones between Araucaria forest and grasslands at high elevations in the east of the southern Brazilian highlands, but the palaeoecology of the region's other forests is far less well understood. Existing pollen records agree that grasslands covered the highlands from the last glacial period, but their spatial limits are not known. The extent to which subsequent late-Holocene forest expansion was driven by climate changes or pre-Columbian societies is another topic of considerable debate. Broad-brush modelling studies have predicted a large area of high biome stability in southern Brazil, with potentially sizable refugia of Araucaria forest and grasslands identified and smaller forest microrefugia inferred. However, the locations of these putative areas are not well constrained, and the type of vegetation which occupied them is largely unknown: the region's forests exhibit significant floristic heterogeneity, containing variable mixtures of temperate, cold-adapted and tropical taxa – the biome is unlikely to have remained unchanged since the previous glacial period.

Here, we provide detailed insights into the dynamics of the whole southern Atlantic Forest through the Quaternary, using robust models with high spatial, temporal and taxonomic resolution. By combining published palaeoclimate data with statistical downscaling techniques, we make detailed projections of the extent of the region's various vegetation types at dozens of key intervals since the Last Interglacial, identifying potentially microrefugial areas. Modelling ecologically key taxa from five different vegetation types allows floristic changes within the forests over time to be examined, identifying no-analogue assemblages and highlighting areas where non-climatic drivers (e.g. grazing, fire or competition) may have dictated community composition. We make detailed comparisons between the models' outputs and an extensive suite of palaeoecological records, allowing our predictions to be verified and potential causes of disagreement (e.g. changed CO<sub>2</sub> concentrations or human land use) to be explored.

By shedding light on the Atlantic Forest's past in this unprecedented detail, we hope to inform the ongoing debate around the origins and maintenance of the biodiversity in this hotspot, as well as helping to secure it in the face of an uncertain future.

P-3227

## Hunting deer at Cerro Mangote: A Panamanian Late Preceramic site

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### Abstract

People used pacific isthmus route to migrate to South America, as the Panamanian archaeological record shows. The first populations take advantage of natural resources and they direct impact the pristine environment that they found. Late Preceramic Communities (7000-6000 BP) located on the coast and in the foothills of Panama practiced a mixed economy of fishing, hunting, shore-line foraging, wild fruit collection and farming. Cerro Mangote (5900-3020 cal yr BP) is a preceramic dump site where abundant marine shells and cultural debris are present. Cerro Mangote is situated top of a small hill on the north bank of the Santa María River, at the inland edge of high tidal flats, or "albinas". This site evidences coastline changes in Parita Bay, because at the time when was occupied it was likely to have been 7 km further inland, today the site's eastern edge is now 8 km from the active marine shoreline of Parita Bay. The actual environment surrounding the site is characterized by the presence of cane fields and cattle pastures and remnants of wooded savannas. The zooarchaeological record of the site evidences mud flats, mangroves, riverine woods and open areas.

The subsistence strategies held by the human groups that inhabited Cerro Mangote consisted in hunting deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), iguanas (*Iguana sp.*) and other small reptiles. They also birding in mangroves and scrub forest, collecting shellfish, crabs. As well, collected and cultivated plants. They hunted deer's one of the most important prey because they provided meat, fat and bone marrow. The white-tailed deer has a great plasticity for its nutritional requirements. They also are well adapted to crops. Crop cultivation could increase the deer population, because it has been observed that deer prefer second-growth vegetation and would thus have been favored by the disturbance of primary forest cover by the expansion of agricultural fields. The aim of this presentation is to better understand the evolution of human subsistence strategies through time towards deer hunting and the importance of environmental patterns in these changes in Panamanian pre-ceramic groups focus on the archaeological sample of Cerro Mangote. To achieve so, I propose a multi-proxy zooarchaeological and taphonomical analysis. I will present the results of a taphonomic and zooarchaeological analysis of deer remains.

**P-3228**

## **Late Holocene climate implications and later prehistoric landscape modifications in the tropical and semi-arid regions of Indian Peninsula**

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### **Abstract**

This paper stress on the number of cultural features studied as a signature for micro studies in our archaeological projects to understand the changes in economy, politics of south Indian later prehistoric population resulted at major landscape modifications, and site formation processes associated with frequent climatic variations occurred during the late Holocene. Paleoclimate studies on reconstructing the Indian Summer Monsoon (IMS) from various lakes, river and ocean sediment cores identified aridification of climate in the Indian subcontinent during last c. 4500 to 1500 ka. Unstable river behaviors such as weakening of river dynamics and occurrence of recurrent flash floods determined by the monsoon precipitation in the rivers of Western Ghats originate (example Kaveri, Krishna and Tungabhadra) in Indian Peninsula have implications on the developments of later prehistoric societies during the last three millennium BCE (Neolithic, 3000-1200 BCE and Iron Age during 1200-300 BCE). Such developments in the environment coincided with the nature of expansion of agricultural population, crop suites, subsistence changes and settlement established away from the riverine environs. However, recent archaeological studies by the present author in South India focusing on two different ecology, such as the tropical Western Ghats (Koppa Archaeological Research Project) and semiarid region of central Deccan plateau (Brahmagiri Landscape and Settlement Survey project) are showing differences in population adaptability to regional ecologies and resources. Their commonalities are relatively contemporary in the expansion of sites at such above dynamic environments bearing with similar production of cultural materials in the society. Yet in the terms of their landscape modification and how they managed space within the sites and nearby sites have major variations to record from the cultural features (stone tools, ceramics and burials) and spatial patterning beyond the cultural materials; which are associated with the ritual and economic practices invariably governed by fluctuating climate and nature of landscapes. Number of key distinctions is evident on this regards from the various sites in above study areas; one, water collection and management led by fluctuating monsoon precipitation taking shape in local politics and resource of economic importance regulated through the introduction of artificial pools/ reservoirs. Two, sites shifting from riverine to non-river environs and surrounding the natural springs in shaping the site economy; three, living in the rock shelters and open scrubs on whether imprints of rock art and sonic production due to nature of denudational and pediplain landscapes etc. They collaterally indicate at the development of new cultural landmarks with changes in climate and availability of suitable landscapes.

P-3229

## Deep-time habitat dynamics coupled with ecological constraints explain the latitudinal diversity gradient in reef fishes

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### Abstract

The global increase in species diversity towards the equator, referred to as the latitudinal diversity gradient (LDG), is one of the most striking biodiversity patterns on Earth. In this study, we propose a spatially explicit model of diversification to evaluate the predictions of four major hypotheses potentially explaining the LDG, namely, the 'time-area', 'tropical niche conservatism', 'ecological limits' and 'evolutionary speed' hypotheses. This mechanistic model consists of simulating the evolutionary dynamics of species ranges by explicitly linking speciation, extinction and dispersal processes to both changes in habitat configuration and climatic conditions through geological time. We compare simulation outputs to observed diversity gradients in the global reef fish fauna, which are a dominant group of vertebrates with thousands of species found in shallow reefs worldwide. The distribution of reef fishes has been intensively studied for decades, but its underlying causes and processes are still under scrutiny. Simulations were run based on the paleo-environmental reconstruction of potential reef habitats in temperate and tropical regions over the last 130 million years. Our results show that the relative importance of these hypotheses depends on the time scale considered. Habitat changes caused by plate tectonics determined the global distribution of reef fish diversity during deep geological periods, while ecological constraints due to the shrinkage of tropical habitats during the Neogene likely produced the marked LDG that we observe today. Overall, this study calls for studies combining different disciplines, such as biogeography, macroevolution and paleoenvironmental reconstruction, in order to provide a temporal and spatial understanding of the role of speciation, extinction and dispersal in generating contemporary biodiversity patterns.

**P-3230**

## **Palaeoenvironmental reconstruction of four shell midden sequences in caves within the Tràng An massif, northern Vietnam**

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### **Abstract**

Over the course of the past two decades there has been a growing research interest in the site formation processes associated with shell middens and how these features can enhance dietary, cultural and palaeoenvironmental reconstruction. Coastal shell middens have drawn particular attention; comparatively less has been devoted to middens containing fresh water or terrestrial molluscs from more inland localities. This paper examines midden formation from caves set within a sub-tropical karst landscape in northern Vietnam – the Tràng An massif, World Heritage Site – that has experienced both coastal and inland conditions.

Four cave sites are discussed (Thung Binh 1, Hang Moi, Hang Boi and Hang Trong), combining previous work with assessments of new archaeomalacological assemblages. Excavation of these sequences has been undertaken as part of the SUNDASIA project, a multi-disciplinary research initiative focusing on the past 40,000 years of archaeological, geological and ecological development of the Trang An massif in Ninh Binh Province, northern Vietnam.

Within the studied midden sequences, the terrestrial Mollusca component, mostly comprising various species of intact Cyclophoridae (>90% of midden assemblages) is dominant throughout. Most contexts in each studied sequence also contain varying quantities of freshwater and estuarine species of Mollusca, mainly; *Sermyla riqueti*, *Unio* sp., cf. *Meretrix* sp., *Ostrea* sp. and *Crassostrea* sp. Taphonomically, the majority of midden assemblages contained intact or near intact specimens. This suggests that, along with the presence of burnt shell layers of *Ostrea* sp. and *Crassostrea* sp. and the presence of occasional shell artifacts throughout all four sequences, that the formation of midden stratigraphy occurred predominantly through human action and that cave occupation was largely associated with their formation. The very low incidence of 'micro mollusc species' <5mm in size, which only start to appear in sub-tropical forest soils during periods of long term vegetation stability, suggests that significant parts of the record of human occupation at these sites was associated with disturbed habitats.

The Tràng An massif contains evidence of human occupation across and between the last three major marine transgressions in northern Vietnam; the Quang Xuing (2600-1500 cal. BP), Dong Da (7000-4000 cal. BP) and Vinh Phuc (59,000-30,000 cal. BP). Analysis of archaeomalacological assemblages from these sites offers us a reliable, independent palaeoenvironmental dataset that can be associated directly with their geoarchaeology and chronostratigraphy, enabling the reconstruction of conditions across much of the last 40,000 years, and helps to elucidate the impact that marine transgressions had on ecology of this landscape as well as the humans living there.

**P-3231**

## **Spatial distribution of mass movement processes in tropical mountains: Implication for geohazard assessment based on examples from Colombia and Peru.**

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## Abstract

Recent climate changes and land-use/land-cover changes can control geomorphic dynamics in many tropical mountain areas. Observations and simulations suggested a substantial role of land use changes in the intensification of hazardous debris flows and landslides (Figure 1); however, this has yet to be fully recognised. Moreover, the quantitative aspect of recent geohazards related to land-use and climate changes remains also largely unknown despite being critically important due to their potentially substantial impact on numerous human communities. This study employed field-based and remote sensing observations to quantify and compare the geomorphic sensitivity of tropical mountain landscapes to direct anthropogenic influence in two key locations in the Andes characterised by different socio-economic and environmental conditions: Eje Cafetero, Colombia and The Cordillera Vilcanota, Peru.

We mapped the distribution of mass movement processes based on their traces detectable in high-resolution satellite imagery. Mapped features included landslides, debris flow channels, erosional rills, and rockfall deposits. Time-series of imagery allowed us to study temporal changes in the occurrence of hazardous geomorphological processes and their potential impact on human communities and infrastructure. Mapped areas were also ground-checked during the fieldwork, and detailed topographical data were collected for several key locations using repetitive unmanned aerial vehicle surveys.

Studied sites comprise reasonably small areas (~500-1000 km<sup>2</sup>); hence, the global factors (like climatic conditions, tectonic activity, indirect global human impact) were more or less uniform in any given area. As such, it allowed us for investigation of local factors and their correlation with mass movement activities. Four main groups of factors were tested: (1) topographic properties (slope, curvature, slope length, size-dimension-orientation of valleys); (2) geology (type of rock, pre-existing rock conditions); (3) local climate (exposition, potential amount of solar energy); (4) direct human impact (changes in land-use, occurrence of roads, mining sites, and other types of infrastructure). Statistical analyses were performed to assess the influence of individual factors (and their groups) on the distribution and intensity of mass movement processes. Based on the results we proposed a conceptual model presenting the development of modern-day mass movements in mountain areas affected by different degrees of direct human impact.

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Figure 1. Landslide conditioned by land-use change, Valley de Cocora, Colombia.

P-3232

## Paleoclimatic reconstitution of the Monte Cristo Cave, Minas Gerais, Brazil, through Phytolith analysis

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### Abstract

The study area is part of the project known as "Environmental Dynamics and Biogeoclimatic Evolution in Karst Environments formed in Carbonatic and Siliciclastic Rocks at the Western Edge of the Southern Espinhaço Range" in the state of Minas Gerais, Brazil. The project aims to contribute to the understanding of paleoclimatic variations in karst environments throughout the Quaternary. In the present study, results are presented on the Monte Cristo Cave, formed in quartzite. The objective is to contribute to the understanding of paleoclimatic variations in the region during the Holocene, evaluating how the caves respond as a paleoenvironmental analysis environment using phytoliths as proxy. Phytoliths are microscopic particles of biogenic opal, which are formed through precipitation of amorphous silica between and within cells of several living plants, as a result of silicic acid absorption of the soil solution by plants. Previous studies carried out in the region using phytoliths as indicators of climatic variations in areas of "*cerrado*" (savannah) formations have shown promise for inferences on vegetation and climate. Two profiles were collected, the first being an Organosol outside the cave and the second consisting of mostly sandy sediments inside the cave, in layers that vary in color between light and dark tones. The results showed that both profiles present a high stock of phytoliths, with very similar observed morphotypes, which follow the pattern of decreasing with the depth. The phytoliths are well preserved; with a predominance of globular echinate and globular granulate types, produced respectively by *Arecaceae* and woody dicotyledons, besides the presence of bulliform cuneiform, cross, bilobate, rondel and trapeziform types, produced by *Poaceae*. The tree density index (D/P) is low in both profiles (between 0.19 and 0.36), indicating open vegetation. The mean values of the Bi% index (32.8 to 53%) indicate moderate water stress, similar to the results found in previous studies in nearby regions. The Ic (climatic) index showed variation in plant adaptation at lower temperatures, with a predominance of C3 grasses, while the Pa/P index (palm tree density) indicated the presence of palm trees along both profiles. The ages obtained by <sup>14</sup>C-AMS in the organosol were from 4440/4230 to 2740/2430 years cal BP, and the sediment samples within the cave from 1000/920 to 660/550 years cal BP. The vegetation type remained stable during the analyzed period, characteristic of rupestrian fields with the presence of woods in more humid environments. The phytoliths found inside the cave have an allochthonous origin indicating that the material is alterite, not sediment, it probably having been carried by flooding in periods under different hydrogeomorphological conditions. The results were promising for the paleoenvironmental understanding of the region.

P-3233

## Palaeoclimatic reconstruction of areas of the Caatinga Biome, Northeast Brazil

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### Abstract

The *Caatinga*, a typical biome in Northeast Brazil, is composed of a mosaic of dry forests and steppe vegetation with enclaves of moist montane forest and savannah. Despite this, it is the Brazilian biome with the second lowest number of protected areas in its domain and with very few paleoenvironmental studies. The current prevailing climatic conditions are semi-arid, and their intensification has affected economic and social development. In order to contribute to the discussion on the paleoenvironmental evolution of this biome, the objective was to investigate if there have been changes in the vegetation linked to climatic variations during the Holocene. Twenty soil samples were collected in four profiles in the states of Rio Grande do Norte and Ceará. In this study phytolith analyses are used, complemented by pedological and carbon isotope studies. Phytoliths are microscopic opal particles that are formed by precipitation of amorphous silica within or between the cells of living plants. The amount of organic carbon and phytoliths in the soil present a normal trend in all the profiles, decreasing with depth, except for some horizons with a higher stock of phytoliths, which is probably due to the finer grain size or organic matter accumulation. In all the profiles the phytoliths are well preserved, with the classified percentage decreasing with depth. The predominant phytolith types in all the profiles were those of grasses (bulliform and acicular), in some cases with the presence of saddle type, characteristic of dry environments. For the period being studied (between 10000 and 500 years cal BP), the tree density index (D/P) always presented low values, Profile 1, which has the driest environment, being that which presents greater anthropic changes in vegetation and soil use. The climate in the Northeast has undergone changes during the Holocene, for example there are records of a moister climate and/or moister environments than the current at around 3000 years cal BP. In all the profiles, there is a tendency of decreasing D/P and increasing water stress towards the surface, indicating that tree coverage was denser in the past, suggesting a more humid environment than the current. This increase in aridity may be due to natural causes of variations in the regional climate, but one cannot ignore the hypothesis that this natural tendency is aggravated by the anthropic influence on the vegetation of the present *Caatinga*, since the region is historically and erroneously associated with low diversity and drought, and thus has few affirmative actions of preservation and conservation. Phytoliths have been shown to be promising for vegetation studies in this biome, because they are well preserved in the soils, especially since this is an area lacking suitable environments for the use of other proxies.

P-3234

## Pyromagnetic enhancement of an Anthropogenic Dark Earth from Amazonia

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### Abstract

In the Amazon basin, paleoindian occupation and land use are associated with a dark, organic-rich soil, known as *Terra Preta do Índio* or Amazon Dark Earth (ADE). Although the anthropic origin of ADE is currently accepted, it is not clear yet if it resulted as by-product of daily human activity or it is an allochthonous sediment intentionally deposited to improve the fertility of the latosols. Rock magnetism analyses have been carried out on samples from the Bom Socorro archeologic site (Itacoatiara, Amazonas), where the ADE occurs over an area of 6 ha at the rim of the fluvial terrace of the Urubu River. From top to bottom the site stratigraphy consists of ADE (30–50 cm-thick), a transitional horizon (50–60 cm-thick), and the lateritic soil. Radiocarbon chronology indicates that ADE experienced a polyphasic development through two different moments of anthropic occupation at 385–535 cal yr AD and 1460–1635 cal yr AD, respectively. Magnetic susceptibility values show a ten-fold increase from the lateritic soil to the ADE, associated to the occurrence of low-coercivity magnetic mineral, interpreted as maghemite on the base of thermomagnetic curves and FORCs. Unmixing analysis of the IRM acquisition spectra indicates goethite as main magnetic mineral in the lateritic soil, with a minor amount of hematite. The distinctive magnetic properties of the ADE are interpreted to have been originated by fires related to the daily anthropic activity at the settlement, including both ceramics production and waste burning. Formation of maghemite, primarily responsible for the magnetic enhancement of the ADE, is directly linked to burning in the presence of organic matter. Temperatures of about 200–300 °C allowed the conversion of iron (oxyhydr)oxides from the lateritic soil to magnetite, which eventually transformed into maghemite by low-temperature oxidation. Magnetic enhancement of the ADE with respect to the underlying lateritic soil may be used as discriminant physical property for future large-scale prospecting, considering that the total extent of the ADE in the Amazon basin is still largely unknown.

P-3235

## Quaternary evolution of North Andean high mountain biomes.

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### Abstract

Vegetation dynamics-inferred climate change, changing sedimentation regimes, and evolutionary history of the North Andean flora during the Quaternary have been remarkably well monitored in high-resolution pollen records from deep sedimentary basins. Here we present a composite pollen record from three high-Andean lakes jointly reflecting the full Quaternary in over 6000 pollen spectra. Records from Funza09 (2550 m alt., from 2250 to 128 ka; 1200 years resolution), Fúquene-9C (2540 m alt., from 280 to 14 ka, 60 years resolution), and La Cocha (2780 m alt., last 14 ka, 30 years resolution) show a stunning record of glacial-interglacial cycles, millennial-scale climate variability, and numerous events of rapid climate change (mostly 2-4°C, up to 10°C at Pleistocene Terminations). Temporary disappearance of biomes due to differences in upslope migration speed, immigration of Northern Hemisphere arboreal taxa, and suites of no-analog vegetation types are also shown. Grain-size analysis documents periods with riverine and lacustrine environmental settings and allows improved interpretations of long continental pollen records.

This unprecedented documentation of *temporal* change provides insights to understand better the *spatial* dynamics of high mountain biomes. Reconstructed changes in the pollen-based upper forest line positions were used to estimate quantitatively changing páramo distribution and extent during the last million years. Highly variable periods of fragmented and connected páramo areas reflect the extremely dynamic history of this archipelago of 'paramo sky islands'. The stunning high rates of speciation of the páramo flora during the Quaternary (shown by molecular phylogenetic studies) are now better understood in the context of this extremely dynamic system of páramo 'islands' fuelling connectivity (gene flow and hybridization), isolation (speciation), and fragmentation (allopatric speciation). Remarkably, numerical analysis of pollen composition of the last 10 interglacial periods during the last million years shows a high resilience of floral composition. No significant difference is observed in North Andean upper montane forests among the last 10 interglacial periods. Indeed, connectivity of the montane forest appeared to be extremely high during most of the Quaternary as cool and cold glacial conditions prevailed c. 75% of the time. Plant populations migrated maximally over 1500 m vertical distance with low risks of species loss as a consequence.

Long-continental pollen records are now contributing to a new field of geo-ecological research and allow quantifying the conditions which stimulated an unprecedented rate of speciation in the North Andean páramo biome.

P-3236

## Vegetation changes in the catchment of Lake Alaotra, Madagascar

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### Abstract

To understand the driving processes for changes in tropical landscapes and its related problems such as soil degradation, it is crucial to gain insight in the relative importance of human disturbance and natural variation in these environmental changes. Madagascar is known for its particularly high erosion rates in the central highlands, yet the role of human disturbance versus natural processes are not well understood. Recent studies have challenged the traditional view that the observed erosion processes and sediment fluxes in Madagascar are mainly driven by recent large-scaled deforestation. However, at present almost no quantitative data is available to couple vegetation dynamics and sediment fluxes over time in Madagascar. This study aims to provide more insight in landscape changes (vegetation changes, sediment mobilization and deposition) in central Madagascar, and in the specific role of human disturbance versus natural drivers. The study focuses on the 1800 km<sup>2</sup> catchment of Lake Alaotra, located ca 200 km northeast of Antananarivo, Madagascar's capital. Lake Alaotra is formed in a graben system in the highlands of Madagascar, and is the largest freshwater lake of the country (400 km<sup>2</sup>). A pollen record from Lake Alaotra was used to reconstruct regional vegetation changes. Radiocarbon dates of extracted pollen provide a detailed chronostratigraphic framework. The pollen record provides an overview of natural vegetation dynamics and increasing human impact on the vegetation throughout the Late Holocene. Multivariate statistical analysis of the pollen data (cluster analysis and non-metric multidimensional scaling) was used to semi-quantify human impact on the vegetation. The organic carbon concentration in the lake record varies between 10 and 20 %.  $\delta^{13}\text{C}$  data on the organic carbon shows an increase towards present (from -21 to -15 ‰). Overall, this study provides a spatial and temporal integrated reconstruction of vegetation changes in the catchment of Lake Alaotra and provides a better understanding of landscape changes in central Madagascar.

**P-3237**

## **Reconstructing tropical wetlands and Maya agroecosystems in northwestern Belize**

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### **Abstract**

Wetlands are threatened and critical components of tropical systems globally. The geomorphology and ecology of these systems were once limited areas of study, but are now growing disciplines that scholars are embracing to meet the challenges of the Anthropocene. Further, Neotropical wetlands are proving to have played an intensive role in agriculture among the ancient Maya. These wetland agroecosystems were spatially and temporally complex, and served different purposes across the Maya world depending on groundwater quality and spatial arrangement. Here we present our recent research within forested fluviokarst wetlands along the Belize/Guatemala border. Through LiDAR and other remote sensing efforts, field survey, and excavation, and we now recognize that wetlands in this region have undergone extensive anthropogenic modification in the form of agricultural field building and channelization during the Maya Classic (1650-1050 years before present) with use possibly extending into the early Maya Postclassic (1050-700 years before present). Through many field seasons of study, we have developed a chronosequence for paleosols and a temporal understanding of human management within this wetland environment. Here we characterize soil profiles, present new geochemical (ICP-MS) and isotopic ( $\delta^{13}\text{C}$ ) analysis of these buried soils, and refine our understanding of soil development and sedimentation within the system, as well as explore the lines of evidence for and against an anthropogenic burn layer throughout the system that could represent wide scale clearing during the Maya Terminal Classic. By synthesizing soil geochemistry as well as micro and macrocharcoal records from wetland sediment cores, we consider anthropogenic forest clearing and cultivation, as well as natural patterns of tropical fire sequences to better understand how these factors control long term wetland development and geomorphology. The spatial and temporal patterns of charcoal variability within these sequences enhance our understanding of both long term anthropogenic impacts on fire regimes as well natural drought cycles and environmental change within the region. This research demonstrates the complexity of human engineering and modification during culturally significant periods of ancient Maya occupation in this region, provides new chronologies of soil development and wetland genesis, and provides a case for the succession and recovery of tropical wetlands after intensive anthropogenic manipulation terminates. Further, this research enhances our understanding of the direct and indirect benefits of tropical wetland agroecosystems, and can be synthesized with ongoing research on tropical watershed and wetland ecology, modern use and restoration, and long-term environmental change.

**P-3401**

## **Vegetation history and sea level changes at the terminals of the Gorgan and Tammisheh Walls (SE Caspian Sea)**

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### **Abstract**

In northern Iran, the Walls of Gorgan (c. 200 km, W-E) and Tammisheh (12 km N-S) were built to protect the Sasanian rural and urban populations from the northern nomad attacks. They were built of fired mudbricks around the 5<sup>th</sup> century AD. The Tammisheh Wall ends below the present-day water level of the Caspian Sea in the Gorgan Bay; while the former wall is covered by marine sediment at its extremity close to the sea.

A series of cores were taken at the known ends of the walls by the sea or in the sea in order to link the timing of the wall construction to sea level change and vegetation history. The Caspian Sea level has fluctuated widely in the last millennia with a highstand around 600-300 BC (the likely ground on which the wall was constructed), the Derbent lowstand (Late Antiquity-early Middle Ages) when the walls were constructed, and finally the Little Ice Age highstand long after the walls had been abandoned.

The vegetation history reflects on the one hand human activities such as agriculture and arboriculture, and on the other hand the extension and contraction of the Alder carr along the coast. Other microfossils contribute to establish the palaeosalinity of the water.

**P-3402**

## **Micro disseminated noble metals in Pleistocene sediments of the South Caspian oil-gas basin**

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### **Abstract**

The geochemical testing of the fault zones within the oil fields in the South Caspian sedimentary basin revealed the significant gold-oil paragenesis. The faults' thickness is more than 100 m. Preliminary testing of one of such zones within distance of 80 m across the strike of the fault showed hurricane concentrations of gold (0,3 to 0,9 g/t), palladium (0,2-0,7 g/t), corresponding to the lower boundary of commercial (cutoff grade) amounts, as well as indicators of Carlin type epithermal gold mineralization - arsenic on average 1665 g/t, antimony – 30g/t and barium - 1794 g/t, which are exceed clarks 1700, 250-1000 and 170 times respectively. There have been also determined abnormally high contents as related to the clark of the following elements: iron-10-15 times; manganese and nickel - up to 100 times, copper - 10 times. Zink and lead exceed the clark up to 2 times. Contrary to the above mentioned metals, silver and uranium in the investigated zone are tens times below the clark.

As a result of statistical work, we can conclude that in the mineralized zone there have been determined three associations of elements: I-Fe-Cu-As-Ba-(Mn); II-Cr-Ti-Zr; III-Au-Pd-Pb. Elements from associations I and III negatively correlate with elements from association II, and do not correlate or weakly correlate with each other. This indicates that Fe, Cu, As, Ba, Mn, Au, Pd and Pb have been supplied to the fault zone and control balance of Cr, Ti and Zr, which are components of stable in situ accessory minerals of the enclosing sandstones. Superimposed character of the mineralization is confirmed by microscopic investigations of samples from the fault zone.

A visible gold has not been determined. Absence of correlation of gold, palladium and lead (association III of elements remobilized from oxidation zone) with iron excludes their accumulation in iron hydroxides. At the same time, the strong correlation and high contents of elements from association Fe-Cu-As-Ba-Mn are caused by their accumulation in the zone of hypergenesis and iron hydroxides. It is very important, that abnormally high amounts of gold and palladium were recorded in calcareous highporous sandstones with extremely low amounts of clay minerals, organic matter (OM) and bitumen, which are main sorbents, and concentrators of noble metals in stratiform deposits of Carlin type. This enables to make a conclusion about the existence of commercial concentrations of gold and palladium in the sediments with a high amount of pelitic material and OM, such like shales, silts, silty sandstones, muddy sandstones, which constitute most of the Quaternary sections in the study fields. By the analogy with gold epithermal deposits in Nevada and Alberta, we can make a conclusion about the initial concentration of gold in pyrite in the South Caspian basin as well.

P-3403

## Unraveling lake level changes through bottom sediment of the Lake Urmia (NW Iran)

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### Abstract

Lake Urmia Lake (LU) is a low-lying area; its watershed is of  $\sim 50000$  km<sup>2</sup>. The climate of the region is cold semi-arid with average annual precipitation of 380 mm. Water and sediment are supplied to the LU through 40 rivers with 4 km<sup>3</sup> and 4 mil ton respectively. The LU itself is a shallow water brine basin. Its water depth has changed from maximum 13 meters to a few meters during instrumental measurement time. The surface area fluctuated between 2000 and 6000 km<sup>2</sup>. The last lake level drop happened during the past two decades.

A total of 12 cores have been taken with maximum penetration of 20 m; four were located in the area covered by water in the extreme low stand, 8 others were excavated around the LU with average one meter depth. Two cores have been XRF scanned and *Artemia* counted along the cores sub-samples. Here we present preliminary results of two cores for unraveling past lake level impacts, they cover the last lake level fall.

Comparison of pair elements could highlight the role of detrital and chemical/biochemical material in the sediment composition. We identified several groups. The first, detrital fraction group, is represented by Si, K, Ti, Fe, Rb and Mn. This fraction is more abundant towards the bottom of core. The second group is carbonate/gypsum fractions shown by Ca and Sr. High intensity of Sr, probably displays aragonite content in the sediment. Some Ca peaks below 400 cm coincide with S peaks, suggesting gypsum occurrence. The third group possibly related to pore-water and salt, is shown with Cl and Br. The elements are more abundant at the shallower depth in the core. Cl, possibly related to salt, strongly dilutes other mineral such as detrital and carbonate phases at depth shallower than 400 cm. Below 400 cm, the carbonate/gypsum and detrital fractions are major phases and dilute each other. *Artemia* cyst has been counted along the core; in the top salt part of the core almost does not have any cyst. The cyst number in the muddy part varies from 20 to 800 per sample. Surface salt deposit encircled the LU since 2001 with rapid drop of the lake level. The salt deposits are unevenly distributed. In the northern part of the LU, it is  $\sim 3$ m thick; it decreases toward the south, with  $\sim 70$  cm in the middle part and to negligible amount on the southern shores adjacent to the river mouths. Detrital, chemical and biological components of the sediment that cover late Pleistocene and Holocene represent different lake level changes. However current salt deposition never discovered through sediment cores; that could be attributed to the both climate change/variation and intensive human interventions.

**P-3404**

## **Urmia Lake's Upper Quaternary Deposits Analysis - New Data and Interpretation**

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### **Abstract**

Urmia Lake, NW Iran, has been a focus for many geologists during the past years because of its critical condition. The condition is deeply rooted in considerable lowering of its water level in a relatively short time span, mainly caused by great decrease in the water inflow to Lake Urmia. Our French-Persian research group is one of the teams recently involved to study sedimentology, geophysics, hydrology, and hydrogeology of the lake for the purpose of paleo-environmental and paleo-climatic reconstruction for the Holocene time. Current study, as a part of that comprehensive project, focused on sediment analysis of the lake substrate and cores obtained from the upper parts of the lake deposits in order to indicate evidences of the lake level fluctuations.

Reconnaissance studies of many coastal areas of the lake have led to selection of the Golman-Khaneh district, at the vicinity of the city of Urmia, for coring and detailed sediment sampling. Seven sediment cores have been obtained from recently dried out parts of the lake in Golman-Khaneh. The core sediments (up to 12 m thick) are dated as 5.2 Kyr or younger. Detailed sediment analysis of the upper Quaternary deposits of the Golman-Khaneh area (based on field observations and laboratory studies) has been done. The sedimentary succession consists of great amounts of sand with intercalations of organic matter rich clayish/silty deposits, and some horizons of marl and marly clay. The upper (thin) part of the succession, which is exposed at the surface, comprises some 10 to 15 cm of well cemented hard crust of sandy carbonates. To investigate this hard crust in detail, some oriented samples were collected. Standard thin sections were prepared from those samples for petrographic and facies analyses. All of the rock constituents (allochems, cement, matrix, detrital grains and porosity) were determined. Classification and nomenclature of carbonates were on the basis of Dunham (1962). Identified facies were compared with standard facies from well known sedimentary environments (Flügel, 2004).

The mentioned studying processes have led to recognition of an oolitic carbonate hardground (beachrock) in the most recent parts of the basin. The beachrock unit covers a thick column of siliclastic deposits and generally overlies unconsolidated sands and muds. From facies analysis viewpoint, this hardground comprises sandy ooid grainstone and peloid (fecal pellet) grainstone facies. Occurrence of carbonate/mixed siliclastic-carbonate facies on the overwhelmingly siliclastic environment indicates reduction in sediment influx from the land and considerable lake level drop during the latest Holocene, which has finally led to the subaerial exposure of saline beach. Thinness of the carbonate strata in the studied columns is attributed to shortness of this period or some subsequent erosional phases. Available data suggest that the long term lake level changes responded mainly to climate oscillations.

P-3405

## **Abrupt climatic events during the Early and Middle Weichselian - the pollen record at the Dzierniakowo site, NE Poland**

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### **Abstract**

The response of Central Europe environment/vegetation to rapid global climate changes during the Last Glaciation, including Early Weichselian (MIS 5d-5a) and Middle Weichselian (MIS 4) was assessed by pollen and geochemical analyses, and by radiocarbon AMS dating of palaeolake sediments from the Dzierniakowo site, NE Poland. This record is the one of the longest Late Pleistocene sequences both in Poland and throughout Central Europe. The dominance of open communities and their considerable diversity were the most characteristic features of the vegetation during the first stadial of the Early Weichselian (MIS-5d). At that time, the lake in Dzierniakowo lay near the northern forest boundary. During the Brørup interstadial (MIS-5c), the expansion of birch forest, as the first response to the warming, was interrupted by a brief cold oscillation, after which birch woods returned, and then birch-pine forests developed. The northern forest boundary moved north of Dzierniakowo. Then, during the second stadial of the Early Weichselian (MIS-5b), tundra and cold steppe communities spread again. During Odderade interstadial (MIS-5a), after a brief birch phase the development of boreal pine forests took place. The boundary between Early and Middle Weichselian (MIS5a/MIS-4) was put above the Odderade interstadial. Within the Middle Weichselian (Pleniweichselian; MIS-4) part of the Dzierniakowo profile, which contains 13 local pollen assemblage zones, it has been assumed that increases in AP values correspond to climatic variation of interstadial rank, while falls in AP and increases in NAP correspond to periods of poorer climatic conditions, i.e. stadials. Seven stadials and seven interstadials were determined in the studied profile. However, low AP frequency, both during stadials and interstadials, shows that the lake in Dzierniakowo was situated outside the northern line of closed forest throughout the Pleniweichselian. The high degree of completeness of studied sequence allows its correlations both with Greenland ice cores and with sea-surface temperature records from the North Atlantic. Interstadials registered in the Dzierniakowo profile well correspond to 18-24 Greenland interstadials, while recorded here stadials, and cooling within the Brørup to 18-25 North Atlantic stadials. Cooling noted in the middle part of the pine phase (E7) of the Eemian Interglacial is equivalent of the 26 North Atlantic stadial, and warming at the very end of this phase is equivalent of the 25 Greenland interstadial.

P-3406

## Provenance of terrestrial materials and paleoenvironmental reconstruction in northwestern continental shelf of South China Sea

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### Abstract

The north-western continental shelf of South China Sea has deposited a series of terrestrial materials since the late Pleistocene, which has recorded the paleoenvironmental changes of the coastal areas during the glacial-interglacial periods. In this study, high-resolution pollen analysis has been utilized in the core ZBW with 100.65 m in this area. The main results have showed that the pollen assemblages of percentage and concentration has presented a significant zoning characteristic. When pollen concentration is low, the diversity of pollen assemblages is simple, mainly *Pinus* and *Quercus*, indicating the transport distance is further during this period, and the core site is far from the pollen source and estuary of rivers, mainly transported by wind and ocean currents, as a result, the sea level during this period is relatively higher. *Quercus* is a dominated species of evergreen trees in the South China, therefore, the pollen source in this period is mainly from the South China.

When pollen concentration is higher, the diversity of pollen assemblages is rich, and the lowland tropical pollen content increases significantly, indicating the transport distance is close, and core site is nearly with the estuary of rivers in the tropical areas. In addition, alpine trees as well as the deciduous broad-leaved trees has also increased significantly, meaning the pollen source is from the mountain as well. For example, there is Wuzhi Mountain in the nearby Hainan Island, and the island is close to the drilling location and belongs to the tropics. It is speculated that pollen deposition in this period is mostly from the barely shelf area in the lower sea level period as well as the Hainan Island.

According to the seismic data, there was formed a Hainan Delta during the transition period of MIS4-3 stage, and the pollen concentration has undergone a lowest-high-moderate process according with pollen zone 3-2, 4-1, 4-2. The source of pollen has also experienced a transition from further mainland to nearer delta frontier. During this period, the climate is relative warmer and humid according the pollen assemblages. Increasing discharge of rivers in the Hainan Island has brought amounts of sediments into the continental shelf to deposit. Therefore, there is a stable source of sedimentation from the Hainan Island to the near shelf in the MIS3 stage and eventually form a delta.

**P-3407**

## **Heinrich Event Instability as an Example of Self Organized Criticality**

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### **Abstract**

We investigate the possibility that Heinrich event one (H1), which occurred during the most recent glacial-interglacial transition, may be an example of the phenomenon known as Self-Organized Criticality (SOC), in which a dynamical system has a critical point as an attractor. Heinrich event instabilities were responsible for triggering the Dansgaard-Oeschger mode of climate variability that dominated such variability during Marine Isotope Stage 3 of the last glaciation cycle (Peltier and Vettoretti, GRL, 2014). The most recent Heinrich event (H1) was similarly responsible for the related Bolling-Allerod warming transition. In our model, the instability is triggered and thereafter continuously forced by the tides until the ice loss proceeds up the strait to Nottingham Island or beyond over a period from 500 to 1000 years. We find that the amplitude of the dominant M2 semi-diurnal tide reaches its maximum when Hudson Strait is filled with grounded ice that extended to the shelf break, and it is important to note that following H1, tidal amplitude falls precipitously throughout the North Atlantic. It is equally important that during the instability an extremum of tidal amplitude tracks the retreat of the grounding line up the strait. As the strait deglaciates, the up strait paleobathymetry begins to rebound due to Glacial Isostatic Adjustment until the ice stream stabilizes and reforms. At this point, the resonance in the North Atlantic is re-established, M2 reaches a maximum and the conditions for a subsequent Heinrich event are created. For the purpose of this investigation, we have employed a discontinuous Galerkin method to solve the shallow water equations on the sphere using a non-uniform icosahedral grid. The model was fully described in Salehipour, Stuhne and Peltier (OCMOD, 2012) where it was benchmarked against the standard aquaplanet suite as well as modern altimetric observations of the main tidal constituents.

**P-3408**

## **Heinrich events recorded in annually laminated sediments in Maar Lake Sihailongwan, northeastern China**

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### **Abstract**

Heinrich events are widely observed in North Atlantic marine sediments cores, ice cores, loess and Chinese caves, however, few paleo-temperature time series extend to these events. Here, we present a branched glycerol dialkyl glycerol tetraether (GDGTs) based temperature reconstruction from annually laminated sediments in Maar Lake Sihailongwan, northeastern China. The reconstruction was weighted towards the warm-season (April to October) when the lake is ice-free. The branched GDGTs-based temperature suggested the ice sheet collapses were coupled with the atmospheric summer temperatures.

The warm season temperatures in Sihailongwan northeastern of China varied between 10.8°C and 16.2°C during 50-8.7 ka. Our records mentioned five obvious Heinrich events (H5-H1) which are consistent with ice core  $\delta^{18}\text{O}$  records at about 46.0 ka (12.8°C), 39.4 ka (12.3°C), 31.2 ka (13.2°C), 23.1 ka (11.8°C) and 15.8 ka (11.9°C), respectively. The most rapid and biggest temperature decrease occurred in the YD and H1 events, however, H2-H5 showed a slight temperature drop, which was different slightly with East Asian Summer Monsoon signals in the stalagmite  $\delta^{18}\text{O}$  records. Our brGDGTs records suggest that the climate in northeast China were impacted by the ice sheet collapse in North Atlantic, while the warm season temperature and EASM intensity exhibited deviations in Heinrich events.

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P-3409

## Evolution of the Cantabrian Mountains maritime glaciers during the latest Heinrich Stadials and coupled response with the Atlantic thermohaline circulation

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### Abstract

Ice sheet melting during the Last Glacial Termination or Termination-I triggered important changes in thermohaline circulation which caused changes in atmospheric circulation and seasonality. The comparisons made between marine and terrestrial records in the Northern Hemisphere suggest synchronous but heterogeneous responses of both environments in Southern Europe during Heinrich Stadial 1/Oldest Dryas (HS1/OD). Focusing on the Iberian Margin, which is under the direct influence of the North Atlantic Drift current, vegetation variations recorded in core MD03-2697 indicate a climate signal during HS1/OD event with three distinctive phases: extremely cold/relatively wet (HS1-a), cool/dry (HS1-b), and relatively warmer/increasing precipitation (HS1-c) (Naughton et al., 2016).

Here we focus on reconstructing the evolution of maritime mountain glaciers in the Cantabrian Mountains of Northern Spain (43°N). This deglaciated mountain chain reaches elevations of up to 2648 m a.s.l. running parallel to the Cantabrian Coastline, westward of the Pyrenees and all along the northern margin of the Iberian Peninsula. Its short distance to the North Atlantic Ocean, less than 100 km, makes it ideal to study the coupled response between marine and terrestrial archives during the latest Heinrich Events (HS1 and HS0).

Our previous studies based on <sup>10</sup>Be surface exposure dating of 20 boulders from moraines and rock glaciers in the Monasterio valley revealed progressive recession and thinning of glaciers between 18.1 ka (glacier front at 1150 m) and 16.7 ka (glacier front at 1170 m), during HS1a and HS1-b (Rodríguez-Rodríguez et al., 2017). The last stagnation of the glacier front ended at a minimum age of 14 ka (marked by a cirque moraine located at 1540 m), during the Oldest Dryas (OD). The stagnation age obtained at the foot of a rock glacier nested within the OD moraine suggests that the Monasterio valley was fully deglaciated during the Allerød. The Monasterio valley lacks a glacier response to the HS0 event (also known as Younger Dryas) probably due to the modest elevation of the source area (2022 m a.s.l.). Here we present 64 new <sup>10</sup>Be and <sup>36</sup>Cl surface exposure ages from boulders taken from similar landforms sampled in nearby valleys. Landforms selected are distributed at similar (1560 m) to higher elevations (up to 2100 m) than those from the Monasterio valley in order to better reconstruct how glaciers responded to the HS1 and HS0 events in the Cantabrian Mountains, and what the distribution of equilibrium lines was with regards to paleoclimate conditions.

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**P-3410**

## **Geomorphological and geoarchaeological impacts of Heinrich stadials in central Portugal**

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### **Abstract**

Due to its position at the southwestern extremity of Europe, Portugal was strongly influenced by abrupt climatic reversals during Heinrich events of the Late Pleistocene. Proxy records from the Portuguese margin demonstrate large environmental responses to Heinrich stadials (HS) including cold/arid climate, reduced sea surface temperature, changes in upwelling intensity, and reduced forest cover. Records from caves in the Estremadura region of central Portugal support these observations, with evidence for reduced soil moisture and chemical weathering during HS, in some cases leading to hiatuses in speleothem growth. Climate fluctuations (including HS and D-O cycles) and their ecological impacts have also been implicated as triggers of Paleolithic cultural transitions in Iberia, with various authors linking these to the start or end dates of the Mousterian, Gravettian, Solutrean, and Magdalenian phases.

Our coastal geoarchaeological survey in central Portugal presents numerous examples of HS-driven geomorphic change. The evidence comes from stabilized dunes, fluvial terraces, deep valley fills, and eroding coastal bluffs in the Estremadura region surrounding Nazaré. Intense landscape instability in this area between 11-70 ka is indicated by sandy aeolian, fluvial, and colluvial deposits with OSL ages that cluster around HS1, HS2, HS3, HS4, and HS6. The cessation of extreme climate fluctuations at the end of the Pleistocene corresponded with a period of prolonged forest expansion and an overall reduction in geomorphic activity, including transitions from braided to meandering river channels in the study area. The Early and Middle Holocene were instead marked by geomorphic stability and pedogenesis, as evidenced by a well-developed spodosol soil profile that is found today on undisturbed parts of the landscape. In places, the spodosol is buried beneath Late Holocene aeolian and fluvial deposits associated with anthropogenic landscape disturbance. Surface and buried exposures of this paleosol are valuable indicators of Pleistocene-aged geomorphic surfaces that often preserve Paleolithic archaeological evidence.

These observations are consistent with a biogeomorphic response model first proposed for fluvial contexts by Knox (1972). The model suggests short-lived episodes of severe hillslope erosion and sediment yield after a transition from arid to humid climate as vegetation cover adjusts to the new climatic regime. We argue that such conditions occurred at the end of each HS in our study area, and that the concept may be more broadly applicable to unglaciated extratropical regions. Given the adjustment time required for forest expansion and soil formation following an arid phase, the occurrence of HS at 5000-7000 yr intervals (along with higher frequency D-O cycles) during the Late Pleistocene may have precluded formation of mature soils and favored geomorphic instability throughout MIS 2, 3, and 4.

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P-3411

## The millennial-scale climatic variability in central Asia during last glacial

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### Abstract

In the North Atlantic and the surrounding region, more than 20 rapid millennial-scale climatic fluctuations occurred during the last glacial-interglacial cycle (Dansgaard *et al.* 1993). These oscillations, known as Dansgaard-Oeschger (D-O) and H-events. Simulate studies suggest that the millennial-scale climatic signals can spread to a wide area by atmospheric and oceanic circulations. However, it lacks of such record in central Asia which is climatically characterized by arid and sensitive to climate change.

Here, we present the record of millennial-scale fluctuations from loess deposits in Tajikistan in central Asia. The frequency dependent magnetic susceptibility ( $c_{fd}$ , a moisture proxy) record in the Darai Kalon (DK) section (38°23'4"N, 69°50'1"N, 1561 m) can be readily matched with the NGRIP oxygen isotope curve, especially during the interval from 60-30 ka in which typical D-O cycles and H-events are well developed (Fig. 1). Most of the long-lasting D-O cycles in Greenland, e.g., D-O 8, 12, and 14, are also evident in the Tajikistan loess. Similarly, the short-duration D-O cycles in Greenland, e.g., D-O 6, 7, 9, 10 cycles, have their damped counterparts in the Tajikistan loess. However, some significant differences in detail can be observed between the two records. The most distinct difference occurs in the case of last D-O cycle, which includes the well-documented Oldest Dryas (OD or H1), Bølling-Allerød (BA), and Younger Dryas (YD or H0) events, which are not clearly present in the  $c_{fd}$  curve.

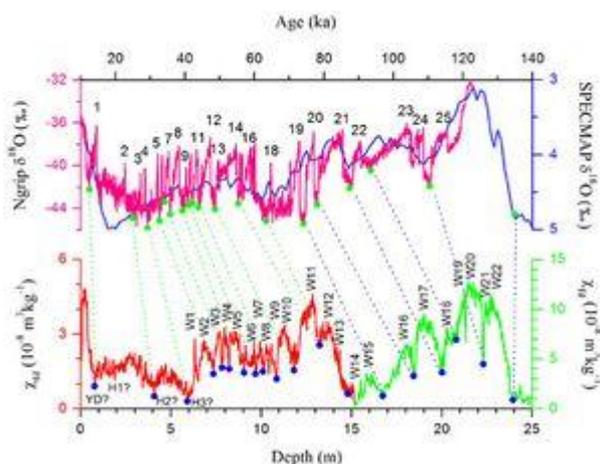


Figure 1

The magnetic results support that the climate is humid in interstadials and dry in stadials in central Asia. And, the variation of humidity is much more remarkable in central Asia than in Chinese Loess Plateau which is climatically dominated by Asian Monsoon. It exhibits the humidity in central Asia is sensitive to millennial-scale climate oscillations during last glacial. The comparison results further indicate propagations of millennial-scale climatic signals were different between these two regions. We assumed the former one is the Westerlier which can directly

and effectively force the millennial-scale climatic variability in central Asia, and latter one is thermohaline circulation and Asian Monsoon, the complex propagation weakened the millennial-scale climatic variability Northern China.

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**Figure 1.** Correlation of millennial-scale climate variations recorded by the DK section (red curves) and the NGRIP Greenland ice core (pink curve) (NGRIP members, 2004) and SPECMAP curve (blue) (Lisiecki & Raymo, 2005). Numbers (i.e., 1, 2, 3) indicate D-O events, and W1, W2, W3, etc., indicate humid events recorded by the DK section; H-events are indicated by i.e. H1, H2.

**P-3412**

## **Abrupt changes in the hydrologic cycle of the Neotropics during Greenland stadials**

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### **Abstract**

A seesaw existed in precipitation between the northern and southern Neotropics during the last glacial period related to the migration of the Intertropical Convergence Zone in response to changes in North Atlantic heat transport. During stadials, and especially those containing Heinrich events, aridity increased in the northern Neotropics at the same time as rainfall increased in the southern Neotropics. Lake Peten-Itza at 17°N in northern Guatemala contains an exceptional record of millennial and centennial climate variability during the last glacial period that is marked by alternating clay and gypsum deposits, reflecting relatively wet interstadial and dry stadial conditions, respectively. New high-resolution XRF data from Peten Itza sediment cores reveal a complex structure during each stadial period when rapidly changing hydrologic conditions occurred on centennial time scales. The distinct patterns of centennial variations within each of the stadial stages may provide a means for locating the short-lived Heinrich events within the longer period of stadial conditions and for correlating records and refining age models. As a case study, we will report on internal variations in temperature and rainfall/humidity that occurred during Heinrich stadial 1, which includes Heinrich Event 1.

**P-3413**

## **Into the next dimension – coupling GPR, hydroclimate proxies and pollen to understand lacustrine records at Swallow Lagoon, Queensland, Australia**

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### **Abstract**

Lakes have the potential to hold long records of climate. Previous studies have used various techniques to access these records, primarily through coring the inferred deepest part of the sediment sequence. Cores have been analyzed for microfossils (pollen, diatoms, chironomids) as proxies for hydroclimate, temperature and ecological structure. Water levels have been inferred from macrofossils of plants that have specific depth ranges. This work is time consuming and may not yield desired results. Ground penetrating radar (GPR) has been employed in lacustrine situations to evaluate sediment thickness and palaeoshorelines. The capacity of GPR to image subsurface architecture is directly applicable to accessing climate records from lakes and can substantially augment the information gained from sediment records.

North Stradbroke Island, the world's second largest sand island, is home to numerous lakes and wetlands. Previous and ongoing studies have used these environments to reconstruct the climate from pollen and stable isotopes at several sites that date to the LGM and one site that extends to the previous interglacial.

New work employing high-definition, high-resolution digital dual frequency (160 and 670 MHz) GPR equipment has recently been completed as a test case at Swallow Lagoon (SL). SL is a high-altitude (~150 m above sea level), perched terminal lake within a small interdune depression. GPR lines were collected around the lake on the terrestrial margins and over the lake using an inflatable raft. As a part of previous research to elucidate the climate of NSI, SL was cored and a basal radiocarbon date of 11.5 kyBP was recovered from 4.8 m below the lake floor above a sand-rich layer (Tibby et al., 2017). The core site was imaged on several GPR crossings.

GPR imagery shows there may be twice as much sediment accumulated in the basin as has been recovered previously and numerous submerged and emergent shorelines. The dataset allows for correlation of lake levels with core chronology. The terrestrial GPR lines revealed palaeoshorelines at elevations of 5 m above present lake level with numerous palaeoshoreline complexes buried beneath the present regressive surface.

Further analysis of GPR data using techniques of sequence stratigraphy will allow for an understanding of previous lake levels on a relative time scale. GPR data will be used to target key horizons and units to provide detailed chronology for lake levels. The result will ultimately be a lake level curve that can be used to infer regional climate and in combination with planned lake hydrological modelling, these data have the potential to provide quantitative hydroclimate reconstructions from the Holocene and beyond.

Tibby, et al. 2017. Persistence of Wetlands on North Stradbroke Island (south-east Queensland, Australia) during the last glacial cycle: implications for Quaternary science and biogeography. *JQS* 32(6) 770-781

**P-3414**

## **Towards a reconstruction of high-resolution environmental and sedimentary records spanning the last glacial cycles from Orakei Maar, Northern New Zealand.**

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### **Abstract**

Precise linkage of thin-section observations and high-resolution elemental data produced by micro-XRF scanning of corresponding epoxy resin-impregnated sediment slabs can significantly improve our ability to detect abrupt shifts in climatic forcing, as well as identification of short to long-term changes in seasonality. Located within the Auckland Volcanic Field, Orakei Maar's well-laminated and continuous lake sediments are very suitable for the application of this integrative approach in New Zealand. Compared to its northern counterpart, long, high-resolution mid-latitude terrestrial paleoclimate archives from the Southern Hemisphere are few and suffer from age controversies. Consequently, we propose that our ongoing work will substantially reduce the existing gap in paleoclimate data from the New Zealand sector of the Southern Hemisphere spanning the last glacial cycle.

During a recent drilling campaign, ~73.5 m of mainly laminated lacustrine sediments were retrieved from Orakei Basin with nearly 100 % sediment recovery achieved with two overlapping sediment cores. The main objective of the present study is to apply the integrative approach of high-resolution micro-XRF scanning on impregnated Orakei Maar Lake sediments with observations made on corresponding thin-sections to thoroughly identify and examine micro-facies transitions. Using this approach, we can identify and document of shifts in environmental and climatic conditions, as well as short to long-term changes in seasonality at very high precision. Supplementary Laser Ablation-ICP-MS measurements carried out on the impregnated sediments allow precise calibration of the micro-XRF data time series. In addition, automated grain size analysis application 'RADIUS' (=Rapid Particle Analysis of digital images by ultra-high-resolution scanning), is being applied to establish an event stratigraphy, identified via sub-mm scale, aeolian dust records contained in the Orakei core. This supports the identification of phases with cooler and drier conditions that are either related to a shift of the Southern Westerly Winds over the last glacial cycle as well as sub-decadal alterations in the El-Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO).

**P-3415**

## **Palaeoenvironmental changes since the late Pleistocene revealed by ostracodes record to the east of Bangong Co, western Tibet**

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### **Abstract**

A 4.9 m section (BG-1), located 45 km to the east of Bangong Co, west Tibetan Plateau, provides a continuous climate records from the Late Pleistocene to the mid-Holocene, on the basis of ostracodes assemblages and shell trace elements. Results show five distinct climate changes in the east Bangong Co area from 23.4 to 4.9 ka based on U-series dating. It remained extremely cold till 13.0 ka due to the influence of LGM, as indicated by very few ostracodes and no snail occurring in this stage. After that, the temperature increased gradually meanwhile the paleolake (Dagutuqiong) enlarged with well developed ostracodes, though the dominance of cold water species and low Mg/Ca of ostracodes shells indicate the climate was still cool. More glacier melting waters in relatively warming climate into the lake, as suggested by the high U/Ca and Mn/Ca of ostracodes shells, led to a high lake level in this stage, which was also verified by the low Sr/Ca values. The warming climate was interrupted by a transient extreme event during 11.5-11.1 ka, which was attributed to the Younger Dryas event. It was characterized by rapid drop of temperature at the beginning and slow warming thereafter, with little lake level variations. The temperature was recovered and the climate remained cool and wet till 10.3 ka. In 10.3-6.23 ka stage, it was still cool as indicated by low Mg/Ca of ostracodes shells. However, it dried substantially during this stage with saline water ostracodes dominating at the beginning and then disappearing in the middle due to higher salinity of lake water. At the end of this stage, few saline water ostracodes appeared again suggesting that the climate become wet again. It was a transitional stage toward a warm and wet climate. The 6.23-5.25 ka stage was the optimum period throughout the section. The climate was warm and wet and the paleolake enlarged. Thereafter, the temperature continued to rise, resulting in an increasing evaporation and extremely dry climate, as indicated by sharply high Mg/Ca and Sr/Ca of ostracodes shells during 5.25-4.9 ka. The paleolake shrank rapidly and dried up at some time after 4.9 ka. The extremely dry climate after 5.25 ka, especially after 4.9, was responded by the records from other lakes in west Tibetan Plateau, suggesting a large scale drought event. The eastern Bangong Co likely closed and separated from the Dagutuqiong paleolake during this stage.

P-3416

## The paleoclimate recorded by phytolith in Anguli-Nuur Lake since the mid-late Holocene

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### Abstract

Bashang area of Hebei Province, Northeastern of China, is located in the East Asian monsoon-margin region and the ecotone between agriculture and animal husbandry. East Asian monsoon variability significantly affects the development of human civilization within its area of influence. In order to reconstruct the climate changes in Bashang area and understand the interactions between past climate and human civilization, a continuous 120-cm sediment profile was recovered from Anguli-Nuur Lake based on phytolith and pollen analysis. The results showed that, the climate in this region is gradually becoming cold and dry during the last 5000 years, which is related to the weakening of East Asian monsoon produced by gradually of solar radiation. However, the climate is relative wet during the periods of 5030~3074 cal. a BP. On the centennial scale, Anguli-Nuur has experienced seven obvious cold and dry events, which occurred during ~4500 cal. a BP、 4100-3800 cal. a BP、 ~3500 cal. a BP、 ~3000cal. a BP、 ~2100 cal. a BP、 ~1100 cal. a BP和800-270 cal. a BP. The cold and dry events are consistent with weakening stage of the East Asian monsoon that is probably affected by high latitude climate and the solar activities. In this region, the development of human civilization is sensitive to climate change. Agriculture civilization is relatively developed during warm and humid stage, and grassland civilization appears during cool and arid stage.

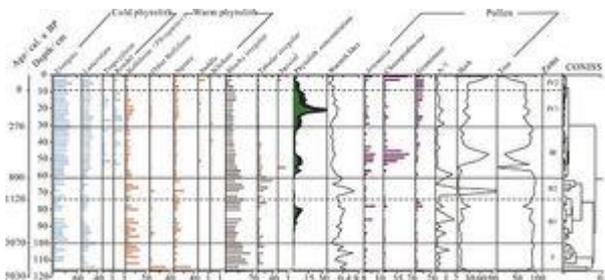


Fig. 1 Phytolith and pollen diagram (%), warmth index in the Anguli-Nuur Lake profile

**P-3417**

## **Influences on a Central Asian mountain lake systems: insights from the laminated (varved) record of Lake Chatyr Kul (Kyrgyz Republic)**

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### **Abstract**

Lake Chatyr Kul is located in arid central Asia at 3530 m a.s.l. in the Tian Shan/ South Kyrgyzstan. Present day climate conditions are controlled by the Westerlies and the Siberian High. To disentangle processes and consequences of changes in dominating atmospheric circulation patterns on a freshwater system throughout the Holocene, high resolution records are needed.

We present a sediment record of ~6.25 m length, which is the first in this region showing seasonal laminated sediments almost throughout the entire late Pleistocene-Holocene. Sediment cores were retrieved in 2012 and 2017 with piston corers from ~20 m water depth. Two independent dating methods have been applied: (1) Varve counting between 63 and 623.5 cm composite depth with a mean counting uncertainty of ca 3.8% and (2) Radiocarbon dating including 22 AMS <sup>14</sup>C ages from wood, other plant remains, *Daphnia*, TOC Bulk and *Ruppia maritima* seeds. BACON has been applied for reservoir corrections. The floating varve chronology has been anchored to the absolute time scale at 990 cal a BP as adopted from modelled radiocarbon BACON ages. The resulting ages for the sediment record base for the varve chronology (~12,230 cal a BP) and the radiocarbon age model (~12,700 cal a BP) are within uncertainties in good agreement. Based on <sup>137</sup>Cs, <sup>241</sup>Am and <sup>210</sup>Pb profiles, the uppermost 20 cm homogeneous sediments were radiometric dated.

The late Pleistocene deposits contain well preserved clastic-pyrite varves with sporadically occurring aragonite and vivianite sublayers. The Early to Mid-Holocene comprises changing intercalations of clastic-organic, calcite-clastic and diatom varves, with decreasing varve qualities until ~2,000 cal a BP and mean varve thickness (mvt) of 0.39 mm/a. The Late Holocene exhibits again well preserved clastic-organic varves with highest mvt of 1.55 mm/a. Changing microfacies structures are accompanied by variations of varve thickness, species assemblages and of the proxy data ( $\mu$ XRF data of Ca/Ti and geochemical data of TOC,  $\delta^{15}\text{N}$ ,  $\delta^{18}\text{O}$ ) mainly mirroring changing intensities of erosional processes.

The synthesis of all available data documents highly variable environmental conditions with a prominent transitional change at ~4,300 cal a BP possibly related to a declining Indian Monsoon influence. Distinct periodicities in varve microfacies, mvt and Ca/Ti ratios of ca 100 years between 11,700 - 8,700 cal a BP, and 200 years in the period from 8,700 - 4,300 cal a BP possibly reflect De Vries solar cycles. The abrupt change from organic-clastic varves (0.39 mm/a) to clastic varves (1.55 mm/a) at 2,000 cal a BP suggests a combined control on depositional patterns by climate and human impact. Comparison with other regional records (Lake Son Kul, Uluu Too Cave Stalagmite) suggests a dominance of westerly influence for the mid-late Holocene.

This is a contribution to the BMBF-funded project CAHOL.

P-3418

## Past land-use in Russia Karelia: The pollen record of Lake Lavijärvi

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### Abstract

Paleoclimate and paleolimnology studies done on the Northern boreal zone remain scarce (Alenius et al., 2013). As this area covers an important body of water, Lake Ladoga, the need to understand the vegetation and land-use dynamics of this region has advanced. Here, based on 21 pollen and spore types identified in a window of ~3000 years, the results of vegetation, land-use reconstruction of Lake Lavijärvi located in western Karelian Russia are presented. These data helped to understand major land-use shifts and climate pattern of the area. The pollen diagram of Lavijärvi was divided into 4 zones determined by the main vegetation changes: Zone A (750 BC to 550 AD) representing a consistent arboreal forest; Zone B (550 to 1300 AD) demonstrating a transition from forest to forest-steppe vegetation; Zone C (1300 to 1940 AD) illustrating fluctuations of vegetation patterns; and finally, Zone D (1940 to 2016 AD) showing the recent post-war relaxation of land-use. *Pinus*, *Picea*, *Betula*, *Alnus*, *Chenopodiaceae* and *Poaceae* are among the major pollen types. Throughout the core changes in vegetation patterns and slash and burn cultivation are well represented. The Medieval Warm Period and the Little Ice Age are also moderately present in the pollen frequency and variety. The anthropogenic effects of farming are displayed by large abundances of *Poaceae* and *Cerealia* pollen especially in Zone C, eutrophication of the lake and the absence of *Picea* pollen due to fires. Today, the lake's surrounding is mainly pasture with arable farming taking place moderately. The climate of Lavijärvi appeared to have had long winters with excessive snow cover especially in the early stages (2600 to 1000 cal BP or 650 BC to 950 AD) and a moderately dry temperature due to *Chenopodiaceae* growth though maintaining enough soil moisture for cultivated plants. Lake Lavijärvi is a good example of shifting from dense arboreal forest to steppe-like vegetation and finally pasture throughout a window of 3000 years.





figures were drawn relatively.

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P-3419

## A multiple biotic proxy approach to decode Holocene climatic variability from Central Ganga Plains, India

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### Abstract

The fertile and densely populated floodplains of river Ganga host many oxbows and meander cut-offs, offering the possibility of obtaining high-resolution paleoclimatic data. Few of these lakes have previously been studied for their climatic history but are constrained by a lack of robust chronology. To gain insights on the role of local and/or regional climate forcings, an oxbow lake in the Central Ganga Plains was studied using multiple biotic proxies to obtain a well resolved Holocene paleoclimatic record. Broadly, four climatic phases (Phase 1 to 4) were identified. Phase 1 (~13.0 to 10.6 kyr BP) shows relatively higher net rate of sediment accumulation, which declines by 28% in phase 2 (10.6 to 7.8kyr BP). Only a slightly lower net rate of sediment accumulation (23-24%) was observed in phases 3 (7.8 to 2.9kyr BP) and 4 (2.9 to 1.1 kyr BP). This indicates a high fluvial input during phase 1 that drastically reduced in Phase 2, and finally the sediment succession indicates a lower sediment input due to the formation of the ox-bow lake in phases 3 and 4.

Palynological results show a drastic increase in arboreal pollen (AP) by 60% in phase 3 as compared to 9.9%, 21.1% and 7.9% in phases 1, 2 and 4, respectively. The ratio of AP and NAP (non-arboreal pollen) is therefore, 0.07, 0.5, 0.2 and 0.8 in phases 1-4, respectively. Thus, the stabilization of the lake ecosystem and nearby floodplain resulted in the establishment of forest accompanied by conducive warm and humid environment with moderate seasonality during phase 3. The aquatic pollens show an ascending trend from phase 1 to 4. Relatively, the maximum was observed in phase 4 (60%) with high percentage of prostrate running *Polygonum serrulatum* suggesting highly disturbed shallow water body. Contrastingly, phase 2 shows moderate percentages of *Myriophyllum* and *Nymphaea* pollen suggesting relatively deeper water column in the lake. Phases 1 and 2 show increased pollen of *Typha* indicating swampy periphery of the water body. The highest percentage of planktonic and benthic siliceous diatoms and freshwater sponge spicules were recorded in phase 3 indicating warm and humid climate with high gammoscleres of sponge spicules that are formed by reproductive bodies only during water scarcity. During phase 4 an abrupt decrease in diatoms and abundance of megascleres/ microscleres indicate permanent water and intense illumination in water column. It is concluded that decrease in vegetation, bilobed graminaceous phytoliths and diatoms along with the chlorophyllous algal content indicate an overall transition from wetter to drier climatic conditions since 13kyr BP; also the local fluvial dynamics in the Ganga Plain played a major role in the development of the succession of the lake ecosystem.

P-3420

## Late Pleistocene (~20-60 ka) hydroclimatic variabilities in arid north-west China: geochemical evidence in Balikun Lake, eastern Tianshan

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### Abstract

Reconstructing the environmental and hydrological response to millennial-scale fluctuations of mid-latitude, climate-sensitive areas, such as the arid areas of Central Asia (CA), is crucial to understand Late Pleistocene climate in terrestrial inland regions. We use sedimentologic and geochemical analyses of a sediment core (BLK11A) obtained from Balikun Lake, eastern Tianshan Mts., to elucidate variations in sedimentation, water-chemistry and watershed weathering intensity of the Late Pleistocene interval. The record documents high-frequency oscillations and alternating hydrological patterns in this region on (multi-) millennial timescales. Balikun Lake changes from nearly fresh to brackish and finally to hypersaline, with evaporate minerals varying from carbonate to sulfate and finally halite. Specifically, the stadials (MIS4 and MIS2) are characteristic of low lake level and weak chemical weathering, reflected by coarse grain size and high Rb/Sr value, respectively. The onset of MIS3 at Balikun Lake is featured by abrupt increase in carbonate and chemical weathering intensity, suggesting warm and wet climate conditions. This optimal episode facilitated regional vegetation and bio-productivity. Halite sedimentation took place from the middle to late MIS3, and it indicates a gradual drying trend that reduced in the lake area and vegetation cover, as well as weakened of chemical weathering in the watershed. These new interpretations challenge the idea of climate amelioration with highest lake level and wettest conditions prevailed in most areas of north-west China during the late MIS3, indicating a possible westerlies-dominated Late Pleistocene climate in Xingjiang area.

**P-3421**

## **Sedimentation dynamics in multi-millennial lacustrine record: varves and slumps in Lake Szurpiły (NE Poland)**

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### **Abstract**

Annually laminated (varved) sediments and inserted mass-movement deposits of Lake Szurpiły track sedimentation dynamics since the Late Glacial and relate to natural and anthropogenic forcing. The chronology of this study is based on varves for the last 8400 years and extends back to the Allerød applying radiocarbon dating and pollen stratigraphy. In addition, the age-depth model was validated by cryptotephra findings. In annually laminated sections before 850 BC, when anthropogenic influence was limited. Gleissberg (88-yr) and Suess (208-yr) solar cycles are detectable in varve thickness data. Additionally, 22-yr and 11-yr sunspot cycles are detectable in the light-to-dark laminae thickness-ratio. Decreases in varve thickness between AD 1500-1800 correspond to Spörer and Maunder solar minima and reflect climatic conditions with reduced human impact during the Little Ice Age. In-between finely laminated sections, different mass-movement deposits were identified including one major turbidite and 85 minor slumps. In the Late Glacial section, highly minerogenic event layers represent increased runoff related to a poor vegetation cover. The major turbidite of  $6400 \pm 100$  BC could have been triggered by an earthquake or very late thawing of permafrost and related transformations of groundwater circulation. Slumps with silt caps indicate humid conditions during the Atlantic. Human activities, as well as flood events or snow melting could have been responsible for slump events since the Subboreal. Despite regional seismic inactivity, deformation of varves could have been caused by an earthquake observed in AD 1803. With the analysed multi-millennial sediment record we demonstrate the complexity of events recorded by lacustrine sediments.

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P-3422

## Is the present the key to the past? Diatom-based lake-level reconstruction of Lake Kinneret (Israel)

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### Abstract

Uniformitarianism is a key concept in palaeoecological research. Based on the assumption that ecological preferences remain constant, a better understanding of the modern lake environment can strongly improve palaeoenvironmental interpretation derived from analysis of fossil datasets preserved in lake sediment archives. In palaeolimnology, the analysis of modern diatom communities and their subfossil death assemblages is a good example. Diatoms (single-celled siliceous algae) are highly useful palaeoenvironmental indicators due to their specific ecological preferences and the long-term preservation of their silica valves in lake sediments.

Meso-eutrophic Lake Kinneret is the largest natural freshwater body in Israel and, by water extraction, a major source of drinking and irrigation water for the region. Although the lake is currently the subject of extensive aquatic monitoring programmes, knowledge of the spatial distribution and habitat preferences of modern diatom assemblages is rather limited.

Twenty-eight surface sediment samples were collected from Lake Kinneret, covering a range of different water depths and habitat areas, to investigate the composition of diatom death assemblages and their distribution within the modern lake system. A quantitative diatom-inferred water-depth model based on simple linear regression between modern diatom assemblages and water depth is presented in this study, as a tool for semi-quantitative calibration of Holocene lake-level change. The new calibrated lake-level reconstruction fits well to palaeo-shoreline measurements and appears to display greater sensitivity to minor lake-level variation than a simple Plankton/Benthos-ratio approach. A close similarity between Lake Kinneret and the Dead Sea is observable, indicating that they were subject to similar regional fluctuations in moisture availability. Our results confirm that the investigation of modern diatom death assemblages can be helpful to understand and calibrate the limnological history of lakes.

P-3423

## Estimated chronology in a continuous lake sediment sequence from Kai Iwi Lake, New Zealand using MIS boundaries as age markers

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### Abstract

It is a common problem in paleoclimate research to have long sediment sequences that are difficult to date due to the ~50 ka age limitation of <sup>14</sup>C dating. A possible solution where other laboratory methods are not available is to approximate the chronology using Marine Isotope Stages (MIS) as age markers via robust interpretation of environmental proxy data. A 9.3 m lake sediment core obtained from dune impounded Kai Iwi Lake in Northland, New Zealand provides a nearly continuous record of environmental changes in multi-proxy and  $\mu$ -XRF data estimated to MIS 5d. Chronology for the upper 3 m of the core is well established until ca. 45 ka via <sup>210</sup>Pb, <sup>14</sup>C and tephrochronology. To identify patterns in the  $\mu$ -XRF proxy data associated with environmental change, principal component analysis (PCA) and cluster analysis were performed on a data set including nine common elements in lake sediments (P, S, Fe, Ti, K, Ca, Si, Al, and Zr) and six element ratios (Sr/Ca, Br/Cl, Mn/Fe, (Fe+Ti)/K, Ti/K, and Inc/coh). PCA indicates that Component 1 represents the detrital fraction, and Component 2 is associated with nutrient influx and biological productivity. The elements and ratios in the Component 2  $\mu$ -XRF variables also indicate a wind component to the data as P, Mn/Fe, Fe, Ca and S are also indicators of anoxic/oxic conditions as a result of wind driven mixing in the water column. The cool periods of MIS 2 and 4 are well-defined in the  $\mu$ -XRF data as having increased detrital influx (Ti, K, Si, Al), less thermal stratification in the water column (P), and more sea spray (Br/Cl, S). Warm periods are identified by high P variability, less detrital influx and increased organic productivity (Inc/coh). MIS 5b is estimated from similar changes in the data as MIS 2 and 4, however the difference between MIS 5c and 5d is not as evident and so the alignment of the cluster analysis of the  $\mu$ -XRF proxy data was used as the definition of this boundary. These environmental interpretations define a framework of age markers from the MIS boundary ages and allow an age/depth profile estimated from a sediment accumulation rate to be calculated in addition to the age profile established via <sup>210</sup>Pb, <sup>14</sup>C and tephrochronology. Since MIS 2 has a slower accumulation rate in the Kai Iwi Lake chronology and the proxy data profile for MIS 2 is similar to MIS 4, it may also be possible to further refine the estimated chronology for MIS 4 by adjusting the accumulation rate for that section of the core.

**P-3424**

## **Mineralogical record for climatic change in Lake Qinghai sediments since the marine isotope stage 2**

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### **Abstract**

Lake Qinghai, the largest inland lake on the northeastern part of the Tibetan Plateau, lies in the critical semi-arid zone between the eastern humid and the western arid areas, and is extremely sensitive to climatic changes. A 18.5m long drilling core (1Fs) from the depo-center of southwest-sub basin of Lake Qinghai provides new information of the climatic dynamics of Asian semi-arid areas since 32ka BP. We applied X-Ray diffraction analysis to determine the content of quartz, aragonite, dolomite and calcite. Based on the characteristics of mineral assemblages, together with sedimentary facies, we divided the 18.5m long core into three distinctive stages at the depth of 11.65m and 4.8m indicating three climate stages. The analysis results indicate that the 18.5m long core recorded three paleoclimate stages: Cold-dry period (32-25.5 ka BP), tempered cold-dry period (25.5-11.6 ka BP), and warm-humid period (11.6-0 ka BP), and the third period can be further divided into three periods: Climatic oscillation period, The Holocene Climatic Optimum and cool-dry period. Quartz content is correlated well with humid and dry climate, high quartz content reflects dry climate, while low content reflects humid climate. During last glacial period, 1F core deposited little aragonite, from the time of deglaciation, aragonite deposited steadily and reach the top value during Holocene. High aragonite content reflects warm-humid climate, while low aragonite content reflects cold-dry climate, and can be reasonably correlated with delta  $^{18}\text{O}$  record of stalagmite in Dongge cave. Quartz and aragonite assemblages may well represent paleoclimate variation in the lake Qinghai.

P-3425

## Late Oligocene Warming Event on the Tibetan Plateau: evidence from a sporopollen record

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### Abstract

A large number of studies have been carried out on the causes and mechanisms of events occurred in the Quaternary, and research on events prior to the Quaternary has been relatively low. Especially, few terrestrial records have yet been employed to verify the *Late Oligocene Warming Event* and investigate its associated driving forces. The Nima Basin, located in the central Tibetan Plateau contains thick Oligocene sediments, allowing its ecological record to be used as verification of the LOWE. Here, we used the reconstructed vegetation record from the Nima basin in the 1,100 m thick DZC section (27.5-22.4 Ma). Sporopollen analysis revealed that the dominant taxa throughout the whole section were conifers (over 85%), including *Piceapollis*, *Pinuspollenites* and *Abietpollenites*. One notable feature is that the broadleaved trees (e.g., *Quercoidites*, *Meliaceoidites*) increased obviously (averaging from 0.9% to 6.6%, max 41.2%) after 25.6 Ma. This change could be interpreted as a response to late Oligocene global warming, which changed the forest line and corresponding plant species composition. The mean average precipitation of 400-850 mm and 800-1,000 mm, respectively inferred from the above vegetation types in the Nima Basin, both exceed the present 150 mm. It indicates that the LOW event accompanied the global warming.

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P-3426

## Fire history during the mid- to late Holocene based on black carbon records inferred from Jingpo Lake, Northeastern China

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### Abstract

Climate change is likely to alter wildfire regimes, but the significance of climate-driven factors in regional fire regimes over extended temporal scales is poorly understood. Comparison of the reconstructed fire dynamics from lake sediments with modern active fires may provide clues about the drivers of wildfire activities, and help us validate models of fire activity for both the past and the future. The results of black carbon (BC) indicates that the patterns in fire activity history observed in Jingpo Lake region during the mid- to late Holocene are consistent with the climate change inferred from paleoclimate proxies. Furthermore, both the BC content and BC mass sedimentation rate (BCMSR) display a close relationship with the percentage of herb pollen from the same sediment core, suggesting that regional vegetation type would be a factor controlling the intensity of fires. Low BC content and BCMSR level during the period of ~5100–3500 cal. yr BP imply low fire episodes and are consistent with wet climate conditions. Limited fuel availability (limited herbs content) inferred from the pollen data also likely reduced intensity of fires. During the period of ~3500–2000 cal. yr BP, the large increase in BC content and BCMSR level indicates that the increased intensity of fires, and are consistent with the climate was cold and dry and more herbs vegetation covered the Jingpo Lake region. The subsequent dramatic changes in intensity of fires during the period of ~2000–150 cal. yr BP was consistent with climate change and also with changes in intensity of human activities. After ~150 cal. yr BP, BC content and BCMSR reach very high levels. The sources of black carbon during this period shift from biomass burning to a combination of biomass and fossil-fuel combustion products, partly reflecting the industrialization of China during the latter half of the 20th century. Moreover, a strong positive relationship is found between  $\delta^{13}\text{C}_{\text{BC}}$  data from surface soils in northeast China and temperature of the warmest month. The general features of the  $\delta^{13}\text{C}_{\text{BC}}$  values are generally consistent with inferred herbs content changes. Therefore, we conclude that the  $\delta^{13}\text{C}_{\text{BC}}$  values in the Jingpo Lake sediments may serve as a reliable proxy for climate change.

P-3427

## Palaeoenvironment variations recorded by sedimentary organic moleculars in Lake Nanyi from the middle–lower Yangtze region since the last deglaciation

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The compositions of GDGTs and *n*-alkanes as well as the specific stable carbon isotopes of *n*-alkanes ( $\delta^{13}\text{C}$ ) in a sediment core taken from the Lake Nanyi, middle–lower Yangtze region were investigated. The chronology of the sediment core was established according to the  $^{14}\text{C}$ -AMS data of TOC and terrestrial leaves from the core sediments. This study reconstructs the paleovegetation and paleoclimate change from 16.0 ka B.P. to present. The East Asian summer monsoon was discussed.

The results show that from 16.0 to 8.0 ka B.P., the undetected sporopollen and long-chain *n*-alkanes ( $n\text{C}_{27}$ – $n\text{C}_{33}$ ) suggested that the *n*-alkanes were mainly derived from algae and aquatic plants. The MAT (mean air temperature) which reconstructed by brGDGTs showed that the temperature was low and the climate was dry and cold in this area.

From 8.0 to 4.8 ka B.P., the *n*-alkanes were mainly consisted of  $n\text{C}_{27}$ – $n\text{C}_{33}$ . The low Paq values suggested that the *n*-alkanes were mainly derived from terrestrial higher plants. Sporopollen records, the increased  $n\text{C}_{27} / n\text{C}_{31}$  ratios and decreased ACL (average chain length) values indicated that herbaceous plants were reduced, and woody plants were increased. Depleted  $\delta^{13}\text{C}$  values of  $n\text{C}_{27}$ – $n\text{C}_{33}$  indicated the surrounding vegetation was dominated by  $\text{C}_3$  plants. The MAT showed that the temperature was high, suggesting that the climate was more humid and warmer in this area and the East Asian summer monsoon was stronger.

From 4.8 to 2.4 ka B.P., the high Paq values and the declined contents of  $n\text{C}_{27}$ – $n\text{C}_{33}$  suggested that contribution of terrestrial plants decreased. The lower ACL of *n*-alkanes and the higher ratios of  $n\text{C}_{27} / n\text{C}_{31}$  indicated that the woody vegetation was dominated. The  $\delta^{13}\text{C}$  values of  $n\text{C}_{27}$ – $n\text{C}_{33}$  were between  $-33.5\text{‰}$  and  $-29.1\text{‰}$ , indicating that  $\text{C}_3$  plants were dominated. However, contribution of  $\text{C}_4$  plants increased. The MAT showed that the temperature was low, suggesting that the East Asian summer monsoon weakened relatively.

After 2.4 ka B.P., the decreased Paq values and the slightly increased  $n\text{C}_{27}$ – $n\text{C}_{33}$  suggested that the contribution of terrestrial plants increased. The decreased  $n\text{C}_{27} / n\text{C}_{31}$  ratios and increased ACL values indicated that the grass vegetation was dominated. The  $\delta^{13}\text{C}$  values of  $n\text{C}_{27}$ – $n\text{C}_{33}$  were between  $-33.9\text{‰}$  and  $-28.0\text{‰}$  and changed rapidly. The MAT showed that the temperature was high, suggesting that the climate tended to be warm and humid. The rapid changes of these indexes might be related to the gradual increase of human activity in the Yangtze River basin since 2.4 ka B.P. All these indexes show that the East Asian summer monsoon was weakened when the summer solar radiation in the northern hemisphere decreased.

P-3428

## Biomarker investigations in Lake Van sediments of the penultimate interglacial/glacial cycle

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### Abstract

Paleoclimatic changes on interglacial/glacial time scales in the Near East are not very well resolved especially going back in time beyond the last glacial. To better identify reasons for changes in this region, we quantified source-specific biomarkers in Lake Van sediments during the penultimate interglacial/glacial cycle. Long chain *n*-alkanes, long chain alkenones (LCAs), and sterols, produced by terrestrial vegetation and aquatic algae, respectively were investigated. Stable hydrogen isotopic measurements ( $\delta^2\text{H}$ ) on *n*-C<sub>29</sub> alkanes and on MeC37:3 LCA revealed three wetter periods interrupted by two drier intervals during the MIS 7 interglacial. On the contrary, during the MIS 6 glaciation, a more stable and generally drier climate was predominant. During warmer and wetter periods of MIS 7, a higher input of aquatic OM vegetation and algae to Lake Van sediment was recorded by higher concentrations of mid-chain *n*-alkanes, LCAs and dinosterol and brassicasterol. Inputs of freshwater and terrestrial element like silica in the lake water column might have boosted the aquatic productivity. On the contrary, during cooler and drier episodes of MIS 7 and MIS 6, only high concentrations of long chain *n*-alkanes were measured in sediments, revealing sustainable terrestrial vegetation when the climate was getting harsher. Generally, in the Mediterranean realm, a wetter interglacial interrupted by drier episodes followed by a dry glaciation was the common feature observed during the penultimate interglacial/glacial cycle. In comparison to the last interglacial/glacial cycle, the extreme dry glaciation registered from MIS 5d to 2 was apparently unique around Lake Van, not preceded by a similar event during the last 250 kyrs.

P-3429

## Developing a regional approach to palaeoflood reconstruction using lake and reservoir sediments for the British Isles.

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### Abstract

Flood hazard management requires precise estimates of extreme flood magnitude and frequency to better inform estimates of future risk, but are challenged by a paucity of data that often fails to capture rare high magnitude events. Data on flood magnitude and frequency in the UK before 1900 are sparse in nature and regionally variable. River gauging station time series in the UK are typically short in duration (<50 years). Records of rainfall and other related meteorological series whilst longer, rarely exceed ~200 years with restricted spatial coverage. Historical reconstructions have been used to augment river gauging station data, but also fail to present a full picture of past flooding with records increasingly fragmentary with time. The duration of flood time series can be extended by incorporating additional extreme events from sedimentary palaeoflood archives.

The palaeoflood data from British lakes have only recently begun to be accessed. A challenge in developing a regional database of palaeolimnological flood series is that lakes are not ubiquitous. In Britain they are numerous in the north and west, but few occur in the south and east. Reservoirs conversely have a broader distribution with many constructed during the nineteenth century. Flood histories have rarely been generated from reservoirs despite the associated instrumental data on water levels and flows. Here, we extend the number of palaeoflood records, with new data from both lakes and reservoirs. A ~200 year sedimentary record has been developed from Thirlmere Reservoir (NW England) in the River Derwent catchment, which can be contrasted to nearby lacustrine palaeoflood series. The repeatability of reservoir palaeoflood records is explored using three adjacent reservoirs draining the western Pennines towards the River Tame catchment near Manchester. Further east across the Pennines, lacustrine palaeoflood data from Semer Water in the River Ouse catchment provide a basis for comparison with the Manchester reservoir records.

Together these archives extend the range and character of sedimentary archives used to understanding past flooding in Britain. The palaeoflood data for each sequence has been interpreted from high resolution particle size analyses and geochemical ratios diagnostic of variations in sediment grain size. Our aims are 1) to explore how reservoir palaeoflood records differ from those preserved in lakes; 2) to build new palaeoflood time series for the Derwent, Tame and Ouse catchments for comparison with existing instrumented and historical palaeoflood data.

P-3430

## Temperature series inferred from high-resolution pollen records from two northern Italian lakes evaluated by comparison with instrumental series

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### Abstract

High-resolution pollen records obtained from well-dated lake sediments are exceptional proxies for palaeoenvironmental and palaeoclimate reconstructions. The availability of modern pollen-climate calibration datasets and the application of numerical techniques to the high-resolution paleoecological records allow the quantitative reconstructions of past climate parameters. Here, we present pollen-inferred summer temperature series for the last 200 years in northern Italy obtained from two published pollen records, Lago di Lavarone (Arpenti and Filippi, 2007) and Lago Grande di Avigliana (Finsinger et al., 2006), provided with good chronological control and sub-decadal sample resolution. The direct comparison between pollen-inferred temperature and site-specific instrumental series enables to discuss methodological issues and validates the pollen-based climate estimates. We find moderate to good correlation during the whole 200 years interval. The pollen-based temperatures capture the general warming of the last centuries and its intensification occurred in the last decades recorded in the instrumental series. Thanks to the sub-decadal resolution of the pollen records, the pollen-based reconstructions detect a short colder interval around 1910 AD and a warmer interval around 1940-1950 AD recorded in the instrumental data. Differences and shifts between the pollen-based temperatures and the instrumental series are discussed in relation to human activities and methodological issues, such as the choice of the numerical method used to develop the pollen-climate calibration models. The pollen-based temperatures provide the base for direct comparison with other proxy-based climate reconstructions (e.g. tree-rings, chironomids).

P-3431

## The story of two lakes: high-resolution landscape changes during the last 1300 yrs in central Italy

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### Abstract

The Mediterranean area has been deeply affected by natural and human-induced changes during the last 10,000 years, resulting in a complex interaction between societies and the environment. These mutual influences deeply marked the landscape and drove the response of the vegetation to the changes, especially during the last millennium.

We reconstruct the history of landscape evolution of the Rieti basin, in the central Apennines during the last 1300 years based on a multiproxy approach. We compare stratigraphic records of pollen, non-pollen palynomorphs (NPP), microcharcoal, palaeomagnetism and rock magnetism, sedimentology, and geochemistry from Lago Lungo and Lago di Ripasottile sediment cores. The two lakes are remnants of an older, bigger lake named *Lacus Velinus* that periodically filled the plain until the late 1500s, as shown by ancient maps recovered from historical archives. The records from both lakes show a sudden decrease in forest taxa percentage during the Medieval period (900-1400 CE) and a rapid increase during the early modern time starting around 1450 CE. The Lungo cored sequence spans 2700 years in 14.37 m while the Ripasottile sequence represents 1300 years in 12.40 m - a higher sedimentation rate.

Despite the proximity and periodic connection of the two lakes, the sediments record different information about the practices of the local population. In particular the disturbance taxa, mostly related to agricultural and grazing activities, reveal a different human impact on the lakes. A higher percentage of chestnut pollen in Ripasottile than Lungo suggests a greater influence of the fluvial sediments and pollen transported by the Velino River into the lake from the surrounding mountains. Ripasottile also shows a high percentage of grass and disturbance taxa (e.g. hemp) throughout the entire sequence, whereas the Lungo sequence shows phases dominated by woodland and phases dominated by grass and disturbance taxa, particularly during the Medieval period.

Comparing the sedimentary records from Lungo and Ripasottile at high-resolution contributes to interpretation of the dynamics and responses of the vegetation to natural and human-induced changes in the landscape of a central area of the Mediterranean region during the last millennium. These results underscore the value of multiple study sites at the local scale to capture the spatial variability of human activity in changing the environment.

P-3432

## Holocene environmental changes in the western Canadian High Arctic (Boundary Lake, Melville Island, 74°N – 109°W)

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### Abstract

The sediment record from Boundary Lake (unofficial name, Melville Island, Nunavut) provides a new continuous Holocene paleoenvironmental record from the western Canadian High Arctic, thus contributing to the geographically distributed network of reconstructions from the Arctic. Changes in watershed and lake characteristics are assessed through physico-chemical properties of the lake since the last deglaciation as well as the potential link to climatic and glacial influences over the Holocene. Boundary lake (74°56N – 109°48W) is located 7 km northwest of Cape Bounty Arctic Watershed Observatory (CBAWO). Unlike most of published studies, Boundary lake is a high elevation site for the region (100 m a.s.l.), thus isolated from marine incursion and long-term base level adjustments. It has a low-relief and small catchment area (8.2 km<sup>2</sup>), which leads to slow accumulation rates (0.15mm/yr).

A 160-cm long sediment sequence was recovered and analyzed at 1 cm resolution for total carbon-nitrogen-sulfur (CNS), visible near infrared reflectance spectroscopy (VNIRS), Chlorophyll-*a* content (Chl-*a*), and particle size. The other core half was also scanned for XRF data. The sediment age-depth model is derived from 15 samples analyzed for <sup>210</sup>Pb and <sup>137</sup>Cs combined with <sup>14</sup>C AMS dating from 7 macrofossil layers, dating the basal of the core to 10,000 cal yrs BP. The sediment sequence consists of long intervals of laminated sediments interrupted by non-laminated sequences, with the best preservation conditions of the laminations coinciding with the highest Chl-*a* content. Following regional deglaciation, Boundary lake watershed remained under sea-spray influence (high Cl/K content) with the absence of substantial lake productivity until 8,000 BP. Within the following millennium, enhanced lake productivity was reflected by a pronounced increase in Chl-*a* along with slightly higher VNIRS-inferred lake-water total organic Carbon (TOC) levels, as well as greater Mn/Fe values suggesting increased oxygen depletion. These favorable conditions remained stable over approximately three millennia during the Holocene climate optimum.

Finally, the largest change in sedimentation occurred at 3,500 cal yr BP with a clear shift towards an erosion-based system, analogous to present day conditions. Higher mass accumulation rates are reflected by the occurrence of discrete sand-sized events, and an increase in lake-water TOC that is decoupled from Chl-*a*. This suggests enhanced catchment inputs through colder and wetter conditions. This record from Boundary Lake will help better understand the spatial pattern of paleoenvironment and paleoclimate changes of the Arctic region.

P-3433

## Comparing highly-resolved records of abrupt climate oscillations from the last deglaciation: testing the coincidence of the Gerzensee Oscillation and GI-1b.

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### Abstract

Palaeoclimatic records of the last glacial to interglacial transition (LGIT) from across the North Atlantic region show consistent evidence for a series of abrupt climate oscillations. The similarity in form of the climate record in the Greenland ice cores with those from terrestrial archives across Europe and the northern American continent implies climate teleconnections operating on sub-centennial scales. Frequently the characteristic abrupt transitions of the LGIT are used as tie-points for tuning records with poor chronological control to the exceptionally well-dated Greenland ice core stratigraphy. Tuning is typically based on the undemonstrated assumption of synchronicity between proxy signals, which may in fact be sampling very different climatic or environmental phenomena. It has already been shown, using volcanic ash (tephra) isochrons and working with annually-resolved ice core and lake sediment records, that not all abrupt climatic transitions are recorded synchronously, even within the same continent (Lane et al., 2013).

In this study, we explore the timing of the Gerzensee Oscillation (GZO), a short-lived cooling event that interrupted the Allerød interstadial, prior to the onset of the Younger Dryas, using high resolution lake core records and tephra correlations to the Greenland ice cores. The GZO was described initially within  $\delta^{18}\text{O}$  records from a series of carbonate lakes on the Swiss Plateau by Lotter et al. (1992). Since then, the GZO has been correlated to concomitant events (including the Killarney Oscillation and the Intra Allerød Cold Period) recorded in lake and marine records across much of the North Atlantic region. The GZO occurs in the same stratigraphic position as Greenland Interstadial 1b (GI-1b), a 212 year long isotopic downturn that terminates precisely 203 GICC05 (ice core) years prior to the onset of Greenland Interstadial 1 (GS-1). It is widely assumed that these two isotopically-defined events are manifestations of the same climatic change. We set out to test this assumption using an independent dating approach, combining tephra, annual layer counting and new radiocarbon dates. Our results raise questions about the accuracy of age models for well-known European LGIT records, key climatic transitions and volcanic eruption events.

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P-3434

## Fade of superparamagnetic particles during catchment-to-lake transport – an important factor for interpreting magnetic properties of lacustrine sediments as paleoclimate proxy

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### Abstract

The lacustrine sediments in Heqing basin (SW China) are a research hotspot for studying monsoon evolution in the Quaternary. Rock magnetic properties have been used as proxies to interpret less and more humid phases in the record of a 168m-deep core (HQ) drilled in the basin. In order to support the significance of magnetic proxies in this record that covers ca. the last 0.9 Ma, our study focuses on understanding the magnetic properties of catchment materials and their changes during sediment transport into the paleolake and after deposition. For this, we investigated a series of magnetic parameters of red soil samples from the catchment and samples from sediments of a small modern lake in the basin. The soil was likely providing the main source material delivered to the Heqing paleolake. It is strongly magnetic due to a large fraction of ultrafine superparamagnetic (SP) magnetite (and maghemite) that is likely an extracellular product of bacterial activity. The soil also contains larger multidomain (MD) magnetite particles inherited from weathering of the prevalent limestone bedrock around the basin. Additionally, hematite is observed which might be an oxidation product of magnetite and maghemite. The SP fraction is evidenced by very high frequency dependence of magnetic susceptibility ( $\chi_{fd}$ %) of ~15-20%, and the presence of MD magnetite and hematite are indicated by thermal demagnetization of isothermal remanent magnetization (IRM) and end-member modeling of IRM acquisition curves. In contrast, as a most remarkable result, barely an SP fraction was observed in the lacustrine sediments of the HQ core ( $\chi_{fd}$ % <4%). Our new results from the sediments of the modern lake indicate that during the transport process the portion of the SP fraction is partly reduced, probably by dissolution or oxidation. This is mainly evidenced by a lower  $\chi_{fd}$ % (~10%) and higher relative hematite content compared to soil samples, and magnetic property changes after CBD treatment. The studied properties of the modern lake samples are rather similar throughout the sampled ~0.5 m thick sediment layer. Although no dating of these sediments is available, we can estimate that they comprise a period of several 100 years or more. Therefore the ultrafine SP magnetite fraction of the soil did not only largely survive during transport from the catchment into the lake but was also relatively little decreasing during hundreds of years while residing in the lake sediment. We thus conclude that the almost complete extinction of SP magnetite particles observed in the HQ drill-core must have been a longer (>1 kyr) lasting process or a diagenetic effect that occurred at deeper levels in the sediment column.

P-3435

## Early middle Holocene climate oscillations indicated by a multi-proxy analysis of a sediment core in Hangjiahu Plain, southeast China

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### Abstract

Hangjiahu Plain is located in southeast China. The East Asian monsoon dominates the climate. During the Holocene, the study area underwent transgression and regression for many times. A Neolithic culture flourished and neolithic sites were widely distributed. In recent years, geographers have debated the climatic conditions existing at the time of the Neolithic cultures. This study reconstructed the sedimentary environment between 11.30 and 4.17 cal ka BP based on a multi-proxy analysis of a 14.3 meter sediment core, drilled in Beihuqiao, Zhejiang Province, China. The results show: (1) The climate was getting warm between 11.50 and 8.77 cal ka BP. Grain size became finer from the bottom to the top layer, accompanied by an increase in the chemical index of alteration (CIA), Mg/Sr ratio, the percentage of clay, pollen concentrations, and a decrease in SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> ratio, and the value of bases–alumina (ba), as well as other trace elements. (2) Between 8.77 and 7.99 cal ka BP, the sediment is composed of gray-yellow and gray silt. The percentage of CaO and the ratio of CaO + Na<sub>2</sub>O + K<sub>2</sub>O to Al<sub>2</sub>O<sub>3</sub> is much higher. The pollen concentration sharply decreases. The climate was cold and dry in the early stages of this period, but became relatively warmer and wetter in the later stages. (3) The Holocene Climatic Optimum occurred at 7.99–5.68 cal ka BP. Higher contents of clay, total Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, CIA, the chemical proxy of alteration, pollen concentration, evergreen pollens, and high values of Mg/Sr are observed at this stage, coinciding with a lower SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> value, (CaO + Na<sub>2</sub>O + K<sub>2</sub>O)/Al<sub>2</sub>O<sub>3</sub> ratio, and an obvious reduction in silt/clay, and SiO<sub>2</sub> and CaO concentrations. (4) During the period 5.68–4.17 cal ka BP, the temperature in the study area declined in a stepwise fashion. The grain size became finer, and the Mg/Sr ratio decreased gradually. As the Liangzhu cultural site is prominent in the study area, a significant increase in the pollen of cultivated *Oryza* in the sediments may reflect a increase in human activities. We propose that cool and dry climate may have led to the declining level of groundwater that was conducive to human activities and cultural prosperity in the area. Supplementary color and environmental magnetism investigations of the BHQ core are consistent with the results. The multiple proxy study of the BHQ core offers a reconstruction of the early middle Holocene environment in southeastern China. The climate conditions vary significantly between 11.30 and 4.17 cal ka BP.

**P-3436**

## **Hydroclimatic changes during lake-level fall from last deglaciation Dead Sea sediments**

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### **Abstract**

The Dead Sea is a terminal lake of the largest hydrological system in the Levant, which covers the boundary between the sub-humid Mediterranean and the hyper-arid Saharo-Arabian climate zones. Due to the strong precipitation gradient in this region, small shifts in the distribution of these climate zones can be documented in the Dead Sea lake sediments. Particularly, the lake level of the Dead Sea is sensitive to climate changes, showing substantial drops and rises that are directly linked with the amount of precipitation in the drainage basin. Increased drying in the Dead Sea watershed is marked by a major drop in lake level during the last deglaciation.

Core 5017-1-A of the ICDP Dead Sea Deep Drilling Project obtained a unique sediment record from the deepest part of the northern Dead Sea Basin. In this study, we analyze the annually laminated sediments of this core between 88.5-99.2 m core depth. This interval records the transition from the last Glacial to the Holocene (ca 16.5-11 ka), when the lake level dropped by ca 160 m. The laminated sediments were investigated using detailed microfacies analyses in combination with XRF element core scanning.

Microfacies analyses reveal alternating lithological facies of aad (alternating aragonite and detritus), greenish aad, gd (massive gypsum deposit within marl), native sulfur concretions (associated with greenish colored aad), mtd (typically graded mass-transport deposits) and homogenites consisting of clay to silt. Element ratios of Ti/Ca and S/Ca are examined and utilized as proxies for relative variations in detrital input (Ti/Ca) and gypsum occurrence (S/Ca). Further, the sediments are correlated to the Lisan Formation of the more distal Masada outcrop, using distinct marker gypsum layers, potentially indicating periods of pronounced lake level drop. A significant drop in lake level exposed the Masada section at around 14.5 ka, but the deep core 5017-1-A records this succeeding lake level drop into Holocene levels. The deep core sediments comprise gypsum layers and gypsum-rich deposits with higher S/Ca ratios. In addition, flood layers have been identified that might indicate severe precipitation events associated with specific eastern Mediterranean synoptic systems.

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P-3437

## Landscape and climate impacts on Holocene lake carbon accumulation along a boreal-subarctic catchment

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### Abstract

Climate-change induced thawing of Arctic soils is rapidly changing both the quantity and the quality of carbon (C) entering lakes. Lake sediments offer long-term records to probe the influence of rapidly changing landscapes, and the relative roles of climate, vegetation and lake characteristics, on aquatic C sequestration.

Here we focus on quantitative and qualitative changes in sediment organic C accumulation in four lakes along the same catchment at the boreal-subarctic ecotone in Finland. We reflect past C accumulation against present-day C flux dynamics and catchment characteristics. The four study lakes have had the same climatic forcing over the Holocene, but different positions, morphology, and vegetation development in their respective close catchments. High-resolution C accumulation rates were calculated for the past ca. 9500 years for each core. Elemental and isotopic concentrations of C and nitrogen (N), C:N ratios, and visible-near-infrared spectroscopy (VNIRS) and diatom analysis were used to infer relative changes in terrestrial and aquatic C inputs.

In their present-day state, the four lakes were placed along clear and parallel upstream-to-downstream gradients in sub-catchment peatland abundance (0–30%) and CO<sub>2</sub> flux (from a slight uptake to 27 mmol m<sup>-2</sup>d<sup>-1</sup>). Spatial pattern of CH<sub>4</sub> effluxes varied from 1 to 1.7 mmol m<sup>-2</sup>d<sup>-1</sup>. Furthermore, long-term average C accumulation rate over the Holocene (from 3 to 13 g m<sup>-2</sup>yr<sup>-1</sup>) followed the elevation, peatland abundance and CO<sub>2</sub> efflux gradients, highlighting the role of peatlands as a key source of lacustrine organic carbon. Rapid fluctuations in C accumulation took place over the Holocene with differing between-lake patterns. Carbon quality changes followed overall Holocene climate development, but again with significant between-lake differences in the magnitude and direction of change.

We suggest that the major shifts in C accumulation and source were associated with water level fluctuations, peatland development and aquatic macrophyte abundance. Despite their location in the same catchment, the four basins faced a unique combination of changes in these factors over the Holocene, and thus presented highly individualistic responses to large-scale climate forcing. We propose that multi-lake data are essential when interpreting landscape modulation of external forcing. Together with increasing the number and geographical coverage of high-resolution datasets, multi-lake data will be pivotal when defining critical ecosystem thresholds in the Arctic.

**P-3438**

## **High resolution climate and environmental reconstruction from lake sediments in Lake Comedero, NW Argentina: preliminary results.**

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### **Abstract**

The Andes forelands of NW Argentina cover the climatic transition zone between the South American Monsoon System and the Pacific Westerlies, which are the two main meteorological precipitation systems of southern South America. Therefore, this region is sensitive to shifts in climatic transition zones due to climate changes and a key region for past climate reconstructions. However, only sparse information on past climate variability is available for this area. Here we present a more than 10 m long sediment record from Laguna Comedero (24° 06' 54.7" S - 65° 29' 7.2" W, 2100 m asl, 5 m deep), located in the Provincial Park Lagunas de Yala, NW Argentina. Preliminary results reveal a clear change in sedimentation from detrital brown layers in the lower part of the core to an alternation of gray clastic and black organic-rich intervals with abundant plant debris in the upper 3.5 m. Below this sediment depth we find low values for TOC, C/N and S in combination with high Si, Ti and K values, revealing no variation of detrital sediments and low amounts of organic matter. However, TOC, C/N and S values strongly increase above 3.5 m. TOC values in the upper 3.5 m ranges from 0.1 to 20.5%, while organic C/N atomic ratio reaches values up to 17, suggesting a substantial contribution of allochthonous organic matter in some layers. These intervals also show low values in elements indicative of detrital input (e.g. Si, Ti) and high Mn/Fe that indicate periods of reducing conditions at the lake bottom. Changes recorded in Laguna Comedero sediments reveal that the deposition in the lake varied strongly. Further analysis needs to be done and a detailed chronology is still required to reveal the link between this sediment record and a climate and environmental reconstruction for this region.

**P-3439**

## **Climate-driven changes in seasonal and interannual variability in diatom assemblages, productivity and deposition in Lake Tiefer See, Germany**

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### **Abstract**

Climate change clearly is affecting aquatic ecosystems. One of climate-induced detrimental effects is alteration of the phenology of biological events. It is expected that climate change alters rates of primary production of algae; thus, causing significant consequences for aquatic ecosystems. Particular attention is paid to the lake productivity and factors affecting it. Diatoms contribute substantially to the total primary productivity of temperate lakes, as Ott et al. (2017) observed that extended periods of lake productivity in the northern-central European Lowland appear in the occurrence of thick monospecific diatom layers. The seasonal succession and productivity of diatoms differ among lakes depending on factors, such as stratification, temperature, length of ice-cover, nutrients. Recently, it has been demonstrated, that timing of spring warming and mixing duration can be crucial factors as well (Kienel et al., 2017). Hence, to permit more reliable interpretations of sedimentary diatom assemblages, it is vital to understand which factors are dominating and how climate change and anthropogenic impact affect lake ecosystems.

The aim of this study is to improve the understanding of the link between the seasonal climatic variation and biological processes in the lakes and their catchment area and to distinguish proxies that most accurately reflect the lacustrine life cycle and changes in the lake environment. We combine the proxy data of trapped lake sediments with instrumental data of weather stations, hydrogeological and limnological monitoring and analyse this comprehensive data set by multivariate statistical methods.

The study comprises a comprehensive monitoring program (sediment trapping, limno-hydrological and weather monitoring) at Lake Tiefer See, which is a part of the larger regional monitoring program the Northeast German Lowland Observatory (TERENO-NE). Since 2012, GFZ has monitored lake water and recent sediment formation using continuously measuring sensors, sediment traps with bi-weekly and monthly resolution at different water depths (50 and 12 m), and a weather station installed on a platform on the lake (Heinrich et al. 2018). Lake Tiefer See was selected as an intensive monitoring site because its sediments consist of seasonally formed laminations that are an ideal tool for the high-resolution reconstruction of climate changes. In the poster, we have provided an overview of the monitoring setup in Lake Tiefer See and preliminary results covering recent 5-6 years.

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P-3440

## Reconstructing climate variables from microfossil proxies with machine learning – thoughts on model assessment and selection

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### Abstract

A range of reconstruction algorithms are commonly used to infer palaeo-environmental variables from microfossil proxy datasets. Here, we test several quantitative approaches as reconstruction tools for North American and European fossil pollen data. We use the classical weighted averaging (WA) and weighted averaging-partial least squares (WA-PLS) transfer functions and the modern analogue technique (MAT), as well as machine-learning approaches based on regression tree ensembles and artificial neural networks.

Our special focus is on the reconstruction of *secondary* climate variables, as their comparatively small ecological influence presents special challenges to palaeo-reconstructions (Juggins 2013). We use July temperature as the primary reconstructed variable, while the secondary variable is water balance in North America and January temperature in Europe. These variables were chosen for their ecological significance and their low correlations to the primary variables (0.05 in North America and 0.28 in Europe).

We test our methods using a novel and comprehensive cross-validation (CV) approach. We run a series of  $h$ -block CV's (Telford and Birks 2009) using  $h$  values of 100–1500 km. This CV method has important strengths. First, the effect of spatial autocorrelation is minimized. Second, at large  $h$  values the CV approximates the challenges faced in palaeo-reconstructions with poor modern analogues available. Third, in some cases we find the model performance to change abruptly with small changes in  $h$ , revealing a sensitivity of the reconstruction model to small data variations.

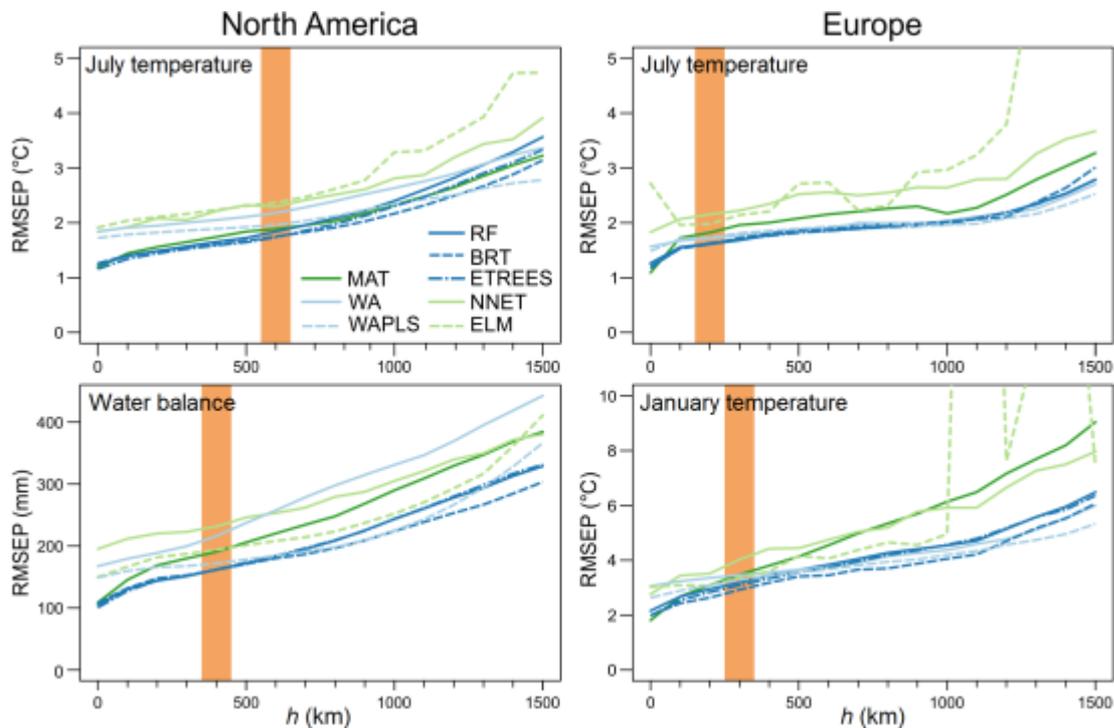


Figure 1. CV errors for North American and European pollen–climate models. Results are shown for  $h$ -block CV runs using a range of  $h$ . Orange bars indicate the  $h$  values suggested to provide neutral performance estimates.

In our CV results (Fig. 1), we find boosted regression trees (BRT) to provide the overall most robust performance, with a small advantage in root-mean-square error of prediction (RMSEP) over other tree ensemble methods (extraTrees (ETREES) and randomForest (RF)) and a more significant advantage in maximum bias. Among neural network models, the Extreme Learning Machine (ELM) generally outperforms the classical implementation (NNET). The overall performance of the best reconstruction models is strong, with errors under 10 % of calibration data gradients for both primary and secondary variables. Palaeo-reconstructions prepared from fossil pollen datasets (example in Fig. 2) show major independent features for the primary and secondary variables, consistent with identified forcings and supporting multi-proxy data.

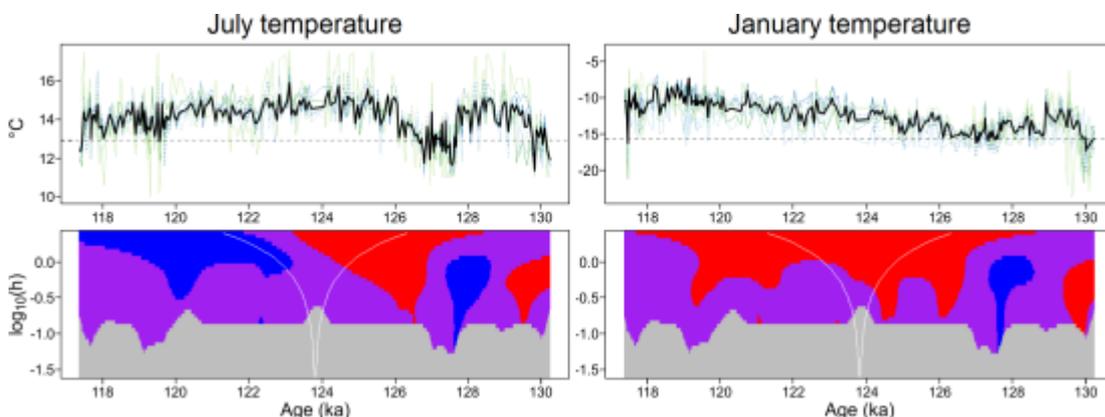


Figure 2. July and January temperature reconstruction from a Last Interglacial fossil pollen dataset from Finland (Salonen et al. 2018). SiZer maps (Chaudhuri and Marron 1999) are shown to illustrate independent features.



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**P-3441**

## **Principal curves in ecological data: insights into palynological shifts in response to abrupt climatic change during the Last Glacial-Interglacial Transition**

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### **Abstract**

Vegetation change during the Late Quaternary is often inferred to reflect either dynamic equilibrium (autogenic migratory or successional lags, population dynamics and seed dispersal) or disequilibrium variability (allogenic climatic forcing). For longer term millennial-scale vegetation development a combination of the above parameters define vegetation present at any given location. However, at the centennial-scale vegetation shifts are likely a response to abrupt climatic change and systemic feedbacks therein. The Last Glacial-Interglacial Transition (LGIT; 16-8 ka BP) is one period containing a suite of centennial to decadal-scale climatic oscillations where palynological responses to these abrupt climatic shifts are poorly constrained. However, where available highly-resolved palynological studies demonstrate increased complexity with variable responses across Britain and continental Europe. To explore this complexity, ordination techniques (Principal Components or Correspondence Analysis) are frequently applied with the first axis of variation used to define phases of change. However, this approach may only explain <40 % of the total variation within the data due to the existence of multiple environmental and ecological gradients during the LGIT. Principal Curves (PrC) may help elucidate this complexity whilst maximising the potential of palynological data.

PrCs are defined as smooth one-dimensional curves fitted via regression through an  $m$ -dimensional data space and have applications in palaeoecology. We present palynological research from sites across a north-south climatic gradient within the British Isles and apply PrCs. The PrCs perform well with the extracted gradient routinely capturing greater than 70 % of the variability within the original datasets. Subsequent palynological scrutiny reveals that the gradient defined by the data has open ground taxa and woodland as each end member permitting assessments of landscape change with shifts in PrCs. Broadly coeval shifts in PrC and climatic indices suggest that at each site the PrC can assist in delineating palynological responses to abrupt climatic change.

The PrC data presented here facilitates an understanding of the magnitudes of palynological responses to abrupt climatic changes during the LGIT. These data, and the re-analysis of key palynological sequences from Britain and Europe alongside summer-temperature isotherm maps demonstrates two major findings: 1) for the early Lateglacial climatic oscillation (a broad correlative of the GI-1d climatic event) the magnitude of the PrC shift is greater in continental Europe, despite climatic forcing being most strongly felt in Britain; and 2) for the later Lateglacial climatic oscillation (a broad correlative of the GI-1b climatic event) the magnitude of the PrC shift is greater in Britain despite climatic forcing being most strongly felt in continental Europe. This finding indicates that different vegetation sensitivities exist between Britain and Europe and/or that additional climatic parameters drive palynological change across abrupt climatic transitions.

P-3442

## Microstratigraphic insights of a mountain closed-lake: A Late Pleistocene laminated record of the Central Andes, Northwestern Argentina

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### Abstract

Rhythmical lamination is preferentially formed in deep lakes with small surface areas without bioturbation in wind protected basins. A contrasting setting characterizes present mountain lacustrine basins of Eastern Cordillera, at the Argentinean Central Andes. In this semi-arid area, seasonal (December-March) precipitation is below 400 mm yr<sup>-1</sup>, mostly supplied by the South American summer Monsoon (SASM). Under these climatic conditions few shallow ephemeral lakes can be found at high-altitudes (>4000 m a.s.l.). Laguna Salada Grande (LSG) (23°S/65°W, 4100 m a.s.l.) is a small (5.8 ha) shallow (approximately 1 m depth), intermittent closed-lake. The presence of a laminated section from ~47 <sup>14</sup>C kyr and ~22.3 cal kyr BP underlying massive sediments, together with paleoshorelines situated several meters above the present lake level, provided the basis for a high-resolution study of the Late Pleistocene paleoenvironment in this area. Using high-resolution techniques, the laminated section of a short core has been analyzed in detail with magnetic susceptibility, XRF scanning and micro-XRF mapping, and dated with AMS. The application of automated scanning electron microscope, QEMSCAN™, in impregnated thin sections was explored to picture differential mineralogical distributions. Grain size analysis in discrete laminae have shown that mixed laminae are formed by alternation of silty sands with carbonate shells, white carbonate muds, siliciclastic (illite) clays and yellow ochre Fe-rich clays. The elemental mapping of Ca/ Fe ratios indicates changes in detrital input to the lake pointing towards runoff, slope wash and rainfall processes controlling the development of lamination. Biogenic sediments also indicate seasonal changes in productivity. Ochre laminae indicate variable redox conditions and subsequent diagenetic processes. The combination of XRF geochemistry, mineralogy and image analysis at different scale resolution allows establishing a high-frequency event stratigraphy for this high-altitude lake system during a deep perennial paleolake stage. Differences within the laminated sequence suggest a shift at ~34 ka from productive conditions in a relatively deep perennial productive paleolake with water column stratification to more variable lake-stands in a smaller paleolake. These stages can be regionally correlated in time with Late Pleistocene wet cycles on the Altiplano/Puna plateau tied to the SASM activity.

P-3443

## Sedimentological and high-resolution pollen and aquatic microfossil analysis of Middle Pleistocene lakeshore deposits of paleolithic site Schöningen 13 II-4, Germany

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### Abstract

The internationally well-known Lower Paleolithic site of Schöningen is located within an open-cast lignite mine in Lower Saxony, Germany. This site is outstanding due to the finding of the world's oldest wooden hunting spears as well as large quantities of excellent preserved flint artifacts and faunal remains. The embedding sediments originate from a remarkably complete Middle Pleistocene sequence, locally named the Reinsdorf Interglacial, which is correlated with MIS 9. In order to characterize the paleo-lakeshore environment and its final transitional sedimentation cycle of lake marl (level 13 II-4c) into organic mud (level 13 II-4b) containing the spear find horizon, geochemical and high resolution palynological and aquatic microfossil analyses were undertaken on small sediment sections distributed along the shoreline of archeological site Schöningen 13 II-4. Palynological analyses focused on both taxa percentages and pollen concentrations, the latter providing additional information on conditions of sediment accumulation. Carbonate content of the horizon underlying the archeologically significant horizon is generally very high while carbon and nitrogen increase with higher biomass production and stronger silting tendencies in the upper horizon. Pine (*Pinus sylvestris*) and particularly birch (*Betula* sp.) are the dominant tree species. Based on pollen concentration, pine pollen is considered to have been transported over longer distances. At higher topographical locations and in greater distance from the lakeshore pollen concentration of aquatic taxa declines and heliophytes such as *Centaurea* sp. and *Helianthemum* sp. increase, indicating dryer and more open vegetation conditions. Pollen records of *Picea*, that most of the spears are made from, are extremely rare in both analyzed horizons which clearly indicates that the raw material was not locally derived and the spears were not manufactured close to the place of deposition. Ostracod and diatom analyses indicate shallow water at the study site with higher salinities and rich aquatic vegetation. Mesorheophilic ostracod species along with tychoplanktonic diatom taxa point to small streams at the lakeshore, presumably originating from springs on nearby highlands. A progressive terrestrialization from horizon 13 II-4c to 13 II-4b is supported by considerably decreasing microfossil concentrations and increasing proportions of benthic taxa. According to their position in relation to the paleo-lakeshore, the samples show a diverse vegetation pattern including small patches of local birch forest and species favoring wet and nitrogen rich loamy soils as well as submerged areas indicated by the occurrence of aquatic taxa. Other samples of this transitional phase point to very dry, also partly saline, terrestrial locations indicated by plants of dry grass, meadow or steppe vegetation.

**P-3444**

## **Boom and bust on different scales – Neolithic and Bronze Age examples from northern Central Europe**

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### **Abstract**

Linking lake records enables for a high resolution comparison of environmental records and for a comparison of the course of settlement and abandonment phases. If we are able to interlink our records, we can identify over-regional patterns of boom and bust but also local peculiarities. Thus behind the palaeo-environmental data a reliable chronological framework is necessary for a good probability of synchronism or asynchronism of events. As pollen stratigraphic connection may involve the danger of circular reasoning, an independent dating based on <sup>14</sup>C-determination – ideally of land plants – and interlinking tephra-layers is necessary. In the frame of a collaborative research center about 'Scales of Transformation' (CRC 1600), supported by the German Science Foundation, we were able to produce high resolution palaeo-environmental records from lake sediments along a transect from Northern Germany to Greater Poland. The poster will show examples of common trends and events and of transformations that differ from site to site. This regards to boom and bust phases in the Neolithic as well as in the Bronze Age.

**P-3445**

## **High-resolution quantitative reconstructions of abrupt cooling events during the Lateglacial Interstadial – Spatial trends across the British Isles.**

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### **Abstract**

The IPCC predicts that Northwest Europe will become increasingly susceptible to abrupt cooling events (ACEs) in the near future, triggered by fresh meltwater pulses into the North Atlantic originating from the Greenland ice sheet. The Lateglacial Interstadial (c. 14.7-12.9 kyr ago), a relatively warm period at the end of the last glaciation, was punctuated by several centennial-scale ACEs. These ACEs, commonly referred to as GI-1d, GI-1cii and GI-1b, are thought to have been in the order of several degrees cooling in magnitude and provide useful analogues to investigate such key research priorities. The ACEs of the Lateglacial Interstadial have been intensively studied in Britain and Ireland; however, qualitative rather than quantitative techniques have largely been utilised and have generally been applied at a low temporal resolution only. This restricts our understanding of the magnitudes and rates of climate change associated with the ACEs and their impact on the local environment. The application of quantitative techniques will enable ACEs to be fully quantified and further improve our knowledge.

Chironomid-inferred temperatures and Oxygen-isotope analysis are powerful tools for palaeoenvironmental reconstructions, as they provide quantitative inferences of past climate. As both methods require little sediment, very high-resolution datasets can be generated that are decadal, and even sub-decadal, in scale. To date, however, these techniques are rarely applied at sufficient stratigraphic resolution for the full magnitude and structure of centennial-scale ACEs to be adequately resolved. Another issue is the strong sampling bias towards certain regions, particularly the North of England, Central Scotland and the Swiss Alps. This poor, uneven spatial coverage of sites further means the spatial expression and complexities of ACEs are not properly defined across large continental scales.

This study aims to explore the requirements needed to fully investigate and characterise ACEs including: 1) the minimum number of samples needed to adequately represent past ACEs, 2) the selection of an appropriate training set(s), and 3) the geographical position of sites. To this end, we present new data from Crudale Meadow, Orkney, and Llangorse, South Wales, showing the ACEs of the Lateglacial Interstadial in near-decadal resolution, greater detail than any published site to date. The application of very high-resolution sampling has enabled their full magnitude to be identified. Our results furthermore show that ACEs, like the Lateglacial Interstadial cold events, can be easily overlooked when a more conventional sampling strategy is employed. Finally, this new data shows GI-1d is of greatest intensity in the North of the British Isles whilst GI-1b is most strongly expressed in the South.

**P-3446**

## **Climate and environmental changes during the last 3000 years on Barentsøya (E-Svalbard)**

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### **Abstract**

The Svalbard archipelago is positioned at the northern limb of the Atlantic Gulfstream and, therefore, highly sensitive to climate changes related to changes in ocean circulation. At present, a strong climate gradient from SW-NE Svalbard illustrates the Atlantic influence. While from Spitsbergen (W-Svalbard) several palaeoclimate records are available, palaeoclimate records from Barentsøya and Edgeøya (E-Svalbard) are lacking.

During the 2015 NWO-SEES expedition (<http://www.sees.nl/>) the first lake sediment records from Barentsøya and Edgeøya (E Svalbard) have been collected. The lakes, formed in isolation basins on intrusive dolorite plateaus, were selected based on their elevation above current sea-level. Based on published isostatic rebound values, the lakes became disconnected from the sea around 3000 years ago. Since then the lakes recorded biological production changes which are clearly reflected in the lithology of the cores. The presence of abundant plant macro fossils including *Salix polaris* leaf remains allows for plant palaeophysiological paleoclimate estimates, which together with pollen and diatom analysis provides a high detail palaeoenvironmental reconstruction for the last 3000 years. Age assessment of the sediments is based on Pb-210 and AMS C-14 dating on botanical macrofossils, while indications for the presence of Icelandic tephra opens up the potential for additional tephrochronological time-control.

The first results on a shallow gravity core from Lake Andsjøen, Barentsøya have been published recently and show a strong increase in organic production during the last decades. This increase in organic production appears to be the result of temperature rise and prolonged ice-free period rather than eutrophication (Woelders et al., 2018). Here we focus on the deeper part of the core where more subtle changes in organic production after the initial isolation are recorded. It appears that these organic changes reflect natural climate changes which seems to be comparable to the Roman Warm Period, Dark Age Cold Period, Medieval Climate Optimum and Little Ice Age. The recent climate warming trends seem to be out of range compared to the natural climate and environmental changes during the last 3000 years in this vulnerable area.

*Reference: Woelders, L., J.T.M. Lenaerts, K. Hagemans, K. Akkerman, T.B. van Hoof & W.Z. Hoek (2018) Recent climate warming drives ecological change in a remote high-Arctic lake. Scientific Reports 8-6858.*

<https://www.nature.com/articles/s41598-018-25148-7>

**P-3447**

## **Sedimentary record of the Naleshwar Lake (India): a witness of climate change and human activity during the last 100 years**

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### **Abstract**

In the present study a multiproxy approach including sedimentological, mineralogical and geochemical analyses was carried out on two cores sampled in the Naleshwar lake (Maharashtra, central south India). The small reservoir lake is located on a basement of metamorphic sedimentary rocks. Forest and small villages surround the area and the local people main livelihood consists in animal breeding, fishing and agriculture activities. The semi-arid climate affected annually by the monsoon causes important yearly water level fluctuations.

The study aimed to provide a reconstruction of the recent history of the lake. First, the sedimentary record was analyzed, in order to correlate the weathering of the catchment and the detrital supply due to climate variations, seasonal or over a larger scale. Secondly, the anthropogenic influence on the lake sedimentation regime was evaluated. A precise chronostratigraphy was carried out for the first time on central India lakes using the method of <sup>137</sup>Cs activity within the sediments.

The dating showed that studied sediments approximately cover the last seventy years, with sedimentation rates of 1.7 cm/year. The data revealed very fine sediments with cyclical variations between a silty and clayey deposit, which could be mainly related to climate and seasonal variation (magnetic susceptibility, granulometry, mineral fraction (%)). In the upper part a positive excursion of clay minerals, iron and phosphorus is observed. Suggesting that some change in sedimentation or supplies is registered, this could be natural or human induced.

The record shows an allochthonous source of organic matter to the lake. However, the increase of phosphorus in the upper part of the core reflects an eutrophication of the basin, with a resulting increment of primary productivity in the lake. TOC (%), N<sub>tot</sub> and the organic carbon isotope increase towards the top of the core, the combined higher HI reflects an enhancement of the algae proliferation in the basin. Additionally, a uranium rich layer corresponding to the increase of primary productivity suggests the setting of anoxic/suboxic conditions in the lake basin. This observation is coherent with the resulting depletion of phosphorus towards the top of the core. Finally, the main weathering product of the catchment is kaolinite. This clay mineral is very common in warm and humid regions and is often a product of quartzitic rocks. The clay minerals as well as the CIA (around 85%) remain constant all over the record.

To conclude, the recorded eutrophication could result from human activity and the surrounding cultivated fields. But except this, the sedimentological record seems to be related to natural variations as climate. Nevertheless, the sedimentary record shows a decrease of the organic carbon isotopic composition from bottom to top of the cores. This could be the result of the global and human induced environmental change.

**P-3448**

## **Lake Gorgana paleolake – New insights in the mid-Holocene evolution of the Lower Danube valley, southern Romania**

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### **Abstract**

Geoarchaeological studies in the periphery of the archaeological site Măgura Gorgana, one of best studied settlements representing the transition from Neolithic times to Copper Age, uncovered the environmental situation in this area to contribute to a better understanding of human-environment interactions during this period.

Within the framework of sedimentological research using a multi-proxy and a regionalisation approach, it was proven for the first time that the Lower Danube valley was covered by an extensive lake from the 8<sup>th</sup> millennium BC to the beginning of the 2<sup>nd</sup> millennium AD. The analyses of the sediments of the so called 'Lake Gorgana' also provided valuable insights into the lake's paleoecology, which changed within the course of lake evolution. These new findings that will be presented are of great importance for archaeology as they shed a completely new light to the prehistoric settlement in the Lower Danube region. From a geoscientific point of view, the lake sediments also represent an extremely valuable geoarchive that allows conclusions to be drawn about changes in the lake ecology, the paleoclimate, and the human influence on the landscape on various spatial and temporal scales.

P-3449

## Early Holocene ecosystem dynamics: a palaeontological approach from the annually-resolved record of Diss Mere, UK

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### Abstract

Understanding the resilience and sequence of change in different components of an ecosystem is a priority research area in ecology, especially during periods of environmental instability. Testing the sensitivity of ecosystems to external forcing (i.e. climate and human impact) and assessing rates of change requires records on longer timescales (decadal to millennial scales) than those typically addressed in contemporary ecological studies. Combining ecology and palaeoecology, therefore, provides crucial data to refine our understanding of ecosystem change, yet, the integration of the two is often limited by the temporal resolution.

The use of annually-laminated (varved) lake sediments provides a unique means to analyse multiple biological indicators (pollen, plant macrofossils, diatoms) at an annual to seasonal resolution. Diss Mere is a small lake in East Anglia (UK), that provides a 17-m annually-laminated (varved) sediment record spanning much of the Holocene. New cores were retrieved from the deepest part of the lake (6 m) in 2016 and an independent chronology established, based upon varve counting, radiocarbon dating and tephrochronology. This study presents new data from the early Holocene portion of the record (ca 10.6-8 ka BP) with high-resolution, decadal-scale pollen analysis. The earliest sediments within the laminated sequence are characterised by an increasing dominance of the temperate woody taxon *Corylus*. The *Corylus*-dominated woodlands transition through a successional sequence towards a mosaic of deciduous forests with stands of *Quercus*, *Ulmus*, *Tilia* and *Alnus*. Given that the early Holocene in Britain is known to be one of low level, pre-agricultural human occupation and thus major anthropogenic influence is thought to be minimal, the varved sediments of Diss Mere allow us to present an insight into the landscape sensitivity to major rapid climatic oscillations identified during the early Holocene (i.e. the 10.3, and 9.3 ka BP climatic events).

P-3450

## Investigating meromixis dynamics in varved lake sediments of Lake Jaczno, Poland using high-resolution hyperspectral imaging and XRF data.

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### Abstract

Lake ecosystems are very sensitive to environmental changes, of both climatic and human induced origin. Eutrophication and meromixis can occur naturally as part of the lake evolution or much faster due to external forcing, leading to altered biogeochemical cycles and anoxia. Yet, not much is known about events of paleoproductivity, meromixis and hypoxia in the past due to analytical difficulties and lack of effective proxies. The assessment of the causes and dynamics of such changes require long term, high-resolution data.

The varved lake sediment record of meromictic Lake Jaczno has so far been analyzed for the last 1700 years, revealing its great potential for a long-term assessment of the causes and dynamics of meromixis and hypoxia [1]. Here we analyze a 12-meter sediment record utilizing recent developments in novel hyperspectral imaging (HSI) techniques combined with XRF scanning. This study completes a series of applications across Europe (Greece, Switzerland, and Poland). The aim is to show how and when meromixis/hypoxia established and vanished over Holocene time scales and which where the forcing factors (erosional input, land use change, climate). For this, we perform HSI scanning at very high spectral (3 nm) and spatial (40  $\mu\text{m}$  pixel size) resolution, able to detect sedimentary pigments at sub-millimeter scale. We use hyperspectral indices to infer quantitatively {Chl a and chlorins} as an indicator for aquatic primary production and Bacteriopheophytin a (Bphe a) as an indicator for meromixis [2]. Bphe a is a diagenetic product of Bacteriochlorophyll a, produced by anoxygenic phototrophic bacteria in the chemocline. Pigment compositions are inferred from sets of spectral indices, such as the Relative Absorption Band Depths (RABD). Indices are calibrated with absolute pigment concentrations of selected samples of the sediment sequence as measured by HPLC, using linear regression models (e.g average RMSEP of 9% or 200  $\mu\text{g g}^{-1}$ ). Chronology is based on radiocarbon dating of terrestrial plant microfossils. In addition, we measured relative changes in sedimentary element composition by high resolution XRF scanning and the organic matter and carbonate content by LOI/CNS analysis. Preliminary results show a strong link of the lake mixing regime with catchment processes. Meromixis is present during periods of a closed and more stable landscape around the lake (i.e. without human disturbance). Remarkably, meromixis is interrupted mainly by the presence of an open landscape around the lake during periods of intense deforestation and soil erosion in the catchment.

<sup>1</sup>C. Butz, M. Grosjean, M. Goslar, W. Tylmann, *J Paleolimnol* 2017, 58:57–72

<sup>2</sup>C. Butz, M. Grosjean, A. Poraj-Górska, D. Enters, W. Tylmann, *Glob. Planet. Change* 2016, 144, 109

P-3451

## Potential keystones to paleoenvironmental studies: characteristic phytoliths in Norway spruce needles

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### Abstract

Phytoliths (also known as silica bodies or plant opals) are preserved in soils and sediments as well as have taxonomic relevance, therefore phytoliths can be fingerprints of the vegetation of the period from which they originated. Comparative phytolith studies are essential for finding phytolith morphotypes with taxonomic relevance. These are used to build reference collections for future paleoecological and archaeobotanical studies.

Biogenic silica extracted by dry ashing method from six woody species commonly occurring in temperate climate plant communities were examined (*Corylus avellana* L., *Fagus sylvatica* L., *Quercus robur* L., *Abies alba* Mill., *Picea abies* [L.] H.Karst, *Pinus sylvestris* L.). Elemental analysis of phytoliths was conducted by scanning electron microscopy (Hitachi S4300-CFE) using Energy Dispersive X-ray Fluorescence. The phytolith taxonomic diagnostic potential of element content was tested by discriminant analysis. The anatomical position of the silicon accumulation was examined by X-ray element mapping.

High concentrations of aluminium and magnesium in phytoliths are associated with two of three conifer species. *Abies alba* and *Pinus sylvestris* could be differentiated statistically on the basis of elemental content. An inventory of phytolith types with anatomical origin was provided and type-frequencies were assessed. The most important finding is that a characteristic cubical phytolith morphotype ("*Picea* – cubic type") originating from transfusion tissue was described as a distinct layer encompassing the central cylinder of the needle.

To make sure that these characteristic cubical phytoliths are preserved in the fossil needles of *Picea abies*, a 4 m long sediment section was retrieved at the deepest point of Černé Lake, Bohemian Forest, Central Europe (1028 m a.s.l.), with a modified Kullenberg type piston corer. Subsamples of sediment were taken contiguously, over 1 cm depth intervals, and fossil *Picea abies* needles were sorted out. Phytoliths were identified in situ position in the fossil tissues on the longitudinal and cross sections of leaves cut by blade using stereomicroscope. Microphotos of phytoliths were also taken in situ position, the element content of phytoliths was analysed by SEM EDX. Radiocarbon dating of bulk and fossil needle samples were completed at the Hertelendi Laboratory of Environmental Studies, Debrecen, Hungary. There was not any significant difference between the fossil phytoliths (oldest are 7680–8023 cal yr BP) and the recent ones in the element content and ultra structure of surfaces, thus there was no any traces of corrosion. Consequently, *Picea* – cubic type phytoliths allow comparative, *in situ* studies to provide the possibility to find further measurable proxies. Moreover, our findings provide the possibility to identify the taxa based on phytoliths from soils and sediments.

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P-3452

## Late Holocene aridification in the Indian subcontinent: Myths versus reality

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### Abstract

Isotope-based records, pollen, and productivity data suggest that variations in Northern Hemisphere summer insolation affected Indian summer monsoon (ISM) precipitation during Late Holocene. The subsequent gradual decrease of summer monsoon precipitation has also been linked with regional (reduced convection, a shift in moisture source) and remote (SST change in Pacific Ocean) climatic factors. In contrast to well explored ISM variability, no detailed study has evaluated the influences of these factors on its boreal winter counterpart-Northeast monsoon (NEM), despite observing an inverse relationship between modern ISM and NEM precipitation. In boreal winter months (October to December), southern peninsular India receives dominant fraction of annual precipitation from NEM while ISM contributes only about 25% of the total precipitation. Understanding the variability of the relative contribution from each monsoon to the annual precipitation cannot be resolved by studying the fluvial architecture or elemental concentrations in sediment. In the absence of monsoon-source specific climate records from southern peninsular India, the onset and causal factors of the anti-phase relationship between two monsoonal precipitations remain elusive.

Here, leaf-wax hydrogen isotopic composition ( $dD_{n-alkane}$ ) from the pit sediments retrieved from now-dry Lake Ennamangalam, southern peninsular India has been used to understand precipitation change during the last 5000 cal yr BP. Isotopic compositions of modern precipitation and vegetation served as the basis for interpreting climatic signals retained in lacustrine archive. The monthly amount-weighted oxygen ( $d^{18}O_{prec}$ ) and hydrogen ( $dD_{prec}$ ) isotopic composition at nearby station (Chennai) varied from  $\pm 1.5\text{‰}$  to  $\pm 7.4\text{‰}$  and  $\pm 12.0\text{‰}$  to  $\pm 52.0\text{‰}$ , respectively. More positive  $dD_{prec}$  values ( $\pm 19\text{‰}$  to  $\pm 9.7\text{‰}$ ) were associated with precipitation sourced from Arabian Sea during ISM while more negative  $dD_{prec}$  values ( $\pm 37.4\text{‰}$  to  $\pm 14.7\text{‰}$ ) were related to precipitation derived from Bay of Bengal during NEM. Therefore, more negative isotopic excursions in geological archives in southern peninsular India would correspond to high NEM precipitation. The most prominent feature of the  $dD_{n-alkane}$  curve is the gradual lowering since the last 3000 cal yr BP, which reflects an increase in NEM precipitation over southern peninsular India. Intensification NEM precipitation was related to southward migration of Intertropical Convergence Zone and subsequent higher frequency of El-Nino events. However, the same mechanisms were responsible for the reduced summer monsoonal precipitation in the Indian subcontinent, and thus established an inverse relationship between two monsoonal precipitations. The present study also identifies that enhanced cold season NEM precipitation favored  $C_3$  plants in the study site after 3000 cal yr BP. Our findings on precipitation-vegetation interaction are expected to improve crop-management policies, especially when increasing El-Nino activity is predicted under warmer climate.

**P-3453**

## **The Island of Amsterdamøya: A key site for studying past climate in the Arctic Archipelago of Svalbard**

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### **Abstract**

Due to its location near the interface of oceanic and atmospheric systems source from Arctic and Atlantic regions, Amsterdamøya is a key site for recording the terrestrial response to marine and atmospheric changes. We employed multi-proxy approaches on lake sediments, integrating physical, biogeochemical, and isotopic analyses to infer past changes in temperature, precipitation, and glacier activity. The results comprise a series of quantitative Holocene-length paleoclimate reconstructions that reveal different aspects of past climate change. Each of the four papers addresses various facets of the Holocene climate history of north-western Svalbard, including a reconstruction of the Annabreen glacier based on the sedimentology of the distal glacier-fed lake Gjøavatnet, a reconstruction of changing hydrologic conditions based on sedimentology and stratigraphy in Lake Hakluytvatnet, reconstruction of summer temperature based on alkenone paleothermometry from lakes Hakluytvatnet and Hajeren, and a hydrogen isotope-based hydrological reconstruction from lake Hakluytvatnet. We also present high-resolution paleomagnetic secular variation data from the same lake, which document important regional magnetic field variations and demonstrate the potential for use in synchronizing Holocene sedimentary records in the Arctic. The paleoclimate picture that emerges is one of early Holocene warmth from ca. 10.5 ka BP interrupted by transient cooling ca. 10-8ka BP, and followed by cooling that mostly manifested as two stepwise events ca. 7 and 4 ka BP. The past 4ka were characterized by dynamic glaciers and summer temperature fluctuations decoupled from the declining summer insolation.

P-3454

## A multi-proxy lacustrine record to understand role of global teleconnections in triggering extreme events in Indian Monsoon realm

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### Abstract

We aim to develop a comprehensive picture of late Holocene climate variability over the North-Eastern India to address the existing large spatial gaps in paleoclimate data coverage in Indian subcontinent. This region receives precipitation only from the Indian Summer Monsoon (ISM) and lies in the region sensitive to the impact of various teleconnections (e.g., El-Niño, North Atlantic oscillations and Indian Ocean Dipole). A multi-proxy approach involving elemental concentration, isotopic geochemistry ( $\delta^{13}\text{C}_{\text{org}}$ ,  $\delta^{15}\text{N}$ ), pollen as well as biomarker (*n*-alkane) investigations have been performed on short sediment cores (ca. 1.0 m long) retrieved from Shilloi Lake, Nagaland, NE India (25° 35' 44" N, 94° 47' 33" E) to decipher climate vis-à-vis vegetation dynamics in the region.

The chronology of the core sediment is based on the  $8^{14}\text{C}$  dates derived from bulk organics, charcoal and organic fragments. The  $\delta^{13}\text{C}_{\text{org}}$  values from the core sediments ranges from -34‰ to -23‰ with a sharp excursion of ~8‰ observed during 1000 cal yr BP. The grain size parameters (D[4,3]- De Brouckere Mean Diameter) also demonstrate enhanced ISM precipitation from 1000 cal yr BP. Furthermore, pollen and *n*-alkane indices also provide evidences of vegetational shift corresponding to the changes in the rainfall variability. The present work will provide an improved picture of the ISM variability and helps to identify the possible teleconnections responsible for the changes in regional paleoclimate during the late Holocene.

P-3455

## Which different sources drive the distribution of biomarker lipids (brGDGTs) in lacustrine sediments?

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### Abstract

Branched glycerol dialkyl glycerol tetraethers (brGDGTs) are membrane-spanning bacterial lipids that show a large structural diversity in the environment. In lakes the lipid fingerprint, i.e. the fractional abundance of all 15 brGDGT compounds, has been shown to correlate with the surface temperature of modern lakes (Russell et al., 2018). The interest of the paleoclimate community in using lacustrine sediments to reconstruct continental climate stems from the limited bioturbation (especially in anoxic sediments) and absence of wind erosion, which allow the development of continuous geological archives, often with an annual resolution. BrGDGT compounds are thus recovered from lacustrine sediments formed in lakes of different sizes, in different climates and at different time scales. For example, Holocene temperature records have been based on a Maar lake in subtropical China (Hu et al., 2015) and changes since the late Pleistocene have been reconstructed based on East African lakes (Loomis et al., 2015).

However, at all these sites the use of brGDGTs relies on a major assumption: that the brGDGT encountered in the lake sediments are sourced from a single source: the lake surface water. However, brGDGTs are produced in high abundance in soils and transported with surface run-off, they are produced within the rivers that drain the watershed (Buckles et al., 2014a; De Jonge et al., 2014), within the lake water column (Buckles et al., 2014b; De Jonge et al., 2015) and within lake sediments (Tierney et al., 2012). Also inflowing and outflowing rivers, and deep water layers compared to surface water layers are characterized by different brGDGT signatures (De Jonge et al., 2015: Lake Baikal; Buckles et al., 2014b: Lake Challa; Buckles et al., 2014a: Loch Lomond, Weber et al., 2018: Lake Lugano).

In this presentation I will show how the changing contribution of different brGDGT sources is observed in modern ecosystems, using examples from literature (i.e. Weber et al., 2018). Secondly, I will show a long-term database of high temporal resolution sampling in the Swiss Sihl river watershed, to illustrate how the different run-off regimes are reflected in the lipid signatures in modern aquatic systems. As brGDGTs remain very powerful tools to reconstruct climate change in lacustrine sediments, I will introduce a method to identify those lacustrine archives in which brGDGTs can be used with confidence.

**Buckles** et al. (2014a) BGS 11, 5539-5563. **Buckles** et al. (2014b) GCA 140, 106-126. **De Jonge** et al. (2015) OG 83-84, 241-252. **Hu** et al. (2015) Palaeo3 435, 167-176. **Loomis** et al. (2015) Palaeo3 423, 80-90. **Russell** et al. (2018) OG 117, 56-69. **Tierney** et al. (2012) GCA 77, 561-581. **Weber** et al. (2018) PNAS 115 (43), 10926-10931.

P-3456

## Atmospheric dust loading, sediment geochemistry and East Asian summer monsoon linkages since the last interglacial of Lake Xingkai, northeast China

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### Abstract

A 336-cm-long sediment core spanning the last 130 ka was recovered from Lake Xingkai on the northeastern margin of the East Asian summer monsoon domain to reveal the linkage between lacustrine depositional processes and environmental changes. Bayesian end member modeling analysis was conducted to partition and interpret the grain-size distributions of Lake Xingkai sediments. Our results suggest that the sedimentary system is characterized by three end members (EMs). EM1 and EM2, with a modal value of 13 and 10  $\mu\text{m}$ , respectively, indicate the variation of local hydraulic conditions. EM3, with a modal value of 5  $\mu\text{m}$ , reflects the background atmospheric dust loading. Major elemental analyses on lacustrine samples and sand samples from Lake Xingkai and the surrounding sandy ridges in northeast China indicate that their abundance varied in relatively narrow ranges. The samples had only undergone the primary stage of chemical weathering. Similar Ti/Al and K/Al ratios between the lacustrine samples from Lake Xingkai and the loess-paleosol samples in north China were observed, which suggests that they come from broadly similar desert sources. Due to the significant dependence on grain-size and influence of sediments recycling, Chemical Index of Alteration of the lacustrine sediments could not be regarded as sensitive indicators of source regions' weathering on the glacial-interglacial timescale. Alternatively, the geochemical proxies of the lacustrine sediments could be linked to the Asian summer monsoon through the development of runoff and physical erosion in the catchment.

In summary, high atmospheric dust concentration generally occurred during Marine Isotope Stage (MIS) 5d, MIS 4, and early MIS 3, when the climate in the Asian dust source region was cold and dry. In contrast, low dust concentration prevailed during MIS 2, likely due to the southward shift of the westerlies driven by maximum ice volume in the high latitudes. However, weakened Asian summer monsoon caused more fine particles transported to the lake basin by reduced runoff in the last glacial period. In contrast, coarser and less-weathered detritus are transported into the lake accompanying strengthened Asian summer monsoon during the warm periods. Our results suggest that the BEMMA and Chemical Index of Alteration method represents a powerful tool for indicate erosion in the lake catchment and unmixing of the polymodal grain-size distributions of lacustrine sediments, which, in turn, deepens our understanding of the sedimentary processes of clastic materials in lake systems and the environmental conditions of the catchment during the geological past.

P-3457

## Paleoclimatic Records During The Early-Middle Pleistocene Transition From The Katata Formation West Of Lake Biwa, Southwest Japan

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### Abstract

The Early-Middle Pleistocene Transition (EMPT) is characterized by the change in climatic pacing from precessional variations to glacial-interglacial cycles with a quasi-100 kyr frequency, which has been clarified from many marine and terrestrial sediments, and Antarctic ice cores. The EMPT includes two important chronostratigraphic horizons of the Jaramillo Subchron (1.07-0.99 Ma) and the Matuyama-Brunhes boundary (MBB; around 0.78 Ma). During the geomagnetic reversals, short cool climatic events were reconstructed within the warmer interglacial intervals from the marine sediment core (Higashinada 1700-m core) from Osaka Bay, southwestern Japan. It is suggested that the cooling was caused by weakening of geomagnetic intensity through an umbrella effect. However, the cooling event during the MBB has not recognized in the marine facies of the Early-Middle Pleistocene Kokumoto Formation exposed in the Boso Peninsula, eastern Japan. To confirm the cooling event and its mechanism, along with the clarification of high-resolution climate changes in the early half of the EMPT, we focus on the Katata Formation of the Kobiwako Group outcropping in the hilly area west of Lake Biwa, southwestern Japan. Lacustrine sequences predominate in the formation, with intercalated less fluvial beds and some widespread volcanic ashes named the Kisen, Biotite-1 (Bi-1) and Biotite-2 (Bi-2) volcanic ashes in ascending stratigraphic order. The MBB was detected approximately 10-m above the Bi-1 by previous researchers. The Kisen and Bi-2 volcanic ashes are correlated with the Azuki (0.86-0.85 Ma) and Hakkoda-Kokumoto (0.76-0.75 Ma) tephra layers, respectively, which are contained in the Kokumoto Formation. The Higashinada 1700-m core also includes the Azuki and Bi-1 tephras. Sixty one zircon crystals are collected from Bi-1 and used for the LA-ICP-MS U-Pb dating. After removing one broken crystal and correcting the non-equilibrium effect, we determine the concordant U-Pb age of the Bi-1 to be  $0.80 \pm 0.01$  Ma (error in 2-sigma) based on 7 grain results. Thus, these three marker tephras can chronostratigraphically correlate the marine and fluvio-lacustrine sediments among these localities, providing the comparable palaeoclimatic records during the early phase of the EMPT. We have obtained an 84.5-m long core from the Katata Formation in late 2018. It covers the horizons below the Bi-2 tephra possibly with the Kisen and Bi-1 tephra horizons and includes oriented all-core samples about 60-m long. We will present the precise horizon of the MBB in this core and the preliminary results of palaeoclimatic reconstruction based on pollen and diatom analyses.

P-3458

## Reconstruction of the Holocene palaeoenvironmental conditions in Taymyr Peninsula according to the sedimentary cladoceran assemblages

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### Abstract

Cladocera (Crustacea: Branchiopoda) constitute a major component of the planktonic and benthic fauna of the high-latitude lakes. They are tolerant to extreme environmental conditions and are one of very few groups of aquatic animal that are not only able to persist in cold thermokarst lakes but to build up viable populations. Subfossil Cladocera investigations in northern Siberia have the potential to reveal Holocene environmental variations, which likely have consequences for global climate change because of the strong high-latitude feedback mechanisms. Here, we present results of subfossil Cladocera analyses of a lake sediment core from the southern Taymyr Peninsula (northern Siberia) covering ~7100 cal years BP to present.

In total, 24 Cladocera taxa from five families were identified in the core, consisting mainly of Chydoridae. The distribution of the most common Cladocera taxa across the depth gradient showed heterogeneity among the samples. For the lowest part of the lake sediment sequence, we hypothesise initial thermokarst refers to a suite of landscape processes associated with the thawing of ice rich permafrost, or melting of massive ground ice, which modify the local topography. During that time, high temperatures and high humidity together with poor drainage may have promoted the formation of a small water-filled depression at the study site lasting for around 500 years. Our subfossil Cladocera data from the period following the initial lake formation from 6550 until around 5100 cal years BP are closely linked in to the processes of a deepening water body. An increase in the abundance of phytophilic and cold-water taxa ca 5100–2150 cal years BP indicates the ongoing development of a macrophyte belt in the shore area. The reconstructed conditions were close to the modern after 2150 cal years BP. Our results confirm earlier investigations from north-eastern Siberia using pollen and/or macrofossils analyses (Andreev et al 2011; Klemm et al 2015).

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**P-3459**

## **Using varved lake sediments to reconstruct eutrophication and recovery in Lake Vesijärvi, Southern Finland**

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### **Abstract**

Lake Vesijärvi in Southern Finland experienced strong anthropogenic eutrophication and hypoxia in the mid 20<sup>th</sup> century, principally due to the discharge of municipal and industrial waste waters from the adjacent city of Lahti. Comprehensive rehabilitation actions, including improved waste water treatment, removal of fish, and most recently aeration, have led to a recovery of water quality in recent decades. Due to spatial and temporal gaps in water quality monitoring, varved sediments in the Enonselkä basin of Vesijärvi may provide the most complete record of the evolution of hypoxia in the lake. Sediments in the Enonselkä basin of Vesijärvi have previously been reported to exhibit varve formation during periods of hypolimnetic hypoxia.

Here we study the occurrence of varved sediments along water-depth transects in the Enonselkä basin. Varve preservation started in the 1950s, reflecting the growing anthropogenic influence on the lake at this time. This result contrasts Vesijärvi with other Finnish lakes with varved sediments, whose varve preservation started thousands of years ago due to natural vulnerability to stratification. Varve thickness and continuity are greatest in the deepest stations, due to focusing of organic material and strongest oxygen depletion in these areas.

The results suggest that varve formation persisted beyond the improvement in waste water treatment (late 1970s), implying continued deep water oxygen stress, although varve thickness declined at this time due to lower organic matter flux to the sediments. Varve formation was terminated by lake aeration since 2009, indicating that this restoration action had the single most dramatic impact on bottom water oxygen conditions.

P-3460

## Climatic oscillation cycles modulating the Río de la Plata fluvial discharge into the adjacent continental shelf, during the Late Holocene

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### Abstract

The Río de la Plata estuary (RdIP) and adjacent inner continental shelf exhibit complex hydrological processes, resulting of the highly variable continental discharge and associated terrigenous supply, primarily controlled by regional climatic forcing in interaction with the oceanographic system. This study aims to analyze the cyclicity in the continental supply and the associated climatic oscillation behind it over the past 1,000 years. To achieve this, we used a 10-m-long sediment core GeoB13813-4 retrieved from the RdIP mud depocenter, which exhibits an extremely high sedimentation rate, with a mean of 1.1 cm yr<sup>-1</sup>. We analyzed Fe/K, Ti/Al, Fe/Ca, Ti/Ca and Si/Al XRF element ratios considered as regional proxies for inferring fluvial supply and freshwater and marine diatom indicative groups, and performed time series analysis (Lomb periodograms and wavelet analyses).

The most significant cyclicities occur at 2- 8, 35, 37, 47, 49, 100, 115, 192 and 215 yr recurrence times. The long-term cyclicity is persistent throughout the whole record and it is most probably related to solar forcing, i.e. the 200 yr Vries/Suess cycle, which determines the activity of the South American Monsoon System activity. In addition, the shorter climate-related cyclicities (<100 yr) were assigned to the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation (ENSO) climatic modes.

This study provides new evidence that both tropical Pacific and Atlantic SSTs and solar forcing are the main drivers of changes in rainfall over Southeastern South America on inter-annual to decadal, multi-decadal and centennial scales, and thus modulates the RdIP river discharge.

P-3462

## Landscape changes in the southern Amazonian foreland basin during the Holocene inferred from Lake Ginebra, Beni, Bolivia

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<sup>1</sup>LPB-HNB, La Paz, Bolivia, Plurinational State of, <sup>2</sup>ISEM-IRD, Montpellier, France, <sup>3</sup>MNHN-LPB, La Paz, Bolivia, Plurinational State of, <sup>4</sup>Institute of Geography, University of Bern, Bern, Switzerland, <sup>5</sup>LMI-EDIA, IRD, Montpellier, France

### Abstract

The Beni region is located in the southern Amazonian foreland basin and exhibits numerous lakes and rivers at the rainforest forest–cerrado ecotone. Geomorphological, paleoenvironmental and archeological studies showed subregion-specific responses to past environmental changes. Our study is located in the Northern Beni and aimed to improve our knowledge on regional landscape changes during the Holocene. We performed pollen and charcoal analyses on an 8600-yr sediment core collected on the margins of one of the largest lake of the area, the Ginebra Lake. Gallery forest and lacustrine sediment were observed from 8645 cal yr BP until 3360 cal yr BP. After 1700 cal yr BP the coring site changed from a lacustrine to a swamp environment. The Cerrado-like landscape with a *Mauritia* swamp on the lake margins became installed 1000 years ago. During the last 1000 years BP anthropogenic disturbances are attested first by fire activity and cultivated plant taxa. Then, after 540 cal yr BP, the absence of fire and the increase in maize and in the Cerrado tree taxa suggest the development of the raised field cultivation. Our results evidence a west-east climatic gradient with the persistence of the rainforest throughout the whole Holocene on the western side and the presence of the Cerrados until the late Holocene on the eastern side. The influence of the Andes on the western Amazonian lowlands mitigated the insolation-linked SASM variability along a west-east gradient. In the last 1000 years Pre-Columbian population around Lake Ginebra initially performed agriculture using fire but then switched to no-fire agriculture on raised fields

P-3463

## Verification of wavelet analysis interpretation of $\mu$ -XRF paleoclimate data from lake sediments using PCA, cluster analysis and empirical climate data

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### Abstract

Reliable interpretation of annual resolution climate proxies for wind, precipitation, and detrital influx are a necessity for understanding the onset and periodicities of climatic events. In particular, verification of individual climate proxies in a  $\mu$ -XRF time series data set is essential for the evaluation of inter-annual, decadal, and centennial periodicities driven by shifting positions of the South Westerly Winds (SWW) and subsequent storm belts associated with the Southern Annular Mode (SAM) and El Niño Southern Oscillation (ENSO) using wavelet analysis. Chronology for the Late Holocene section of lake sediment cores from Lake Kanono, Northland, New Zealand indicate an annual to sub-annual accumulation rate at a 500  $\mu$ m Itrax  $\mu$ -XRF scanning resolution. This fast accumulation rate provides the opportunity to produce quasi-annual  $\mu$ -XRF time series data. Here we present twelve ca. 2200 year long elemental and element ratio  $\mu$ -XRF time series including P, S, Ti, Ca, K, Si, Fe, Mn/Fe, (Fe+Ti)/K, Sr/Ca, Br/Cl, and Inc/coh. These twelve variables were interpreted as environmental proxies using a combination of principal component analysis (PCA) and cluster analysis, then verified with comparison to regionally averaged empirical rainfall and wind climate station data from Northland. Our results show that the wavelet patterns align with the PCA results allowing the  $\mu$ -XRF time series to be classified into: Group I (detrital) and Group II (biological productivity and normalized climate proxies). The normalized Group II  $\mu$ -XRF time series wavelet analyses displayed periodicities in the 2-16 year frequency, likely associated with ENSO, from ca. 237 BCE – 1330 CE. The data shows clear evidence of from both Polynesian and European settlement phases in this part of northern New Zealand as increased detrital influx. There is indication that Polynesian settlement impact was coeval with changes in ENSO intensity and a phase shift in SAM ca. 1350 CE, however European settlement is less associated with climatic shift. The Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA) appear in the  $\mu$ -XRF time series data as separate clusters. This data shows that the MCA is associated with windy/dry conditions with intermittent storms. During the LIA, the 2-16 year periodicity associated with ENSO decreased and centennial length periodicities increase, which may be an indication of an underlying SAM signal within the data. The combination of the methods of PCA, cluster analysis, and wavelet analysis indicates that sediment loading after ca. 1330 CE may be accentuating the climate signal in the Group I (detrital) proxies, and so interpretations after this time must be made with caution.

P-3464

## Evidence for increased expression of the Amundsen Sea Low over the South Atlantic during the late Holocene

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### Abstract

The Amundsen Sea Low (ASL) plays a major role in the climate and environment of Antarctica and the Southern Ocean, including surface air temperature and sea ice concentration changes. Unfortunately, a relative dearth of observational data across the Amundsen and Bellingshausen seas prior to the satellite era (post-1979) limits our understanding of the past behaviour and impact of the ASL. The limited proxy evidence for changes in the ASL are primarily restricted to the Antarctic where ice core evidence suggests a deepening of the atmospheric pressure system during the late Holocene. However, no data have previously been reported from the northern side of the ASL. Here we report a high-resolution, multi-proxy study of a 5000-year-long peat record from the Falkland Islands, a location sensitive to contemporary ASL dynamics which modulates northerly and westerly airflow across the southwestern South Atlantic sector of the Southern Ocean. In combination with climate reanalysis, we find a marked period of wetter, colder conditions most likely the result of enhanced southerly airflow between 5000 and 2500 years ago, suggesting limited ASL influence over the region. After 2500 years ago, drier and warmer conditions were established, implying more westerly airflow and the increased projection of the ASL onto the South Atlantic. The possible role of the equatorial Pacific via atmospheric teleconnections in driving this change is discussed. Our results are in agreement with Antarctic ice core records and fjord sediments from the southern South American coast, and suggest that the Falkland Islands provide a valuable location for reconstructing high southern latitude atmospheric circulation changes on multi-decadal to millennial timescales.

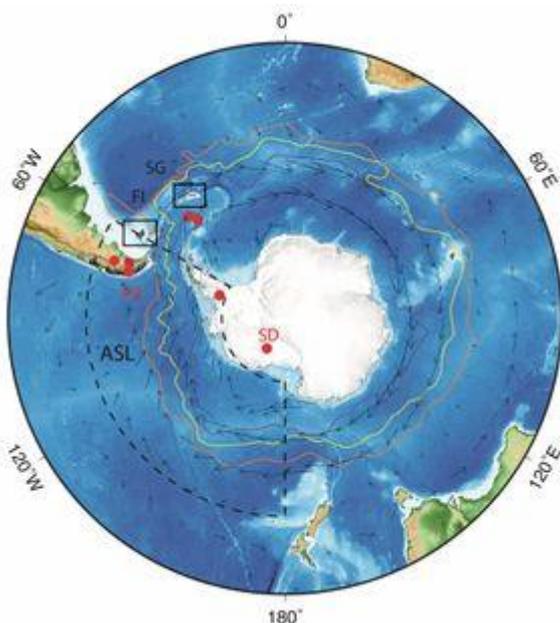




Figure 1. Location of the Falkland Islands (FI) and South Georgia (SG) in the South Atlantic (black boxes). Other key records from the region, including Siple Dome (SD) and Palm2 (P2) (red dots). The dashed line denotes the contemporary limits of the ASL domain defined across the 1979–2001 average (Fogt et al., 2012). The mean locations of the southern limb of the Antarctic Circumpolar Current (purple), the polar front (red) and the subantarctic front (green) are shown, following Orsi et al. (1995), based on analyses of hydro- graphic station data available up to 1990. The grey arrows denote the 925 hPa wind (vectors) trends since 1979 from ERA-Interim (Dee et al., 2011), depicting the location and increase in westerly winds over the satellite era (Turney et al., 2017a). Map made using Generic Mapping Tools (GMT) (Wessel et al., 2013).

P-3465

## The Antarctic Circumpolar Wave in the Brazilian Earth System Model (BESM) during recent past (1850-2005)

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### Abstract

Southern Ocean (SO) is a key region for both carbon sink and ozone depletion. Understanding how these processes varied along recent epochs is essential for the evaluation of human impact on climate. Carbon sink and ozone depletion in the SO sector are modulated by air-sea interaction mechanisms. The Antarctic Circumpolar Wave (ACW) is an ocean-atmosphere interaction phenomenon occurred in the SO on interdecadal to subdecadal time scales, and was first observed in sea level pressure (SLP) and meridional wind stress fields. The ACW is influenced by the El Niño Southern Oscillation (ENSO) phase and intensity, presenting a zonal wavenumber 2 configuration forced by the Pacific-South American pattern. When the ENSO intensity decreases, a zonal wavenumber 3 pattern (ZW3) prevails and characterizes the coupled air-sea interactions. Exploring the ACW representation by climate models during recent past periods may be helpful to interpret paleoclimate records of Antarctic climate variability. This study will investigate long-term ACW variability during the recent past (1850-2005) by comparison of the SLP-derived ZW3 index (Cerrone et al. 2017) with the first EOF mode time series of 850 hPa geopotential anomalies south of 20 °S. The indices will be calculated from historical and preindustrial outputs derived from the Brazilian Earth System Model version 2.5 (BESM-OA2.5) and from the Community Earth System Model version 1.1 (CESM1.1). The numerical experiments followed the Coupled Model Intercomparison Project version 5 (CMIP5) protocols. The historical experiments were run from 1850 to 2005 and include all forcings (i.e. variations in atmospheric composition, solar forcing, variations in emission or concentration of natural and anthropogenic aerosols, and land use), whereas the preindustrial experiments were performed with 1850 prescribed conditions. Historical and preindustrial runs will be compared to isolate the unforced variability of the models, and to verify the ability of BESM-OA2.5 in simulating the SO long-term climate variability.

**P-3466**

## **The climatic significance of Holocene length changes at Dart Glacier, New Zealand**

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### **Abstract**

Understanding pre-industrial or natural climate variability provides an important context for assessing the impact of anthropogenic climate change. However, detection and attribution of human impact on the climate system is limited by short instrumental climate records, especially in the Southern Hemisphere. Mountain glaciers are sensitive climate indicators, thus geological records of their past variability offer the potential to augment instrumental records. Dart Glacier is situated in the Southern Alps of New Zealand and has a ~100 yr record of length observations, one of the longest in the Southern Hemisphere. Using cosmogenic <sup>10</sup>Be surface exposure dating of pre-historic moraines we extend the historic length record to show that Dart Glacier last advanced during the late 17<sup>th</sup> century. Using systematic glacier modelling experiments we constrain the climatic significance of this glacier advance, which coincides with the so-called Little Ice Age. Our findings contribute towards a better understanding of spatial-temporal patterns of Holocene glacier fluctuations in New Zealand, and provide baselines from which to assess the impact of human forcing on the regional glacier-climate system.

**P-3467**

## **Climate variability in Antarctica and the Southern Hemisphere over the past 2000 years (CLIVASH2K)**

Elizabeth Thomas

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### **Abstract**

The CLIVASH2k working group is part of the PAGES 2k network. We aim to improve our understanding of large-scale modes of climate variability and the mechanisms and drivers of climate change in Antarctica, the sub-Antarctic and the wider Southern Hemisphere during the past 2000 years. We build upon previous PAGES syntheses documenting changes in Antarctica over the past 1000-2000 years to focus on the mechanisms driving climate variability. The working group is open to anyone working on climate variability in the southern hemisphere and currently consists of paleoclimateologists working on a range of archives (ice cores, marine sediments, lake sediments, and peat and moss banks), climatologists and climate modellers. Come along to the poster for more information and ways to get involved.

P-3468

## Snow deposition constraints on the isotope/climate relationship at Aurora Basin North, East Antarctica.

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### Abstract

Ice cores are a valuable archive of past climate, often studied for their water isotopes that can be linked to temperature. However, the relationship between temperature and  $\delta^{18}\text{O}$  in ice is not universal, as precipitation patterns, atmospheric pathways for moisture and preservation of the deposited snow largely vary from site to site. In order to understand the isotopic record of the ice core drilled at Aurora Basin North, East Antarctica (ABN, 71°S, 111°E), we investigate the seasonality and driving mechanisms of snow deposition using the regional atmospheric model MAR and ERA-interim climate reanalysis data during the 2005 to 2014 period, and compare it with snow-pit measurements of  $\delta\text{D}$ ,  $\delta^{18}\text{O}$  and  $\delta^{17}\text{O}$  covering the same period at a resolution of about 8 points/year. We find that precipitation events are more intense and more frequent in winter, and that they are associated with warm temperature anomalies, consistent with oceanic air mass advection. Consequently, this will affect the isotope/temperature calibration at this site. We finally discuss the influence of post deposition processes such as wind abrasion and snow evaporation on the snow isotopic composition. We conclude by discussing the limitation of the isotope/temperature calibration and its influence on the climate interpretation of isotope signal at ABN.

**P-3469**

## **A suite of sea-ice markers: Organic compounds in a sub-Antarctic ice core**

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### **Abstract**

Investigation of organic compounds in ice cores is unlocking a wealth of new information in these climate archives. We present results from the first ever shallow ice core drilled on sub-Antarctic island Bouvet, a climatologically important but understudied region. We analyse a suite of novel and more familiar organic compounds in the ice core, alongside commonly measured ions, presenting new records spanning the last two decades. Methanesulfonic acid shows a significant, positive correlation to winter sea ice extent, as does the novel fatty acid compound oleic acid. Both are sourced from spring phytoplankton blooms, which are larger with greater sea ice extent in the preceding winter. Oxalate, formate and acetate are positively correlated to sea ice concentration in summer; these are compounds for which photo-oxidation and cloud-interaction processes are important but sources require further investigation. This study demonstrates the application of organic compounds from the marine biosphere in generating multi-proxy sea ice records.

**P-3470**

## **Holocene temperature, humidity and seasonality in northern New Zealand linked to Southern Hemisphere summer insolation**

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### **Abstract**

In light of contemporary climate change it is more important than ever to understand past shifts in climate, especially past warm phases, and their effects on ecosystems and societies. From compilations of global climate reconstructions, several periods have been identified that might have been warmer than today, the most recent of which is the Holocene Thermal Maximum (~11–5 kyr BP). However, Holocene climate reconstructions display considerable spatio-temporal complexity, which is typically smoothed out in global compilations. We don't have a good understanding of the regional differences around the Holocene Thermal Maximum, especially in the southern mid-latitudes. Additionally, inconsistencies between reconstructions from different proxies are often attributed to seasonal bias or confounding effects.

We use the differences between proxy reconstructions as a source of information about seasonality and precipitation in a multi-proxy investigation of the sediments of Lake Pupuke, northern New Zealand (~37°S). Lake Pupuke is one of the maars in the Auckland Volcanic Field, which comprises 53 basaltic centres located within a 600 km<sup>2</sup> area. Its laminated sediments contain more than 15 tephra layers from both local and distal sources, which form the basis of a robust age-depth model. A 7-m long sediment core, spanning the last 16 kyr, was analysed for pollen, from which mean annual air temperatures (MAT) and effective precipitation were estimated, and chironomids, from which summer air temperature was estimated.

We found no evidence for a thermal optimum in the MAT reconstruction, questioning the validity of treating the early-to-mid Holocene as an analogue for future climate change in New Zealand. Summer temperature increases between 10 and 3 cal kyr BP, correlating strongly with integrated local summer insolation. Early-Holocene low seasonality (from 12 to 9.3 cal kyr BP) was likely driven by low local summer insolation intensity. An early-to-mid-Holocene wet period (9.6 to 7.5 cal kyr BP) corresponds to relatively high southern westerly wind strength. Mid-to-late-Holocene summers following the wet period were hot and dry, especially 4.0 to 2.4 cal kyr BP, consistent with increased evapotranspiration due to higher summer temperatures. Reduced precipitation due to southward displaced westerly winds or increased El Niño frequency may also have contributed.

**P-3471**

## **Extremes of lunar-induced centennial-scale fluctuations in insolation and gravity at high latitudes**

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### **Abstract**

Milutin Milankovitch investigated astronomical forcing of the Ice Ages at orbital scales, during which he identified the latitudinal region bordered by the Arctic Circle as being most sensitive to changes in radiation during the boreal summer. Although the astronomical theory of the ice ages fell into disfavour with the ascendancy of the Greenhouse Gas Theory, the bipolar-seesaw relationship between the Arctic and Antarctic regions and the global nature of many climate signals suggest astronomical forcing of climate, producing different responses based on region and latitude. Current understanding favours orbital forcing of the waxing and waning of the ice-sheets, with outgassing of CO<sub>2</sub> from the Southern Ocean catalysing the bipolar seesaw.

Using physical models of insolation, total solar irradiance, and gravitation, I show the influence of a 133-yr cycle found in astronomical data on insolation at key latitudes. This 133-yr cycle was found in Earth-Moon and Earth-Sun distances and solar declinations, based on the 19-yr cyclical occurrence of the New Moon at perihelion, the closest point in Earth's orbit to the Sun. Maximum swings in TOA insolation were  $\sim 2 \text{ W/m}^2$  at the Arctic and Antarctic circles. This cycle has the capacity to induce regional variations in the climate signal at different latitudes and facilitate rapid changes in as little as a decade, but more often in the 57-yr to 76-yr range. Coupled with evidence of quasi-periodic millennial-scale forcing in this astronomical data, it can be inferred that the interaction of Sun-Moon-Earth produces a number of different harmonics and has the capacity to influence ENSO intensity and variability, and the Pacific Decadal and Antarctic Oscillations. With distance being the common factor influencing gravitation, solar irradiance and insolation, astronomical forcing by these factors therefore plays an important role in influencing the coupled ocean-atmosphere response of Earth's climate.

**P-3472**

## **Diatoms in Ice Cores. Exploring a new proxy for reconstructing past wind strength in Ellsworth Land, Antarctica**

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### **Abstract**

In the last decade, several efforts have been carried out to assess the causes of the current rapid recent warming measured on West Antarctica and Antarctic Peninsula. The increase in wind strength and shifts in atmospheric circulation patterns have shown to play a key role in driving the advection of warm air from mid-latitudes to high-latitudes. Winds are also responsible for driving surface melting in the ice shelves, enhancing the removal of surface snow, and for promoting basal melting through the upwelling of deep warm water. All these combined have shown to produce substantial effects on environmental parameters, such as: sea surface temperatures, sea ice extension, air surface temperatures and precipitation.

Even though winds are fundamental components of the climatic system, there is a lack of reliable long-term observational wind records in the region. This has hindered the ability to place the recent observed changes in the context of a longer time frame.

In this work, we present a record of marine diatoms preserved in an intermediate depth ice core retrieved from the Ellsworth Land coast in the Amundsen Sea region. In particular, this work focus in the second half of the twentieth century where we explore the diatom abundance and species assemblages to assess the capacity of this record to represent the local/regional variability in wind strength and circulation patterns that influence the onshore northerly winds.

**P-3473**

## **The Southern Westerly Winds throughout the Holocene in climate model simulations**

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### **Abstract**

Atmospheric circulation at hemispheric scale integrates large-scale features from tropical, subtropical, midlatitudes and polar regions, including the Hadley and Ferrell Cell, as well as the subtropical anticyclones and in the Southern Hemisphere (SH), the Southern Westerly Winds (SWW). The SWW in particular have been a central element in understanding past, present and future climate in the SH and at global scale, due to their importance in the global carbon cycle via its coupling with the Southern Ocean.

We analyse three transient model simulations of the Holocene to investigate the evolution of the SH westerly wind system. The Holocene, the last 11,700 years of Earth history, is usually depicted as a relatively stable climate period in which human civilization has developed; its climate evolution has been driven mainly by slowly varying insolation forcing and is therefore a prime setting for disentangling external and internal modes of variability in our climate system. A better understanding of natural climatic variations in the SH will help quantify the contribution of both anthropogenic and natural variations to current and future climatic changes in this region.

In the present climate, we know that at the seasonal scale mayor latitudinal changes are found in the Pacific Ocean, and to a smaller degree in the Atlantic Ocean, whereas in the Indian Ocean and the Australian / NZ sector the seasonal shift is minimal. In terms of strength, strongest winds are found in the Indian Ocean sector. On the other hand, at upper levels over the Pacific, the subtropical jet features a split jet. These characteristics are reproduced by the models for present climate and throughout the Holocene. In addition, the models show millennial trends in wind strength that follow the insolation forcing, but also multi-centennial variability. Important seasonal variations are found.

**P-3474**

**A new find of macrofossils of *Picea crassifolia* Kom. in early-middle Holocene sediments of the Qinghai Lake basin**

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**Abstract**

Here we report a new find of abundant woody debris and cones in stratum of two sections located to the east of the Qinghai Lake basin in China. Analysis of the anatomical structure of the wood and cones confirmed that they are *Picea crassifolia* Kom. The results of accelerator mass spectrometry  $^{14}\text{C}$  dating indicate that the buried Qinghai spruce grew during 9.7-4.2 ka, and the ages of the large trunks or branches are mainly concentrated within the interval 7.5-6.5 ka. This finding gives direct evidence at species level about the presence of coniferous forest in the early-mid Holocene in Qinghai lake basin. In addition, the buried cones suggest that early-middle Holocene environment was suitable for the propagation of *Picea crassifolia* Kom. The variations in the occurrence of Qinghai spruce forest in the Holocene probably reflect changes in humidity/moisture. The humid early-mid Holocene was suitable for the growth and reproduction of Qinghai spruce forest, while a shift towards an increasingly arid climate during the late Holocene resulted in the disappearance of *Picea crassifolia* Kom. from the Qinghai lake basin, although human activities may also have contributed to the environmental change.

**P-3475**

## **A systematic assessment of late Quaternary hydrological change from valley fill complexes in Namibia**

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### **Abstract**

Significant hydrological change occurred over southern Africa during the late Quaternary, with drier, western areas impacted by the interplay of temperate and tropical Atlantic and Indian Ocean rainfall sources. On Quaternary timescales, current debates centre on the sourcing of moisture during wet phases, the degree of northerly penetration of winter rainfall systems, and the regional responses to orbital forcing during the Holocene. Given the paucity of geochemical records in Namibia, reconstructing the palaeoenvironmental context of Namibian valley fill sediments presents a potentially important archive for understanding regional hydrological dynamics. Valley fill sediments extend from the presently hyper-arid Skeleton Coast in the North through to tributaries of the Orange River in the South. There exists a discontinuity, however, in how existing studies use data on aggradation of these fills to elucidate the timing of fluvial activity: interpreted variably as either slack-water deposits indicative of increased hydrological activity or as river-end deposits indicative of decreased hydrological activity. This makes it hard to resolve spatial variations within an emerging picture of late Quaternary hydrological change. To address this, this study investigates both the nature and timing of sediment deposition along a northern Namibian ephemeral river valley: the Huab. Valley fill sediments along the Huab have been identified as a particularly significant source of atmospheric dust, yet the palaeoenvironmental context of sediment accumulation in this system has not been studied in detail. Here, the modern ephemeral channel has incised into the valley fill sediments, exposing profiles showing distinct layers in the fill indicating distinct periods of deposition. By explicitly linking a reconstruction of environmental conditions with the timing of sediment deposition, this study aims to systematically reconstruct the late Quaternary fluvial history of the Huab.

Initial optically stimulated luminescence results date periods of deposition in the Skeleton Coast valley fill region to the Holocene. Grain size distributions indicate variations in depositional environments throughout the profiles, presenting evidence of shifts between high and low energy fluvial regimes. Combined with thin section micromorphology, optical microscopy and scanning electron microscopy, we hope to understand the nature of sediment deposition within this system. Ground penetrating radar data collected along transects perpendicular to the river flow show that the laminations in the fill vary in depth over space. Results here indicate lateral variability in the deposition of the fill and present the beginnings of an understanding of how to interpret the fill. Alongside existing fluvial records from other valleys, and geochemical records from the escarpment, this reconstruction of Huab hydrological dynamics will be interpreted in relation to late Quaternary hydrological change in the region. This also presents an important evidence base for understanding the sustainability and sedimentary characteristics of a significant atmospheric dust source.

**P-3476**

## **Reconstructing palaeoenvironmental conditions for human dispersal in the United Arab Emirates**

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### **Abstract**

Southeast Arabia is now recognised as a key region in the ongoing debate on the influence of climate change on early human dispersal. Long-term, high-resolution records of climate change are limited to ocean cores or speleothem records. The latter have provided a valuable insight into changing hydrological conditions over the past 400 ka. Nevertheless, these records cannot be directly translated into evidence of wetter landscape conditions in the desert interior. As a consequence, our understanding of climate change during some periods is limited to a handful of reliably dated records. This study aims to provide better knowledge on palaeoenvironmental and hydrological change based on new chronological, sedimentological and geochemical results of several fluvial outcrops along two major ephemeral streams (Wadi Iddayah & Wadi Dhaid) in the northern UAE. Both streams lay in the direct vicinity of two well-stratified archaeological sites (Jebel Faya and UAQ 2) and connect the Oman Mountains with the coast representing potentially important migration routes. First results from field-work, laboratory analysis and dating (optical stimulated luminescence (OSL) and radiocarbon) distinguished several alternating phases of fluvial activity, soil formation and arid conditions in the Pleistocene and Holocene, which are compared to phases of human occupation at the archaeological sites.

**P-3477**

## **Pleistocene environmental change from more humid to hyper arid conditions in the Gaxun-Nur Basin, NW China**

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### **Abstract**

Central Asia is a large-scale source of dust transport, but also held a prominent hydrological system during the Quaternary. The endorheic Hei River drainage basin in NW China is placed between the northern Tibetan Qilian Shan and the southern Mongolian Gobi Altay and was chosen as a site to study a sediment archive reflecting this hydroclimatic change. We used a 223 m long core (GN200) that has been extracted from the Gaxun-Nur-Basin at the lower reaches of the river. This is an area, where the river has created a huge alluvial fan as can be seen on satellite imagery. The fan has replaced a formerly extended lake area that existed at least during parts of the Late Quaternary (MIS 3 to 2). Three main and texturally distinct sedimentary facies are identified. Facies C (223-218 m) is dominated by coarse-grained layers (fine- to medium-grained sand) interbedded with fine grained sediments (clayey silt). Facies B (218-110 m) has a succession of banked clayey silt with an increasing frequency of intercalated sand layers (dominated by very fine sand to fine sand) towards the top. Some layers containing coarse sand to very fine gravel form a top subfacies in the unit (between 120-110 m). Facies A (110-0 m) is a succession of fine- to medium- to coarse-grained sand layers interbedded with silt banks that decrease in frequency towards the top. The gradational increase in fine silt content in these silt banks is paralleled by a loss of the clay fraction. The Neogene Red-Clay formation is interpreted to occur at the base of core GN200 represented by facies C. It contains a distinctly pronounced portion of mixed layered clay minerals. Lake sediments, partly fine laminated, occur in the lower part of facies B. These sediments show the highest relative smectite proportion. Fluvial sediments make much of facies A with a pronounced increase of river-related chlorite towards the top of the core. We propose a sedimentation model that stretches over the whole Quaternary and with a transition from a more humid to a more arid sediment environment at around 1.2 Myr BP. The age model is backed up by magnetostratigraphy and constrained by <sup>10</sup>Be/<sup>26</sup>Al dating. The studied sediment properties include granulometric and geochemical/mineralogical changes (XRF-scans, XRD-mineral analyzes). The mineral indicators are complemented by the vegetation record based on pollen counting.

**P-3478**

## **Late Quaternary Paleohydrologic Changes in the East Gobi Desert**

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### **Abstract**

Deciphering past landscape in desert under the climate variations is important for projecting future desertification in response to the global warming. The remains of once integrated drainage systems in the desert area are valuable, and in some cases, the only available archive of the past environmental changes. In this study, paleohydrological network in the East Gobi Desert was identified by remote sensing images and digital elevation model. Luminescence, radiocarbon and U series dating methods were used to constrain the chronology. The results show that megalakes with an area at least 14,000 km<sup>2</sup> occurred during MIS 5, representing ~200% of the present day precipitation and 1100 km northward shift of the northern boundary of humid area in east China. Occurrence of *Corbicula Fluminea* indicates substantially warmer winter than present (>8 °C) has prevailed during MIS 5. Carbonate precipitation and lack of paleohydrological remains during MIS 4-2 does not support a humid MIS 3 in the East Gobi Desert. Driven by the intensified East Asian Summer Monsoon, high lake level appeared again at 6.5 ka BP, while the lake extent was only half of that of MIS 5. Late quaternary precipitation changes in the East Gobi Desert show a different pattern with the stalagmite record in south China, implying the cave  $\delta^{18}\text{O}$  value cannot represent the monsoon intensity in northern China. Wet Gobi Desert during MIS 5 is possibly responsible for the “dustier MIS 4” in East Asia and Pacific.

P-3479

## **Westerlies Asia and monsoonal Asia: spatiotemporal differences in climate change and possible mechanisms on decadal to sub-orbital timescales**

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### **Abstract**

The 'westerlies-dominated climatic regime' (WDCR) in the present interglacial period was proposed because precipitation/moisture variations between arid central Asia and mid-latitude monsoonal Asia are out-of-phase or anti-phased on different timescales during the Holocene. In this study, we first review the development of the theoretical framework of the WDCR, and then outline the boundary of its core area: from the Caspian Sea in the west to the western Hexi Corridor in the east, with the northern and southern limits coinciding with the domain of arid central Asia. Next, we present a synthesis of multiple lines of evidence for the occurrence of the WDCR on multi-millennial ('sub-orbital' herein) to decadal timescales during the Holocene. Finally, we examine the possible physical mechanisms responsible for the WDCR. We find that external factors (insolation changes induced by orbital factors) generated the WDCR on a sub-orbital timescale, whereas a circum-global teleconnection/Silk Road pattern was the most significant factor responsible for the WDCR on centennial and decadal timescales. The study provides a comprehensive summary of the development of our knowledge of the WDCR over the past several decades, together with a tentative theoretical framework for understanding climatic and environmental changes within its region of influence. In addition, it forms a scientific basis for environmental management and ecological restoration in this arid region in the context of global warming.

P-3480

## A 4 kyr high-resolution multi-proxy paleoclimate record from Lake Telmen, Central Mongolia

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### Abstract

Semi-arid/ arid Mongolia is a key location for paleoclimatic reconstructions in Central Asia, because it is affected by two large-scale atmospheric circulation systems, the Westerlies and the Asian Summer Monsoon. The climatic evolution of Mongolia during the Holocene is highly debated. Today, Lake Telmen has an area of 209 km<sup>2</sup>, but reconstructed lake level fluctuations during the Holocene indicate past variations of moisture availability. A 160 cm long gravity core was retrieved from this site and analyzed using a multi-proxy approach. This includes granulometric and elemental analyses, as well as leaf wax *n*-alkanes and their compound-specific isotopic signature ( $\delta^2\text{H}$ ,  $\delta^{13}\text{C}$ ). The chronology is based on six bulk radiocarbon ages and reveals a basal age of 3,960<sup>+370</sup>/<sub>-540</sub> calBP. Low terrestrial input (e.g., low Al, Fe, K, Sr) suggest decreased runoff in the catchment of Lake Telmen and point to overall dry conditions in the area between 3,960<sup>+370</sup>/<sub>-540</sub> and 2,970<sup>+270</sup>/<sub>-450</sub> calBP. From 2,970<sup>+270</sup>/<sub>-450</sub> to 2,550<sup>+330</sup>/<sub>-380</sub> calBP high terrestrial input and low Mg/Ca ratios indicate more humid conditions and high lake levels. Drier conditions occurred from 2,550<sup>+330</sup>/<sub>-380</sub> to 1,780<sup>+340</sup>/<sub>-380</sub> calBP and low lake levels are indicated by high Mg/Ca ratios. This phase was followed by a more humid period between 1,780<sup>+340</sup>/<sub>-380</sub> and 1,310<sup>+300</sup>/<sub>-360</sub> calBP (high terrestrial input and low Mg/Ca ratios). From 1,310<sup>+300</sup>/<sub>-360</sub> calBP onwards, drier conditions occurred with a tendency to more humid conditions again. The findings of this high-resolution multi-proxy study confirm previous investigations from (supra-) regional archives and contribute to a more detailed understanding of paleoclimatic conditions in Central Asia. Future leaf wax  $\delta^2\text{H}$  and  $\delta^{13}\text{C}$  analyses will give insights to past moisture conditions and changes of moisture sources.

P-3481

## DATED-2: An updated chronology and time-slice reconstruction of the last Eurasian ice sheets.

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### Abstract

DATED-1 comprised a fully-documented empirical reconstruction of the changing extent of the last Eurasian ice sheets 40-10 ka (at 1000-year resolution after 25 ka) based on a geological-glaciological assessment of all relevant chronological data (Hughes et al. 2016). All uncertainties within the underlying data, quantitative and qualitative (e.g. precision and accuracy of numerical dates, correlations of moraines, stratigraphic interpretations) are expressed in terms of distance; deviation between maximum and minimum limits, and their relative proximity to the position considered most-credible, indicates the degree of uncertainty along the ice margin for each time-slice, according to current interpretations of the available evidence. Explicitly reporting all uncertainties in this way provides a straightforward means to compare geological data with results from numerical modelling of past ice extent. A by-product was creation of an archive of all published dates (and associated data necessary for their interpretation, quality, and recalculation) relating to the build-up and retreat of the British-Irish, Scandinavian and Svalbard-Barents Kara seas ice sheets. A task that took nearly 10 years, but which is a valuable legacy for a diverse range of the Quaternary community. Both the time-slice reconstruction and underlying chronological data are available via the online data repository PANGAEA in GIS and Google Earth compatible formats, and the reconstruction in NetCDF format on request.

Such syntheses run the risk of being frozen-in-time and losing their relevance if not maintained and updated to reflect the latest observations; new geological data is generated almost continually. Here, we present the second-generation Eurasian ice sheets' synthesis, DATED-2, which brings the chronological dataset and reconstructions up-to-date by including all information published before 1 January 2019 (1 January 2018 for the British-Irish Ice Sheet). Six years on from the DATED-1 census the volume of dates, and also associated information such as from geomorphological mapping, has grown significantly; c. 40% increase in the number of dates, including a near doubling of dates derived from terrestrial cosmogenic nuclide dating, and over 2000 new sites added. Nevertheless, the overall spatial and temporal distribution of chronological information is largely unchanged. The time-slice reconstructions continue to rest on relatively few key dates and the largest uncertainties remain, e.g. the timing of coalescence and separation of the component ice sheets, and the nature of deglaciation of the eastern Barents Sea. We highlight the main changes in DATED-2, present a new calculation of the evolution of ice sheet volume in terms of sea level contributions, and discuss implications for understanding the build-up and deglaciation of the last Eurasian ice sheets.

Hughes, A.L.C., Gyllencreutz, R., Lohne, Ø.S., Mangerud, J., Svendsen, J.I. 2016: The last Eurasian ice sheets – a chronological database and time-slice reconstruction, DATED-1. *Boreas*, 45, 1–45. 10.1111/bor.12142

P-3482

## Evolution of Greenland ice sheet since the Last Glacial Maximum: a model assessment based on PISM

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### Abstract

The evolution of the Greenland ice sheet (GrIS) since the Last Glacial Maximum (21ka BP) is accessed by the Parallel Ice Sheet Model (PISM). In order to get the climate forcing for the GrIS, several time-slice simulations have been conducted by the AWI Climate Model (AWI-CM) following the PMIP4 protocol. It shows that the GrIS has reached its maximum volume (relative to present) of around 3 m ice-equivalent sea level at 17 ka BP. Moreover, a minimum ice volume of -0.2 m ice-equivalent sea level is observed during the mid-Holocene (5ka-4ka BP). Since then, the GrIS has experienced an overall increasing trend in ice volume until the 1960s. The model shows that the anthropogenic global warming has reversed the background increasing trend of GrIS since the 1960s. Our study suggests that the GrIS ice volume greatly lags the climate forcing, implying that the consequence of global warming on sea level rise may continue and last for thousands of years.

**P-3483**

## **Testing the drivers of retreat of the last British-Irish Ice Sheet: a numerical modelling study**

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### **Abstract**

Following efforts of the BRITICE-CHRONO consortium the highly resolved retreat history of the last British-Irish Ice Sheet (BIIS) presents a valuable test for numerical ice sheet models. In turn, physics-based models can be used to test different hypotheses for drivers of retreat of the ice sheet. In this study we use a hybrid ice sheet-shelf model driven with a climate model. Our intention is not to try and reproduce the reconstructed extent of the BIIS as accurately as possible, but to find areas where our modeling framework struggles, with the ultimate goal of improving the model. We highlight two areas where there is a significant disagreement between the model and the reconstruction and describe efforts to remedy this disagreement. Firstly, the model fails to simulate ice inception over northwestern Scotland and western Ireland. We suggest that this is due to an underestimate of orthographic precipitation due to our low resolution climate model forcing. A new parameterization for orthographic precipitation has been developed that improves ice sheet inception. Secondly, although the pattern of deglaciation is similar to reconstructions, it is consistently  $\sim 4$  kyr later than suggested from the BRITICE-CHRONO compilation. Again, we highlight an area in our modeling framework that could explain this discrepancy and the steps we have taken to improve the model. To conclude, we discuss what our numerical simulations may tell us about drivers of retreat of the last BIIS.

P-3484

## Interior anatomy of the Fennoscandian Ice Sheet during the last deglaciation

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### Abstract

The last deglaciation of the Fennoscandian Ice Sheet (FIS) is well documented through extensive mapping and dating of marginal positions. Empirical and modelling studies typically show a 2-3 km thick ice sheet as the Last Glacial Maximum, deglaciating to cold-based ice domes in northern and southern Norway. There is unfortunately very little direct evidence that permits robust reconstructions of the changing geometry of the ice sheet interior during deglaciation. Instead approximations have been deduced from indirect evidence, including extrapolation from remote margin positions and isostatic loading estimates inferred from relative sea level reconstructions with the uncertainties they carry. Here we present new geomorphological mapping and surface exposure ages (<sup>10</sup>Be) from the Snøhetta region of southern central Norway providing direct evidence of interior ice sheet anatomy during an interval with strong external climate forcing. This region is at the centre of the hypothesised southern FIS ice dome, therefore staying ice covered until final deglaciation after circa 10 ka. Surface exposure ages from the sides of Mt. Snøhetta (2286 m a.s.l.) suggest the region became ice free before 16 ka. Ages of two well-developed moraines from valleys flanking Snøhetta at 1550-1450 m altitude suggest formation at  $11.6 \pm 0.2$  ka and  $11.8 \pm 0.2$  ka, corresponding to the termination of the Younger Dryas (YD, 12.8-11.7 ka). Two additional moraines deposited by the waning ice sheet at the same altitude support this regional deglaciation pattern. Our results imply that high-elevation areas in Central and Southern Norway emerged prior to the YD which could allow for the co-existence of cirque glaciers at the time in question. These observations also suggest that the downwastage of the FIS was far more rapid and dynamic than previously thought and in part synchronized with the deglacial pattern of the margins of the FIS as well as corresponding shifts in ice sheet volume.

P-3485

## Challenges in defining the above-ice elevation of samples in a complex topographical setting

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### Abstract

Numerical ice sheet models are central for our ability to test ice sheet response to climatic change. To validate the models, empirical data for comparison with model outputs are required. MAGIC-DML is an international collaboration focused on filling critical data gaps in our knowledge of the timing and pattern of ice surface changes on the western Dronning Maud Land (DML) margin of the East Antarctic Ice Sheet (EAIS). A combination of remotely sensed and field-based geomorphological mapping is being used in combination with cosmogenic nuclide analyses to reconstruct changes in the vertical extent (thickness) of the ice sheet surface since the Pliocene. We use the nunatak 'dipstick' approach to measure the timing and rate of ice sheet surface lowering. Accurately determining the above-ice elevation is critical for interpreting cosmogenic nuclide measurements on such vertical profiles as it is the elevation of a sample site relative to the present-day ice surface which defines the amount (and when combined with simple exposure ages of the sites, the rate) of ice sheet thinning.

A significant challenge to this method is encountered where nunataks are surrounded by a highly discordant present-day ice surface. In western DML, a significant topographic escarpment up to several hundred meters high forms the edge of the East Antarctic Plateau, with ranges of nunataks separating the plateau ice from that below. Due to this separation, ice flow on the plateau is not necessarily directly related to that below, complicating the determination of above-ice elevation of sample sites. Here we present some preliminary results from attempts to explore possible solutions to the above-ice elevation problem in this situation.

P-3486

## Early Mid-Holocene wind trajectories in northeastern Africa, based on lake record from the Faiyum Oasis in Egypt

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### Abstract

A climate in northern Africa is highly dependent on interaction of a tropical monsoonal circulation in the south and moist Atlantic/Mediterranean air masses in the north. A contact between them is defined as the Intertropical Convergence Zone (ITCZ) and it shifted several times north-south in the Holocene. The Faiyum Oasis was all the time outside the northern limit of the summer monsoon but the modern Qarun Lake is a relic of an ancient prehistoric, mostly freshwater water body. In 2014 a research drilling at the southern shore of the lake was done, funded by the National Science Centre in Poland (decision no. DEC-2012/05/B/ST10/00558). Complex geochemical, diatom, pollen and magnetic susceptibility examination of a fragment of the core of lake deposits dated at 8.5 – 6.8 cal kyr B.P. prove that fine-laminated sediments represent high-level stands of the lake in the early mid-Holocene, implied by a summer hydrological linkage with the Nile and a winter rainfall brought by the westerlies from the Mediterranean. Based on geographical derivation of tree and herb pollen, environmental affiliation of diatom taxa and varying geochemistry of the examined lake sediments, three main groups of the early mid-Holocene wind trajectories are reconstructed. Northwestern winds were presumably stronger than the northern winds and their weakening enabled expansion of southern winds. Two main atmospheric circulation phases are established with three turns of northwestern and southern winds before 7.83 cal ka B.P., followed by two sequences of northern, northwestern and southern winds after 7.83 cal ka B.P. Northwestern and northern winds brought winter rainfall and caused water turbulence in the lake, and the southern winds were accompanied by regional aridification, lower lake level and brackish episodes. The presented model of wind trajectories extends significantly our understanding of a crucial role of the Mediterranean atmospheric circulation on climate variability in northeastern Africa in the early mid-Holocene.

P-3487

## The preliminary results of the Holocene stalagmite palaeoenvironmental record from Postojna Cave, Slovenia

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### Abstract

Southwestern part of Slovenia represents a transitional climatic zone between the continental and Mediterranean conditions controlled by the air masses from above the Mediterranean, and majority of the precipitation originating from the Atlantic Ocean. Following the worldwide trend of climate warming, the average air temperature in Slovenia is also rising and the precipitation regime, including the intensity of precipitation, is changing. It is postulated that a highly diverse and for the most part of a transitional nature climatic conditions on Slovenian territory (merged in the contact of Alpine, continental and Mediterranean climatic conditions) can result in hazardous weather phenomena leading to natural disasters such as droughts and floods. Understanding the variability of the Holocene climate is therefore essential for accurate predictions of future climate change and the environmental response.

Slovenian territory, as a region merged in the contact of Alpine, continental and Mediterranean climatic conditions, still lacks comprehensive palaeoclimatic data from diverse proxies. We therefore began to focus on speleothems, which are valuable palaeoclimatic archives, with the oxygen and carbon isotope composition as the most commonly used proxies. They are abundant in the Postojna Cave System, one of the most visited show caves in the world.

The preliminary results of a Holocene speleothem reveal its growth rate between 6.6 and 3.3 ka BP to be around 4.7 cm ka<sup>-1</sup>. There is a notable variation in  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  isotopes throughout the growth period. Applying the difference in rainfall  $\delta^{18}\text{O}$  during a temperature change in Slovenia (0.3 ‰/°C), and the calcite/water fractionation at the mean annual temperature of the cave (8.7°C;  $\sim$ -0.25/°C) the net difference is too small for stalagmite  $\delta^{18}\text{O}$  to indicate only temperature changes, so it is likely that the oxygen isotope variations of the stalagmite (-8.11 ‰ to -4.52 ‰) are also caused by the variation in the amount of moisture. On the other hand, changes in  $\delta^{13}\text{C}$  (-11.58 ‰ to -10.17 ‰) are usually interpreted based on the proportion of C<sub>3</sub> and C<sub>4</sub> plants growing above the cave, but only across major climate transitions. Limited to Holocene and considering ecosystem disturbances during the Holocene, it most likely reflects changes in biogenic soil CO<sub>2</sub> production caused by anthropogenic activities above the cave. Both  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  show greatest environmental instability around 4 ka (BP), which could relate to the “4.2 Event” in the central Mediterranean, but further research is needed to confirm this.

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P-3488

## The Late Antiquity climate in central Italy: speleothem evidence for a marked wetter period during VI and VII century CE

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### Abstract

There is increasing evidence that during Late Antiquity a significant climatic deterioration in the Northern Hemisphere occurred with important decrease in temperature during VI and VII century CE (e.g. Büntgen et al., 2016). In the Italian peninsula there are several pieces of historical and archeological evidence of climatic deterioration during this period, such as increased flooding (Cremaschi & Gasperi, 1991). However, these are controversial (Sqatrii, 2010; Cremonini et al., 2013) and very few paleoclimate archives possess the resolution for defining in detail the paleoclimate of the Late Antiquity (Sadori et al., 2016) within the Italian region. Here we present a stable isotope record from a stalagmite collected in the Renella cave, supported by 9 U/Th ages covering a period from the I to IX century AD, with decadal resolution. Between ca. 500 and 650 CE stable isotopes indicate a particularly prominent, double spiked, period of wetter conditions. This corresponds, within age error, to the double spiked reduction in temperature in central Europe (Büntgen et al., 2016) and a prominent period of negative NAO condition as reconstructed by Olsen et al. (2012). This reconciles archeological evidence and historical accounts, indicating that the reported increases of flooding are not just related to the decline of the Roman Empire, but corresponded to wetter climatic conditions.

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P-3489

## Moisture sources of Lake Lisan (Dead Sea Basin, Near East) during its maximum highstand period in MIS 2

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### Abstract

Ancient shorelines and exposed laminated lake sediments at high positions above the modern Dead Sea level show that its late Pleistocene precursor, Lake Lisan, filled a significantly larger basin. Previous studies showed that the level of Lake Lisan was ca. 200 m higher than those of the Holocene Dead Sea between 30-20 ka, and that Lake Lisan and the Sea of Galilee in the north of the Dead Sea Basin formed a merged water body during times of highest lake levels. However, a significant increase in regional moisture availability during the first half of Marine Isotope Stage 2 was not indicated by speleothem and other climate records in the region.

Therefore, we investigated sediments of the Lisan Formation in the northern, western and southern vicinity of the Dead Sea to tackle the question of the water source regions of Lake Lisan during its highstand periods in the late Pleistocene. Upper Cretaceous to Eocene marine foraminifera originating as detrital particles from catchment rocks are used here for the first time to trace the significance of locally generated runoff to Lake Lisan. Allochthonous foraminifera are abundant in sediments of a section near the Yarmouk River inflow into the Jordan River Valley. In addition, valves of autochthonous brackish water ostracods and of probably allochthonous freshwater (*sensu lato*) ostracods were recorded, indicating strong discharge to Lake Lisan from northern sources.

Abundant ancient foraminifera in sediments from exposed sections at Massada and in the Arava Valley provide evidence for significant runoff generated in the presently hyper-arid region in the southwest and south of the Dead Sea. These results indicate that precipitation was apparently not only significantly higher in the northern upland regions of Lake Lisan (Mount Hermon, the Golan Heights and the Upper Galilee) but also in the low-lying region of the Negev Desert.

P-3490

## Holocene Paleoenvironments in the Western Mediterranean Sea : palynological evidences on the Algerian coast

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### Abstract

Along the Algerian coast, present and past oceanographic and climatic conditions are complex. Atlantic Ocean surface waters penetrate today into the Mediterranean Sea by the Gibraltar strait; then, the Algerian current follows the North African coast according to a whirlwinds succession, itself responsible for recurrent deep water upwelling plumes in the Alboran Sea.

This study aims to reconstruct the paleoenvironment changes over Holocene along the Algerian coast associated to the hydrological dynamic on planktonic ecosystems at high temporal resolution (decadal to pluri-decadal). Based on palynological analysis, our goal is to show past sea surface hydrological changes and their sensibility to the regional and global climatic variability. We use the MD04-2801 core (Algerian coast, 2067 m water depth, Prisma cruise) which cover the last glacial and the Holocene with a secular resolution. More than one hundred pollen/dinocysts samples have been counted for the last 14 000 years BP. Among main features, we highlight (i) periods dominated by recurrent upwelling cells during the Younger Dryas (12.7 to 11.7 ka BP) and the Early Holocene (11.7 to 8.2 ka BP) as well as from 6 ka BP onwards, and (ii) periods characterized by increased fluvial outflows between 8.2 and 6 ka BP during the African Humid Period. The comparison between our results and available marine palynological records underlines the Algerian margin singularity in terms of dinocyst assemblages, especially regarding the over-representation of heterotrophic taxa on the Algerian margin, that allows discussing upwelling dynamics through time.

These preliminary results (Master 2 thesis defended in Spring 2018) are part of the PhD project « From western to eastern Mediterranean Basin: Marine palynological evidences for understanding Holocene gradients in climatic and paleohydrological processes » (October 2018–October 2021, Univ. Brest, Brittany Council, France). This project is defined by 3 principal research axes: i) the methodological development of monospecific pollen grain radiocarbon datings on marine cores, ii) the establishment of temporal oceanic reservoir age series by the comparison of the pollen and carbonates radiocarbon ages from the same sedimentary levels, iii) the Holocene palaeoclimatic high temporal resolution (pluri-decadal) study with a robust chronology allowing for a better understanding of the rapid climatic variability. First datings on monospecific pollen grains (*Pinus*) have already delivered some results on 3 levels of MD04-2801 core (ECHOmicADAS spectrometer for AMS 14C dates, LSCE, Paris). Despite their great uncertainty, these first results highlight the potential to succeed and are encouraging for the pursuit of the project. Also, marine palynological data (dinocysts) will be compared with continental palynological data (pollen, spores and other non-pollen palynomorphs) so as to cross land-sea, climate-hydrologic, information across the Holocene. This project is funded by the CNRS (INSU EC2CO(DRIL)-LEFE(IMAGO), Mistrals-PaleoMex), the LabexMer, Univ. Brest and the Brittany Council.

P-3491

## Paleofaunas and Climate in Mediterranean region: a South-east French view

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### Abstract

The Mediterranean realm in Southeast France is located between three mountainous regions (Alps, Pyrenees and Massif-Central) and divided by a main north-south river and valley named The Rhône. The hydrological basin of this river is very important and presently the influence of the Mediterranean climate is sensitive higher in this Rhône' corridor. These geomorphological features condition some partitioning, with two sub-regions (Provence at east of Rhone, and Occitanie at west), as well as a wide coastal plains and more elevated zones at the border of reliefs. In this contribution we will propose a synthetic view and multi-approaches studies (paleontology, paleoecology, biogeography, ecometry...) about the large mammalian associations considered within a diachronic perspective, namely from Late Middle Pleistocene to Late Pleistocene (from MIS 12 to MIS2). This time period is contemporaneous of major climatic phases (especially glacial vs interglacial stages), the succession of Neanderthal and Modern Human cultures, as well as a marked turnover in the faunal biomes known as an important limit between two sub-series: the Middle and the Late Pleistocene. More of 35 archeo-paleontological sites (and many more levels) record as many herbivore and carnivore associations through this space-time which can be analyzed in their dynamic sequence, quantifying several eco-biological factors (body-size, diet category..), including peculiar forms (ex. Cervid: *Haploidoceros*) and evolutive lineage or taxa replacement (ex. *Canis*, *Bison*, *Equus*...). We must note the importance of geographical factors in the taxa distribution together with the sea-level fluctuation especially marked in the west part of the region (Occitanie). Moreover, the area of Rhone delta and the corridor of this river condition strong wind flow which develop some thick deposits of eolian sands (loess), indicators of locally quite cold condition. Among evolutive traits, the particular case of caballine horses is interesting because showing special adaptive features related to the mild Mediterranean climate (peripheral zones) regardless of global climate conditions. Lastly, ecometrical analysis (meso- and micro-dental wear) developed on some sites and taxa are a valuable tool to precise local environmental features within the global climatic variations. It generally suggests a high resilience and adaptive capacities from the large and medium size herbivores (Equids, Bovids, Cervids). Paleofaunas constitute a well-documented terrestrial archives for paleoclimate reconstruction, raising issues about interactions with climate and local geographic factors; our study allow us to envision the real biological changes, responses or resilience of the mammalian guilds/biomes within this peculiar Western Mediterranean space.

**P-3492**

## **The use of coastal geological features and geomorphological evolution as sea-level pressure pattern indicators: two study cases from Apulia (Italy)**

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### **Abstract**

We present two study cases which show how coastal geological features and/or geomorphological evolution can be an useful tool for reconstructing the sea-level pressure patterns.

The first case is the comparative study of the sedimentation patterns at two locations on the Apulia coast, Riviera sud di Manfredonia and Marina di Ugento. Up to c. 5500 cal. yr BP, a phase of accumulation of flint pebbles from the Gargano headland occurred at Riviera sud di Manfredonia (Adriatic coast); their transport from the Gargano headland (north of the study site) is incompatible with the current northward littoral drift and can be explained by a prevalence and dominance of N, NE and E winds and consequent southward littoral drift. After c. 4500 cal. yr BP, there was a rapid accumulation of sediments at Marina di Ugento (Ionian coast), which is best explained by a prevalence and dominance of S, SW and SE winds. The two different wind regimes identified can be explained by a change in the mean pressure configuration in the central Mediterranean. The first phase (until c. 5500 cal. yr BP) consisted of more frequent cyclogenesis to the east-southeast/south of the Italian Peninsula, followed by a second phase (from c. 4500 cal. yr BP) of more frequent cyclogenesis to the west-northwest. The period 5500-4500 cal. yr BP represents a transitional phase.

The evolution of the Ofanto river delta between the 18<sup>th</sup> century and the present, compared with the contemporary evolution of the Volturno river delta can also provide indications of pressure patterns that occurred in the last centuries. We started by the principle that, all other factor being equal, a phase of advancing in the delta is promoted by a phase of frequent floods. Thus we analysed the data on recent floods (1970-2015), and we found that the most favourable situations for floods at both rivers are: omega-blocking, deep low-pressure trough, strong meridional circulation (mode  $\Omega$ ) which create Mediterranean low pressure systems. Instead, a zonal circulation (mode W), can only cause floods on Volturno river. Since the evolution of a delta is driven by the frequency of floods, and because we found that the frequency of floods is guided by synoptic patterns, then a relationship can be established between delta evolution and synoptic patterns in the past. Consequently, past phases of the contemporary progradation of the Ofanto and Volturno deltas suggest the increasing frequency of mode  $\Omega$ , while phases of simultaneous progradation of the Volturno delta and stability and/or retreat of the Ofanto delta are indicative of the increasing frequency of mode W. This conclusion is reinforced by the fact that we demonstrated that anthropogenic factors which interacted with the delta evolution did not control the first-order evolution.

P-3493

## Holocene paleoenvironmental and climate change in the western Mediterranean deduced from a multi-proxy analysis from the Padul wetland record (Spain)

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### Abstract

The Mediterranean area is an interesting location to carry out paleoclimate studies due to its geographic situation between subtropical and temperate latitudes. The Holocene is a significant period to study past climate change, with the objective of analyzing climate patterns, estimating future climate scenarios. In this framework, a high-resolution multi-proxy approach (from millennial to centennial-scale) in the sedimentary sequence of the Padul wetland has been accomplished. To do this, pollen, inorganic and organic geochemical and sedimentological analyses have been performed in the uppermost 3.67 m of the record. This study has been based on seven radiocarbon dates (AMS) used to constrain an age-depth model where the 3.67 m of the sequence corresponding with 11.6 cal kyr BP. The study of the entire Holocene allows us to determine the significant climate shift that occurred during the middle-to-late Holocene transition. From around 9.5 to 7.6 cal kyr BP a significant expansion of deciduous *Quercus* occurred reflecting maxima in humidity in the regional environment. Locally, insolation maxima induced high evaporation, counterbalancing the effect of relatively high precipitation, and triggered very low water table in Padul and the deposition of peat sediments. A transitional period occurred between 7.6 and 4.7 cal kyr BP with a regional change toward more regional aridity and then regional aridification and locally higher water levels due to the decrease in summer insolation (probably related with lower summer evaporation). Superimposed on the general climatic and environmental long-term trends during the Holocene is millennial-scale variability, recorded through several abrupt decreases in forest pointing to arid events ~ 9.6, 8.5, 7.5, 6.5 and 5.4 cal kyr BP with cyclical periodicities (~1100 and 2100 yr) during the early and middle Holocene. A change in the periodicity of these events towards a ~1430 cal kyr BP during the late Holocene around 4.7–4, 2.7 and 1.3 cal kyr BP. The comparison of our results with other paleoclimate records suggests that during the early and middle Holocene forest declines are at least partially controlled by external forcing (i.e. solar activity) and the late Holocene variability is related with internal mechanisms (oceanic-atmospheric).

P-3494

## High resolution characterization of Sapropel 1 in the Central Mediterranean (Adriatic Sea) through planktonic foraminifera, geochemistry and XRF analysis

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### Abstract

The Mediterranean Sea is a semi-enclosed sea where regional climates exert control on the formation of deep water masses at its two basins (eastern and western). At present, there are four major intermediate and deep water convection cells: Levantine Basin (intermediate), Aegean Sea (deep) and Adriatic Sea (deep) on the eastern basin, and Gulf of Lions (deep) on the western basin. These cells are interconnected and act as a driving engine of the Mediterranean thermohaline circulation (MedTHC).

Major changes on the MedTHC occurred during the Early-Middle Holocene (9.5 – 6.5Kyr), when the Mediterranean Sea was characterized by an asynchronous oceanographic pattern between its two sub-basins. On the western, there was a major strengthening in the deep overturning cell, meanwhile, on the eastern started one of its major phases of stagnation, resulting in the Sapropel 1 event (S1). Sapropels are caused by complex interactions between climatic and biogeochemical processes and are considered diagnostic of periods with anoxic deep-waters.

We present new results obtained from the South Adriatic Sea, at a location where deep waters are connected to the waters of the Ionian Sea through the Otranto Strait. This site is well suited to investigate Holocene climatic changes due to its unusually high sedimentation rate and the proximity to the Adriatic deep water convection cell. We have focused on high resolution analysis of the S1 interval of the core ND14M-bis (655m water depth).

Changes in surface water properties were reconstructed based on the ecological interpretation of planktonic foraminiferal assemblages. This information is also complemented with stable isotopes ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ) data of *Globigerina bulloides*. Additionally, variations in deep water properties were reconstructed in base of the geochemical analyses of the U/Mn ratio measured in planktonic foraminiferal coatings, as well as the paleoecological interpretation of benthic foraminiferal assemblages. All this information is combined with XRF elemental data from the bulk sediment.

The results allowed us to clearly define the S1 and its interruption phase. Our new data suggest the onset of surface waters stratification prior to the beginning of sapropel S1. The increase of the abundance of *Globigerinoides ruber* white, and decrease of *Neogloboquadrina pachyderma*, *Globorotalia scitula* and *Globorotalia truncatulinoides* support surface ocean stratification. The deposition of the sapropel is shown by the increase in deep water nutrient content, represented in our data as an increment of XRF Ba and *Globigerinoides ruber* pink. The U/Mn data and the benthic foraminiferal assemblages further support the occurrence of highly dysoxic waters during both phases of S1, and a rapid re-oxygenation event during the interruption, also marked by *Globigerinoides ruber* pink and *Globorotalia inflata*. We finally propose a sequence of events for the occurrence of S1 in the South Adriatic Sea.

P-3495

## Changes in South Tyrrhenian surface and deep waters properties during the last sapropel formation in the Eastern Mediterranean Sea

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### Abstract

The Mediterranean Sea is a semi-enclosed sea formed by two different basins connected through the Strait of Sicily. Changes in the climatic conditions in the region exert control on the formation of dense water masses that fuel the Mediterranean Thermohaline Circulation (Med-THC) through 4 main convection cells. All these cells are interconnected through the Med-THC system, but their individual response during past climate changes is not fully understood.

During the Holocene, a major change occurred in both deep and intermediate convection cells in the E-Mediterranean Sea at the same time of the last sapropel (S1) formation between 10 and 6 kyr cal. BP. But little is known about the impact of these changes in the water properties exported into the W-Mediterranean Sea through the Strait of Sicily. The present study focusses on the analysis of the sediment core NDT-6 from the South Tyrrhenian basin, the easternmost basin in the Western Mediterranean Sea and close to the exit of the Strait of Sicily.

Core NDT-6 was extracted at 1066 m water depth, which is the present-day depth of the interphase layer between the eastern and western Mediterranean water masses in the region. Thus, this core is suitable to evaluate changes in the properties of the water masses transferred from the E-Mediterranean into the W-Mediterranean. A precise chronological framework for core NDT-6 has been established by <sup>14</sup>C accelerator mass spectrometry (AMS) dates on planktonic foraminifera. Here we focussed on the interval between 5936-10501 kyr BP where S1 formation occurred in the E-Mediterranean Sea. Sedimentation rates for this period are between 15.92 and 37.31 cm/kyr allowing the resolution of the interval in study to be between 27 and 62 years per cm.

Changes in surface water properties are reconstructed using stable isotopes ( $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$ ) measurements in *Globigerina bulloides*, as well as based on planktonic foraminiferal ecology. Fluctuations in deep water properties are reconstructed using geochemical analyses in benthic foraminifera (stable isotopes and Mg/Ca ratios), U/Mn ratios measured in planktonic foraminiferal coatings and combined with benthic foraminiferal assemblage analysis. Finally, variations in the intensity of deep water currents is explored by means of grain-size analyses measured on the terrigenous fraction.

Major changes in all the proxies are observed particularly during the time of deposition of the first phase of the S1 (S1a) and during the S1 interruption. Our data reveal the occurrence of rapid changes (decadal scale) in surface water properties and also in the temperature and oxygen content of intermediate waters. We hypothesize that changes in the E-Mediterranean circulation might have had a major impact on the Tyrrhenian intermediate waters particularly during the S1b.



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**P-3496**

## **Sea surface temperatures & planktonic foraminifera palaeoecology during short-term climate oscillations of the Late Pleistocene in the Gulf of Lion.**

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### **Abstract**

The modern Mediterranean can be characterised as a warm oligotrophic sea, with steep thermal and salinity gradients from west to east. In contrast to these generalised patterns, the North-Western Mediterranean is unique in that it is one of the coldest regions of the Mediterranean Sea; it is an area of deep water formation with high sediment influx from the Rhone Delta plume; and it is strongly influenced by global climate patterns, such as the North Atlantic Oscillation. It is well-known that Mediterranean deep-sea sediments are an excellent archive of the intensity and evolution of both regional and global climatic fluctuations during the Late Pleistocene. However, historically the Western Mediterranean has been less systematically investigated, in comparison to the eastern basin. Therefore, this research utilises the planktonic foraminiferal assemblage of a high-resolution sediment core (M40/4 82-2SL) from the Gulf of Lion, to determine the extent of climatic oscillations during the Late Pleistocene in this region, along with the variations in localised hydrology and ecology, and how microfaunal communities responded to these changes.

The chronology of the core was constrained by 9 radiocarbon dates, and the core extends back to the end of Heinrich Stadial 1 (HS1) (~15.5kyr), providing a detailed record of the Bølling-Allerød (BA), Younger Dryas (YD) and Holocene in this region. Using Artificial Neural Networks, the average annual sea surface temperatures (SST) during the BA (~15.08°C) were approximately 3°C lower than modern SST in the W. Mediterranean. During the YD, SST decreased to an average of 8.2°C, approximately 10°C lower than today and 3.5°C lower than the LGM average in the Western Mediterranean [Hayes et al., *Quaternary Science Reviews*, 24, 999-1016 (2005)]. A principal component analysis (PCA) indicates that stratification is the main ecological variable governing species distribution (PC1: 57.03%), along with productivity (PC2: 18.65%) and temperature (PC3: 16.74%). In addition, this high resolution of the core allows for detailed examination of shorter centennial-scale events, such as the 8.2 event and Inter-Allerød Cold Period.

P-3497

## **Anomalous warm and humid climate during GS-2 in Formentera Island (Balearic Islands, Spain, Western Mediterranean).**

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### **Abstract**

The sedimentary sequence developed in Formentera Island records the successive and abrupt climatic changes occurred since the last Interglacial in this part of the Western Mediterranean. Geomorphological, sedimentological and palaeopedological analyses, supported by luminescence dating, phytolith content and magnetic susceptibility allowed reconstructing the environmental and climatic evolution along an entire glacial cycle.

Above the last coastal remains of possibly MIS 5a age, with a sea level close to the present one, a complete terrestrial sedimentary sequence records the change from the humid and warm end of MIS5a, through the arid MIS4 towards a progressively wetter MIS3. During warmer and humid periods, redder colluvial and alluvial deposits with soil development took place; on its turn, arid periods are characterized by dune development, where slight moisture changes are evidenced by differences in root bioturbation (Bardají et al., 2017).

MIS3 is represented in the sedimentary sequence by an intensely bioturbated mass-flow dominated alluvial/colluvial unit with at least three different pedogenic phases, topped by a calcareous crust. On top of this crust a markedly different red clayey unit stand out in the sequence.

This unit shows a marked increase in total number of phytoliths with more dune/intradune grasses than halophytic meadows and presence of fresh water shrubs, that point to a higher water table; magnetic susceptibility also records a marked peak within this unit, witnessing an increase in humidity and temperature. TL/OSL analyses have given ages (17 - 20 ky) that point to late MIS2, correlatable in age to GS-2.1b, stadial that seem to have been slightly warmer than GS-2.1a and GS-2.1c as shown by Greenland data (NGRIP data, Rasmussen et al., 2014).

### **References**

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Rasmussen et al., 2014. A stratigraphic framework for abrupt climatic changes during the Last Glacial period based on three synchronized Greenland ice-core records: refining and extending de INTIMATE event stratigraphy. *Quat. Sci. Rev.* 106, 14-28

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P-3498

## A compositional metanalysis of pollen data reveals climate influence on vegetation in the Central Mediterranean region during the late Holocene

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### Abstract

The Mediterranean area represents a transitional climatic zone between the temperate conditions of continental Europe and the subtropical regime of the African continent. This ecotonal feature determines a high climatic heterogeneity within the Basin: different atmospheric mechanisms and their interplays influence the amount, distribution and seasonality of precipitations, and eventually determine changes in the distribution of plant communities on millennial/centennial time scales. In this study, we present a meta-analysis of Italian Palynological Data from 32 well-dated and detailed lacustrine and marine records, including more than 90,000 observations for the last 3200 years. All the data were interpolated and homogenized at a secular resolution, to allow comparison of the different time-series. The compositional nature of pollen data was considered statistically in a unique holistic system using the R package “compositions”. Pollen taxa were grouped in Plant Functional Types, to ecologically characterize the vegetational variations found along the Italian Peninsula through time. Concordant/discordant vegetation patterns and synchronic/diachronic fluctuations at different latitudes and in different phytogeographic and ecoregional contexts were found. The role of human impact in determining environmental changes and in blurring the natural climatic oscillations during the last thousands of years was considered. A clear 2.8 ka cal BP event is statistically recognized, involving the Italian vegetation with contrasting latitudinal trends: it appears as an arid event affecting southern Italy and leading to a forest decline south of ca. 43°N, while no drought effect on forest cover nor changes in overall composition are statistically recorded north of this latitude below the timberline ecotone. By contrast, a considerable increase in forest cover was found during the Roman Classical Period (RCP) all over the central Mediterranean. Despite increasing human impact in the last part of the Holocene, the forest development during the Roman Period is in line with the so called “Roman Humid Period”. In this case, the compositional-PCA suggests the dominance of natural climatic variability over the anthropogenic influence in determining vegetational landscape changes. Considering our data in a wider geographical context, it was possible to find evidence for a longitudinal variability characterized by opposite vegetational trends in response to precipitation distribution patterns. Thus, studying the Central Mediterranean region provides an important contribution for understanding the so called “see-saw pattern” between the western and eastern regions of the Mediterranean Basin.

P-3499

## Organic Rich Layer deposition in the Alboran Sea (Western Mediterranean Sea) over the last 800 kyr

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### Abstract

Over the past million years sapropels were deposited in the Eastern Mediterranean basin. In the western basin, similar sapropel layers were not formed; instead non-laminated Organic-Rich Layers (ORL's) were found. These ORL contain total organic carbon (TOC) concentrations of at least 0.8 %, and are assumed to be weak equivalents of the sapropel layers (TOC>2%). In this study, we investigate the Western Mediterranean climatic conditions during the last 800 kyr by using the ORL record from the Alboran Sea as indicator of hydrological conditions. The study of organic matter preservation in this area is of special interest since saline Mediterranean Outflow Waters (MOW) spreads on the deepest Alboran Sea, and changes in the rate of formation of these deep Mediterranean waters could affect North Atlantic circulation and thus global climate. Furthermore, a comprehensive study of ORL's occurrence and genesis over the last eight climatic cycles is still missing.

Herein, we present a continuous and high-resolution record of the concentration of C<sub>37</sub>alkenones ([C<sub>37:2</sub>+ C<sub>37:3</sub>]), n-nonacosane and n-hexacosanol. The concentration of C<sub>37</sub>alkenones ([C<sub>37</sub>]) has been demonstrated as an excellent proxy of TOC in this area, implying that it can be used as an indicator of ORL formation. The effect of bottom ventilation is evaluated with the Alcohol Index, which is based on preferential degradation of n-hexacosanol vs n-nonacosane. Moreover,  $d^{18}O_{\text{seawater}}$  is used with the aim of reconstructing past hydrographic changes. Our results show that ORL's were deposited during all major deglaciations. The persistent parallelism during the last 800 kyr between ORL deposition and low bottom ventilation indicates that the main driver of sedimentary C<sub>37</sub> concentration in the Alboran Sea is the variability of Western Mediterranean Deep Water formed in the Gulf of Lions, primary productivity playing a secondary role. Two different ORL profiles were identified. Deposition type I, with well-defined C<sub>37</sub> concentrations peaks prior to interglacial was associated to rapid and short deglaciations. In these cases, the orbital configuration was characterized by a maximum lag of 4 kyr between precession and obliquity, with higher values in the 65°N caloric summer half-year insolation curve. Deposition type II, with C<sub>37</sub> concentrations increasing slowly associated to slow and long deglaciations. In these cases, the orbital configuration was characterized by a longer lag between precession and obliquity, that resulted in values of the 65°N caloric summer half-year insolation curve leading to interstadial and latter to interglacial conditions.

P-3500

## Last glacial and deglacial environments of sub-alpine Northern Tasmania

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### Abstract

Most information on environments for the last glacial period [including the Last Glacial Maximum (LGM)] for Tasmania have been obtained from palaeoecological records from western Tasmania (e.g. Lake Selina) and glacial evidence from the Central Plateau, with a lack of records from eastern Tasmania and sub-alpine regions (~600 to 800 m elevation) in general. This study will report the findings for two new sites that cover the last glacial and deglacial periods, Nicholas Swamp, located at in a depression within the dolerite Nicholas Ranges at 859 m elevation, north east Tasmania, and Yellow Marsh, a *Sphagnum*/Buttongrass/Heath mire situated at Surrey Hills, north central Tasmania at 685 m elevation. Both records extend beyond the traditional Last Glacial Maximum period (i.e. between 22,000 to 18,000 years ago), with Nicholas Swamp providing a 48,000 year palaeoecological record and Yellow Marsh a 30,000 year geochemical and palaeoecological record. Key findings suggest a positive moisture balance for northern Tasmanian sub-alpine environments for at least the last 30,000 years, potential support for an extended LGM (i.e. 30,000 to 18,000 years ago) in eastern Australia (see Petherick et al., 2017) and evidence of increased burning and *Sporormiella* decline between 48,000 to 40,000 years that may indicate megafaunal extinction associated with anthropogenic activity at Nicholas Swamp. Further, both records provide insight into the Last Glacial Interglacial Transition (LGIT) or deglacial period. The Yellow Marsh record shows a transition from alpine herb-fields to rainforest around 12,000 years ago followed by the emergence of the modern vegetation (mixed rainforest/eucalypt forest/buttongrass moorland) between 10,000 to 9,000 years ago. The Nicholas Swamp record shows alpine herb-fields dominating the late glacial period (30,000 to 18,000 years ago) followed by vegetation indicating a climatically more variable LGIT and Holocene period.

Petherick, L.M., Moss, P.T. & McGowan, H.A. (2017) An extended last glacial maximum in subtropical Australia. *Quaternary International* **432**, 1-12.

P-3501

## SHeMax: A regional perspective on the timing of the Last Glacial Maximum in Australia

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### Abstract

It has been hypothesised that the last glacial maximum (LGM) in Australia occurred over multiple stages and at different times geographically, however this hypothesis has yet to be tested objectively. Such an objective comparison is complicated by several factors, including the variety of proxy archives, palaeoenvironmental proxies and dating techniques employed. In addition, recent refinement of the Southern Hemisphere radiocarbon calibration curve, plus advances in Bayesian age modelling and in analysing age-uncertainty in time series, require an approach that treats all data consistently. In order to gain a greater understanding of the spatial and temporal patterns of climate change during the MIS2, we have compiled proxy records of climate variability from across Australia for the period 35 – 15 ka. Continuous records covering at least 10,000 years, as well as discontinuous records of fluvial and glacial activity, were included in the synthesis. For each record, a revised age-depth model was developed using Bayesian age modelling techniques. Complex records (e.g. pollen records) were reduced to one-dimensional Principal Curves, in order to provide a non-linear summary of patterns of change in the full data-sets. Monte-Carlo change point analysis was then used to identify the timing of major changes within each record, along with the uncertainty around that date. We assess the spatial heterogeneity of the timing of the major climatic changes during the 35 – 15 ka period and determine the probability of common timing of change across Australia. Explicitly incorporating the age uncertainties associated with each record allows for a more robust interpretation of synchronous periods of change. Further expansion of our analyses will allow interrogation of both spatial and temporal synchronicity and coherency of the most recent and extreme climate and hydrological changes in Australia.

P-3502

## Developing a chronostratigraphic framework for the Quaternary of southern Africa

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### Abstract

The Quaternary System (last 2.58 Ma), characterized by both significant climate change and the development and spread of human and other species, has been examined in much detail in order to define the timings of different climatic phases within this System, and the regional to global synchronicity of these phases. This effort is underpinned by the principles of chronostratigraphic correlation put forward by the International Commission of Stratigraphy, a commission of the International Union of Geological Sciences (IUGS). The Subcommission on Quaternary Stratigraphy has chronostratigraphic charts for many regions of the world but southern Africa is notably missing. This is a critical omission, given the importance of the region in hominin evolution during the Quaternary. Here, we propose procedures for, and a preliminary chronostratigraphic subdivision of, the later part of the Quaternary System of southern Africa (south of ~15oS). A key difference between southern Africa and many other parts of the world is that the Quaternary has no regional glacial expression (either morphologically or chronostratigraphically), meaning that the glacial-interglacial terminology for Quaternary environmental changes are not meaningful. As such, we use Antarctic Isotope Maxima from the Vostok record as a starting point, providing a high resolution regional temperature curve for regional comparison. The methodology we have adopted integrates multiple published climatic/environmental proxies from many existing sites and records in southern Africa. We look for evidence of a significant system change in the record, corresponding to some kind of threshold-like effect that is of regional scale, synchronous, and does not correspond to merely local variability. The system change should be manifested in several different proxies and should be constrained by some geochronometric control. We also use archaeological evidence (technological and/or cultural) as a valid proxy. Results of this analysis are broadly consistent with the Quaternary chronostratigraphic framework for other parts of the world, but some differences, similarities, and problems remain due to the poor spatial and temporal resolution of southern African records for this period.

P-3503

## Regional climate event stratigraphies for Australia for the period 35-15 kyr BP

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### Abstract

Here we synthesize climatic variability in Australia for the period 35-15 cal. kyr BP, sub-dividing the period into “climate events” by region. This timeframe encompasses the termination of MIS3, the traditionally-accepted timing of the last glacial maximum (LGM: ca. 24-18 kyr) and the onset of the deglaciation. A review of palaeoclimate records from Australia shows evidence for the onset of the LGM prior to 24 kyr, providing the impetus for this work. Emerging records also show that climate during the period 35-15 kyr was significantly more complex than the traditionally-accepted state of increased aridity. In this study we aim to (a) determine whether periods of major climate change occurred synchronously across Australia, (b) identify regional climate events, (c) describe regional climate conditions during these events, and (d) postulate drivers of regional climatic variability for the period 35-15 kyr. To achieve this, Australia can be first divided in six palaeoclimatological regions: summer dominant rainfall, summer rainfall, seasonally uniform rainfall, winter rainfall, winter dominant rainfall, and arid. We integrate continuous and discontinuous records from multiple proxies and environmental archives, identifying spatial and temporal patterns within each region. This allows for regional trends and changes to be identified, and regional signals to be disentangled from broader-scale climate events. In this study, climate event stratigraphies were constructed for each region, based on multiproxy evidence and where these proxies represent a diagnostic climatological signature. Following this procedure, time-coherent climate changes are described, which largely represent spatially-consistent changes in effective moisture availability (rather than temperature), likely including changes in seasonality. From such analysis, drivers of climate variability can be postulated, likely including changes in moisture source areas, trajectories of low-latitude cyclones, and monsoonal and El Niño/Southern Oscillation strength.

**P-3504**

## **Examining the use of a fossil pollen ratio on the Australian Last Glacial Maximum (LGM) record to determine rainfall seasonality.**

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### **Abstract**

Rainfall seasonality is variable in Australia, with three major rainfall seasonality zones across the continent. The northern part is dominated by summer rainfall, most of the central area has no dominant seasonality, or is too arid to have one determined, and most of the southern part of the continent is dominated by winter rainfall, except in the east, where there is no dominant season of rainfall. It has previously been difficult to find adequate proxies to estimate past rainfall seasonality, with the Last Glacial Maximum (LGM) being a particularly important period to study, given the known global changes in precipitation patterns. We propose using the ratio of fossil pollen Asteraceae to Poaceae as such a proxy, where high ratio scores indicate winter rainfall and low ratio scores indicate summer rainfall. This ratio has been used with some success in multiple studies in South Africa, a country affected by two major rainfall seasonality zones, summer and winter. In this study, we examine the validity of using this ratio as a proxy for rainfall seasonality on the Australian LGM record. We use the wider chronozone of 15-35 ka BP to signify the LGM but will also look at narrower time slices. We focus here on the east coast, which has the highest concentration of records. Our results demonstrate the usefulness of this ratio, with a slope-like pattern visible along a north-south transect. In Tasmania the winter rainfall zone is apparent, and in tropical Queensland the results indicate a precipitation pattern dominated by summer rainfall. In between are mainly intermediary sites with no dominant rainfall seasonality during the LGM. Interestingly, some of these intermediary sites are located quite some distance north of the modern boundary between the summer-dominated and non-seasonal rainfall zones. This suggests that the non-seasonal rainfall zone may have been wider during the LGM, possibly extending into the current subtropics. Apart from this, the eastern Australian rainfall seasonality zones during the LGM appear to have been quite similar to those of today.

P-3505

## Geomorphological and chronological evidences for the Last Glacial Maximum in the Cachapoal Valley (Southern Central Andes of Chile, 34-35°S)

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### Abstract

The study presents results of a geomorphological reconstruction of the Quaternary glacier extent in the Cachapoal Valley in the Southern Central Andes of Chile. The Cachapoal Valley shows striking evidences of a formerly more extensive glacier expansion. Classical U-shaped valleys, moraines and roches moutonnées are amongst others geomorphological witnesses of the former glaciations. Topographically and climatically, the Cachapoal Valley provides favorable conditions for glaciation. The E-W trending valley, a tributary of the Rapel River, drains one of the most southern located mountain massifs of the Andes exceeding altitudes of above 5000 m (Picos del Barroso 5180 m). The upper catchment areas are home to some of the largest glaciers of the Central Andes, among them the 12 km long Cachapoal Glacier. In climatic terms, the valley is located in the transition zone from the Dry Central Andes to the Wet Andes with increasing annual precipitation southwards. Thus, the research area marks a key location for the discussion on the dominant factor in the temperature-precipitation regime in regard to the timing of the LGM. In the present research project, geomorphological field work was carried out to identify and map the glacial landform assemblages in the Cachapoal Drainage Basin. Additionally, surface exposure datings were obtained from boulders situated on the crest of lateral moraines in the assumed LGM-glacial margin and along the modern Cachapoal Glacier using cosmogenic <sup>10</sup>Be. The interpretation of the field evidences suggests a dendritic paleo-ice stream during the Last Glacial Maximum with the main affluents of Cachapoal (60 km), Cortaderal (40 km) and Cipreses (37 km) flowing down at least to an elevation of about 950 m a.s.l. In principal, this is in accordance with previous works in the study region. However, the results will be discussed in the light of the discourse of the genetic interconnection of moraines and landslides as amongst others the reconstructed LGM ice margin is located in a large-scale landslide area. The contribution aims to provide additional facts for the establishment of a more detailed relative and absolute glacial chronology of the Central Andes during the Last Glacial Maximum and to shed light on the determination of the nature and timing of glacier changes during the last glacial cycle.

**P-3601**

## **The character of Caspian Sea level fluctuations in Late Pleistocene-Holocene.**

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### **Abstract**

Stratigraphy of the Caspian Sea history as a whole was created in the early 20th century. Most of the data were obtained from the outcrops along the Lower Volga. In them khvalynian deposits lie in the form of thin layers. These are chocolate clays (CC) and sometimes sand layers which are deposited on the sediments of different genesis – subaerial atelian loams, alluvial sand or marine khazarian sediments. It was believed that CC are the deposits of the deep Early Khvalynian basin when the level of the Caspian Sea reached 50 m.

A detailed study of CC – distribution in the Northern Caspian Plain, the character of their position in the outcrops, lithology, etc., allowed us to assert that CC are the lagoons deposits (Badyukova, 2010). As soon as we came to this conclusion, it was necessary not only to interpret all previously studied outcrops differently but also to review the history of the Caspian Sea level fluctuations in the at the end of Quaternary period.

In this connection, the main attention was paid to the laws of the coastal zone reaction to the sea level fluctuations, which were not taken into account earlier. To explain the existing contradictions, the idea of forming lagoon-transgressive terraces against the background of sea level fluctuations, where CC were formed, was put forward. Directly from the surface, CC could form only if there were such terraces.

As a result proposed another scheme of the Caspian Sea level fluctuations, different from the conventional one. According to it, there was the Great Khazarian transgression, the level of which, judging by many outcrops, was slightly lower than the Early Khvalynian transgression. This is indicated by many sections on the Volga where at that time extended the estuary up to Saratov. The entire subsequent history of the Caspian Sea is a gradual sea level fall interrupted by its rising. Early and Late Khvalynian transgressions occurred on the background of general sea level fall, their amplitude did not exceed 20-25 m. This indicates the dimensions of different age alluvial deposits, observed in the outcrops sequentially located along the Lower Volga and other rivers (e.g., rivers Large and Small Uzen) at lower hypsometric levels.

Thus, there was no deep Atelian regression. Moreover, Early Khvalynian transgression did not begin from minus - 100-120 m but was from approximately 0 m. Formation of lagoon-transgressive terraces and CC occurred in various stages. Therefore, the age of the Early Khvalynian transgression varies – from the older on the high terraces to the younger on the lower hypsometric levels.

P-3602

## The Caspian - Black Sea - Mediterranean corridor: water exchange and migrations of fauna during the last glacial epoch

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### Abstract

The last glacial epoch (MIS 2) includes some climatic events: the LGM (26.5-20 ka), the early deglaciation (20-14.7 ka) and the late glacial (14.7-11.7 ka). The late glacial displayed relatively short-term climatic fluctuations known as the Bølling and Allerød (14.7-14.0 and 13.6-12.9 ka) separated by the cooling of the Middle Dryas, and conspicuous cooling of the Younger Dryas 12.9-11.7 ka. During this entire interval, temperatures were changing at a considerable rate. These climatic changes found reflection in development of basins of the Caspian - Black Sea - Mediterranean corridor. They represented the basins of different types. The transgressive and regressive condition of the Caspian Sea (the lake basin) depended on its water balance. The mode of the Mediterranean Sea was defined by fluctuations in the level of the Ocean. The condition of level of the Black Sea depended on the levels of the Mediterranean and the Caspian Seas. In the Mediterranean Sea, the Tyrrhenian transgression was replaced by a long, uneven decrease in sea level. In the MIS 2 horizon of deep-water deposits of the Sea, cold-water foraminifera prevail. Proof of a deep decline in sea level from 100 to 130 m gave a set at this time. In the Pontian, the regressive Neoeuxinian basin (from -110 to -130 m) with mostly fresh water mollusks developed during the LGM. A connection with the Mediterranean Sea was absent. The Sea of Azov was a coastal plain crossed by the Don River whose mouth was located 50 km south of the Kerch Strait. The climatic conditions resulted in a negative water balance for the Caspian (Khvalynian) Sea, causing a sea-level drop. The Khvalynian transgression resumed during deglaciation after the LGM. The Early Khvalynian transgression, having reached the level of the Manych threshold, created an erosive valley and discharged into the Neoeuxinian basin. Transgression of the Caspian type began in the Neoeuxinian basin during deglaciation too. The transgressive interval was dominated by Pontocaspian mollusk species. The occurrences of Khvalynian species in the Neoeuxinian deposits confirm the overflow of Caspian waters. This interval corresponds to a rise in water level to -20 m. At the same time, the presence of Neoeuxinian faunas in the Marmara basin and northern Aegean suggests Black Sea overflow. The Neoeuxinian basin was overflowing. Glacio-eustatic increase in the level of the Ocean in the Mediterranean Sea carries the name of the Flandrian transgression with modern Mediterranean mollusks. Penetration of waters into the Black Sea basin caused the Chernomorian (Black Sea) transgression with euryhaline and moderately stenohaline Mediterranean mollusks. In the Caspian Sea at the beginning of the Holocene there was a deep Mangyshlak regression. The investigations are supported by the RFBR (Projects 18-05-00296, 18-05-00684).

**P-3603**

## **Inner structure and age of development of the Baer knolls in western Volga delta**

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### **Abstract**

The history of the study of Baer knolls (BK) counts more than a century. There are several theories of the origin of BK. In this paper, we provide information about the inner structure of Baer knolls in the western (Mirny, Dolgiy, Troitsky) and central (Yaksatovo, Nartovo) parts of the Volga delta.

The aim of the study is to identify the inner features of the structure of BK and the mechanism of their forming. To achieve this aim, several methods were used (granulometric, geochemical, malacofaunistic and radiocarbon).

BK in the Volga delta, in general, have a similar inner structure. In the basement there are chocolate clays (CC) with lenses of sand. Above there is a lower thickness (LT). The LT consists of cross-bedded dark brown clay and silt with thin layers of detritus. The thickness of LT is about 4–5 m. Above there is an upper thickness (UT) which consists of lighter pale-brown sand and silty clay. The lamination is mainly oblique with monoclinical and wedge-shaped structure. The thickness of UT is 2-3 m.

The grain-size analysis confirms the presence of UT and LT, which are separated by erosion boundaries. Based on grain-size and geochemical data the LT and CC composition are mainly similar. The LT usually contains finer fraction, it has two modes in coarse clay and coarse silt (0.01-0.05 mm). The UT is distinguished by a sand composition with two peaks in clay (0.001-0.005 mm) and fine-grained sand (0.05-0.25 mm).

The radiocarbon dating of the LT in the Yaksatovo BK is  $15280 \pm 180$  cal yr BP.

A malacofaunistic analysis was carried out for two knolls (Mirny and Yaksatovo). On the contact of the LT and CC in the Yaksatovo, shells were found *in situ* *Didacna protracta*, *D. parallella*, *D. parallella borealis*, *D. praetrigonoides*. In Mirny, on the contact between the LT and UT, *D. praetrigonoides*, *D. protracta* were found. These species were distributed at the end of the Lower Khvalynian and the beginning of the Upper Khvalynian stages.

The geomorphology of the central part of the delta reveals that the ridges in the lowermost part are absent, and the thickness of alluvial sediments is more than 20 m, which means that there was an active river runoff in this area that destroyed the ridges (Rachkovskaya, 1951). Consequently, BK could have been formed since the end of the Early Khvalynian transgression, and especially during the Late Khvalynian and the Early Holocene. Probably, the LT was formed in the subaquatic conditions, while the subaerial (aeolian) processes, played an important role in the formation of UT.

This work is supported by the RSCF (Project 16-17-10103).

P-3604

## Stable oxygen isotope analysis of the Northern Caspian Basin during the Late Pleistocene

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### Abstract

Over the past years our group of researchers from MSU and OAO «MorInzhGeologia» studied Late Pleistocene sedimentary evolution of the North Caspian basin (Bezrodnikh et al., 2015, 2016, 2017; Bolikhovskaya et al., 2017; Sorokin et al., 2018; Yanina et al., 2018). Here we report on stable oxygen isotope analyses of cores KOP-4 and IGS-1, from the Caspian North-Western area. The studies are based on drilling material from the shelf. Isotope analysis was carried out on ostracod shells.

Global climate changes were fundamental for both the transgressive-regressive state of the Caspian basins, as well as for glacier formation and retreat on the Russian Plain. Isotopic composition changes reveal the influx of fresh water in the Northern Caspian Basin as well as it reflects global climatic changes. Thereby we show the correlation between transgressive-regressive events among Ponto-Caspian basins and glacial-interglacial epochs at the East European Plain during the Late Pleistocene.

Previously the obtained cores were studied with lithological, faunistic, palynological and geochronological (radiocarbon) methods (Svitoch et al., 2008). We used this data for more accurate paleoreconstruction.

Our first isotopic results show climate factors driving Caspian Sea level fluctuation during the Late Pleistocene. Insignificant peaks of lighter  $\delta^{18}\text{O}$  ratios meaning the increase of meteorological component in water balance, characterize small-scale warm transgressions – like Late Khazarian (-7,04‰) and Novocaspian (-6,24‰), which took place during the interglacials. The Hyrcanian interval is characterized by high amplitude changes of  $\delta^{18}\text{O}$  ratios: records vary from -3,37‰ in lower part to -10,62 ‰ in the middle part (maximum transgression) and again up to -3,65‰ in the upper part of the layer, showing regression that marks the onset of the Atelian regressive stage. The very low  $\delta^{18}\text{O}$  ratios (-10,55‰) found in the base of the interval overlying the base of the Atelian interval. Such values indicate near fresh water conditions at the time. The  $\delta^{18}\text{O}$  ratios in the Khvalynian interval ranges from -13,46 ‰ to 1,16 ‰. The isotopic curve reflects a number of states of the Khvalynian basin level. Thereby the maximum influence of fresh water inflow into the North Caspian basin was during the Khvalynian. The  $\delta^{18}\text{O}$  value -1,62 ‰ was recorded for the Mangyshlakian layer. The last recorded  $\delta^{18}\text{O}$  value -5,86‰ in the Novocaspian layer corresponds with the isotopic composition of the North Caspian water today.

The investigations are supported by RFBR Grant 18-05-00684 (lithological analyses) and RSF Grant 16-17-10103. Further study of Caspian Sea sediments by isotope methods will allow to get interesting results and settle some arguable issues of the Caspian region paleogeography.

P-3605

## Shoreline evolution of the northwestern Turkey (Marmara Sea-North Aegean Sea) evidenced by sea-level markers and relative sea-level changes: preliminary assessment

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### Abstract

Here, we present new data on the morphological, biological and sedimentary records of paleo-sea levels in the northwestern Turkey (Marmara Sea-North Aegean Sea), and discuss their potential use to reconstruct relative sea level changes. These markers represent a significant paleo-environmental proxy because they can record both the vertical and the horizontal evolution of the shoreline. There is a paucity of presently available data in this sector of the Marmara Sea, which is a tectonically active area strongly controlled by the North Anatolian Fault Zone. In addition, late Quaternary relative sea-level changes (RSL) at this region were not homogenous and variations in the tectonic setting played a crucial role in the coastal evolution. In this study, our investigation provides new insights into to delineate regional sea-level variations in the different sections of the Marmara Sea using a wide range of coastal sediments in terms of layering characteristics, stable isotope compositions, consecutive cementation structures, radiocarbon and luminescence dating. Coastal deposits are characterized by locally abundant shells, uplifted near-shore deposits, submerged beachrocks and coastal lagoon sediments the borders of the western Marmara Sea at different elevations. Notches and shore platforms are also identified as erosional morphologies, particularly in microtidal environments in this area situated in various altitudes above modern sea level and we correlate them with RSL changes. Fossil and living populations as biological indicators allow the vertical shift between present and former sea level to be established. In fact, the interaction between coastal processes and uplifting fault blocks contributes to the preservation of geomorphologic and/or biological records of vertical movements through time. Therefore, a detailed mapping of paleo-sea-level markers will be carried out as a tool to quantify coastal uplift/subsidence and RSL changes in this study. Firstly, we also apply online radiocarbon analysis for the ability of reaching a high spatial resolution from marine shells and coastal sediments in different sites along coastline. This study intends to determine a more accurate rate of uplift/subsidence history for the northwestern Turkey and to delineate the relationships between the geological features and regional sea-level variations, using radiocarbon and luminescence dating and field data relationships.

P-3606

## Past environmental changes in the South Caucasus according Armenia lakes and geomorphologic archives

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### Abstract

Within the framework of the Russian-Armenian project “Paleolimnological aspect of study of ecosystem evolution of alpine Russian and Armenian lakes»” in July-August 2018, we investigated four high-mountain lakes of Armenia. The research was carried out in the lakes Kari, Umroy, Akna and Sev. All investigated lakes are located at the altitude about 3000 m above sea level. The lakes were first investigated using a multi-proxy method that includes paleolimnological, geomorphological, hydrological, geochemical and biogeographic studies. From all the lakes, sediment sequences were collected for pollen, diatom, geochemical and radiocarbon analyses. For all the lakes bathymetric maps and three-dimensional models of the lake kettles were constructed, as well as the geomorphological maps of the catchment basins. According to preliminary results, the maximum age of the lake formation is about 7 ka. The studies were carried out as a part of the RFBR project No. 18-55-05008 and Science Committee of the Ministry of Education and Science of the Republic of Armenia No. 18RF-045.

**P-3607**

## **The middle Pleistocene sediments of Caspian Sea: the first absolute dates**

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### **Abstract**

During the Quaternary Caspian Sea level changed several times. Researchers have been exploring the Caspian Sea for two centuries. However, there is still no consensus on the number of transgressive-regressive events, their scale, chronology, and causes. The most controversial question is about the chronology of paleogeographic events, since absolute dates were obtained only for the last two transgressions: the New-Caspian (the Holocene) and the Khvalynian (the late Pleistocene). The most interesting transgression is Khvalynian, which had a catastrophic character in the opinion of some researchers.

Estimated age of the last huge transgression (Khvalynian; max. highstand +50 m a.s.l.) by different researchers varied from 70,000 years to 11,000 years, i.e. from the first half of the Wurm to the beginning of the Holocene. Estimated age are based on thermoluminescence dating (Shakhovets, 1987, Rychagov, 1997), electron paramagnetic resonance spectroscopy (ESR) (Molodkov, 1992), uranium-ionium (Kuznetsov, 2008; Arslanov et al., 2015), radiocarbon dating (Arslanov et al, 2013; Arslanov et al., 2015; Tudryn et al., 2013).

However, there hasn't been dating of sediments that correspond to the maximum level of the Khvalynian basin.

Along the valley of the Volga River and the inflowing valleys of small rivers, the Caspian Sea created a network of ingression bays during the largest transgressions. In the 20th century, the Middle Volga region was studied and described in details. But for all this time only two absolute dates have been obtained by the radiocarbon method, which are probably irrelevant. Determining the stratigraphic position of the sediments is difficult due to the almost complete absence of the malacofauna.

We sampled sediments for OSL-dating in one of the most studied sites - Maliy Karaman (Moskvitin, 1962), which reveals coastal sediments (described as deposits of the last major transgression - Khvalynian) and underlying loess with soil horizon.

We conducted the dating in the OSL-laboratory in All-Russian Geological Institute (VSEGEI), Saint-Petersburg. We expected dates as the first decades thousands years and therefore used quartz grains. Purity test and recovery test were conducted. However, it was found that the equivalent dose is significantly higher than we thought, and the quartz is saturated. Therefore, the sediment was analyzed by feldspar according to the post-IR IRSL protocol (Thiel et al., 2011).

For coastal sediments dates were obtained that correspond to the end of MIS 8 — the beginning of MIS 10, and for loess with soil horizon — MIS 13.

Thus, coastal sediments can be correlated with a much more ancient Caspian transgression (early-Khazarian; max. highstand +35 m). Thus, these are the first dates for the middle Pleistocene deposits of the Caspian Sea and the first absolute dates in the Middle Volga region.

P-3608

## Evolution of the South-Eastern coast of the Caspian Sea during last 15ka (Golestan province of Iran)

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### Abstract

Iranian coasts of Caspian sea is a unique region for understanding the history of the Caspian Sea in the Pleistocene, its correlation with the global and regional climate changes. The reason is representativeness of Quaternary sections, presence of both marine and subaerial sediments, paleontological richness of the materials and available for study.

At present, large-scale studies of the subaerial deposits of the region - first of all - the so-called Iranian loess plateau are being carried out. Works on the paleoclimatic reconstructions of the region in Holocene were performed by S.A.G. Leroy (2016). However, the Iranian coast remains one of the few sections of the Caspian where sea level reconstructions based on geomorphological evidence have not been performed. In our work, we tried to reconstruct the history of the development of the last and largest transgression of the Caspian Sea – Early Khvalynian, and to reveal the stages of its development in the territory of Northeast Iran. The object of research was the valley of the Gorgan River, in the sides of which a series of sections with marine, alluvial and aeolian deposits is revealed. We have described more than 30 sections throughout the valley, within the bounds of the possible influence of the Khvalynian transgression (up to a height of +70 m abs).

For the first time, deposits of mixed alluvial-marine genesis, reflecting the early Khvalynian transgression of the Caspian Sea, were found in the sections. Completed OSL-dating of sediments allowed to reconstruct the stages of development of the natural environment of the region after the LGM. Thus, 14-15 thousand years ago the middle part of the valley of the Gorgan River was covered by the waters of the Caspian Sea. In sections of the middle part of the Valley (altitude of +30 m), this stage is represented by rhythmic clays and loams of mixed marine and alluvial genesis. The transition to purely alluvial floodplain deposits. The upper part of the section is represented by subaerial loess deposits, with thickness of 7-8 m. The subaerial phase of sedimentation began about 11 thousand years ago with a high rate of formation of loesslike deposits.

Obtained new data allow us to reconstruct the history of the development of the region's geomorphology in the final stages of the Early Khvalynian transgression of the Caspian Sea (14-12 thousand years ago) and the subsequent continental stage, during which a deep cutting of the Gorgan River channel is noted with a synchronous accumulation of a thick layer of loess.

This work was supported by Russian Funding for Basic Research (17-55-560012)

P-3609

## First optically-stimulated luminescence ages of the early khvalynian "chocolate clays" of the Lower Volga

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### Abstract

During the Late Quaternary dramatic changes in relative sea-level are known to have occurred in the Caspian Sea. However, all previous attempts at resolving the uncertainty associated with the timing of these transgressive/regressive events using standard dating methods have produced inconclusive or controversial results. For the first time a reliable Late Pleistocene chronology has been derived using optically stimulated luminescence (OSL), and post-IR IRSL290 analysis of quartz and K-feldspar grains extracted from 20 sediment samples collected along the Lower Volga River. Analyses were conducted on multi-grain aliquots of the sand-sized fractions of loessic sediments, marine clays and the overlying modern soils from three exposed sections ~50km downstream of Volgograd. The signals from all quartz samples were dominated by the fast component; there was no significant IR sensitivity, and no significant dependence of  $D_e$  on preheat temperature. The post-IR IRSL290 signals from the 5 samples examined also met all laboratory-based criteria for a reliable estimate of equivalent dose. Resetting of the luminescence signals was investigated based on the differential bleaching rates of quartz OSL and K-feldspar signals; we conclude that all signals were sufficiently reset prior to deposition.

Our results show unambiguously that the Early Khvalynian marine Chocolate Clays present at all three sections were deposited post-LGM, between ~13.5ka and ~17 ka ago. These ages are further constrained by those from the overlying Kastanozem soils (0.7 to 9.1 ka) and underlying loess-soil series (19-30 ka). Relative (Caspian) sea-level during the Early Khvalynian must have been well above the sampling altitude of 9.33 m (Srednyaya Akhtuba), 8.51 m (Raigorod) and 6.98 m (Leninsk) to explain the absence of significant alluvial sand and to allow the deposition of the clay-sized particles of the Chocolate Clays marker horizon.

Research was supported by the Russian Science Foundation, project 16-17-10103.

**P-3610**

## **Identifying the stages of great Khvalynian transgression of the Caspian Sea in lower Volga region (Kosika section)**

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### **Abstract**

At the present time the stages of the Caspian sea-level evolution during the largest Late Quaternary Khvalynian transgression remains open. There have been attempts to establish an absolute chronology based almost entirely on radiocarbon dating, often of individual shells. This approach is of course limited to <50 ka but in any case has given very conflicting results; as a result, no consensus view of the transgression/regression history has evolved. In an attempt to resolve these problems, a major project (IGCP-481) was established to re-date the more recent transgressions using radiocarbon<sup>16</sup>. Unfortunately, most ages were again unexpectedly young and stratigraphically inconsistent.

Existing radiocarbon chronology does not allow to resolve two transgressions (Early and Late Khvalynian). Based on clear palaeontological and geomorphological evidence, these must be very different in age, but shells associated with both transgressions gave very scattered ages of between 8 and 50 ka (Arslanov et al, 2015). Another controversial issue is the stage between Early and Late Khvalynian – Enotaevka regression.

During 2014-2018 fieldworks we made an effort to find the section with clear continental sedimentation profile within two Khvalynian transgressive series. And such deposits were identified at Kosika location, on the right valley side of the Volga river, 4 km to the North of the Kosika village. The total thickness of the outcrop is 10 m. The outcrop is confined to the western base of the Baery knoll. The part of the outcrop with the most clear position of the Enotaevka regression deposits is confined to the northern limit of the Baery knoll. The profile of the paleosol represented by a series of genetic horizons and reveals clear evidence of erosion. Apparently, the original profile was abraded during the Later Khvalynian transgression resulting in preserved illuvial horizon. This strata passes into the marine clays with poor collection of shells (mostly *Dreissena* Sp).

The applied luminescence dating allowed us to reconstruct the timing of the main stages of the environmental evolution during the second half of Khvalynian transgression. 15 OSL-dates describes main stages: re-worked Upper Khvalynian sands of the upper Baery knoll strata is dated  $8,3 \pm 0,5$  ka; paleosol formed in the Enotaevka regressive horizon dated 12 – 13 ka; Lower Khvalynian sediments is characterized with three dates 19-22 ka; the basis of the section (Hyrcaian horizon) is dated 113-133 ka.

This research for the first time reveals the structure of Enotaevka regressive series of the Lower Volga and describes the numerical age of the main stages of the Late Quaternary environmental evolution of the region.

Research was supported by Russian Science Foundation (17-77-10134).

**P-3611**

## **Loess formation and Caspian Sea level changes in the Southern Caspian Lowlands, Iran, during the Late Quaternary**

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### **Abstract**

The formation of loess involves several climate-related processes including the production of silt-size particles, aeolian transport, deposition of dust and its post-depositional alteration. Topography and geomorphological factors play significant roles in loess formation, too. For instance, diachronic changes in the location and extent of dust deflation areas may significantly affect dust lithology and accumulation rates. It is widely anticipated that the water level of the Caspian Sea strongly fluctuated during the Late Quaternary. Accordingly, the spatial extent of the southern Caspian Lowlands, a major proximal source area of mineral dust accumulated in loess deposits of Northern Iran, may have fluctuated significantly affecting both the extent of dust deflation areas and regional climatic conditions. The loess of Northern Iran is structured by a large number of interglacial and interstadial palaeosols, formed under forest or steppe vegetation. We established high resolution records of sediment grain size, colour, carbonate content and magnetic susceptibility backed by micromorphology and luminescence dating at several loess exposures. These records are synthesized to propose a detailed pedostratigraphy for Northern Iranian loess including strongly developed palaeosols formed during the Eemian interglacial, equivalent to Marine Isotope Stage (MIS) 5e, and during interstadials of the Early Last Glacial (MIS 5c, and 5a). Moreover, weakly developed interstadial palaeosols formed during the Last Pleniglacial (MIS 4 to MIS 2). The records clearly reflect pronounced changes between dry and moist climatic conditions. It appears that during MIS 5 precession cycles controlled the pattern of dust accumulation and soil formation in Northern Iran, whereas during the Pleniglacial geomorphological factors induced by Caspian Sea level changes may have been responsible for fluctuations in dust accumulation rates and soil formation intensity. This and further hypotheses on possible connections between loess formation and its preservation on the one hand and Caspian Sea level fluctuations on the other hand will be discussed.

P-3612

## Estimation of the Eastern Caucasus (NE Azerbaijan) uplift based on the Neogene-Quaternary marine deposits study

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### Abstract

The Lateral Range of the Eastern Caucasus is one of the highest ridges of the mountain system of the Greater Caucasus. Its neotectonic deformation influences the adjacent homoclinal Gusar plateau, which smoothly rises towards the ridge from the Caspian coastal zone. The plateau is composed of marine and continental sediments of Pont-Apscheronian age, which lie in transgressive unconformity with the pre-Pliocene folded basement. The studied Akchagylian formation is represented by gray clays, silts and sands with traces of wave-formed ripples, sandstones and shell limestones. These deposits are covered by clays, silts and pebbles of the Gusar Unit of Apscheronian age, where limestone interbeds with *Apscheronia propinqua* are described (Geological Map, 1960). The described signs indicate the marine or coastal genesis of the sediments that form the plateau.

From the north the Lateral Range of the Eastern Caucasus is adjacent to the Gusar Plateau. We have investigated the synclinal plateau-like Chereke massif (2383 m), made of similar sediments, and drawn in this way into the folded deformations. The lower part of the Chereke section is represented by silts and siltstones, sands, sandstones with traces of wave-formed ripples. The upper part is formed by pebble-boulder conglomerates, calcareous sandstones with traces of wave-formed ripples, shell detritus with whole shells of gastropods and bivalve molluscs of the family Mactridae. The listed signs indicate the marine genesis of these deposits. According to V.E. Khain the lower section of Chereke has Maikopian age and the tops belong to the Sarmatian, but according to the data of T.N. Kangarli sediments have Cimmerian (Productive formation) and Akchagylian age respectively.

The uplift of the Gusar plateau was caused by total uplift of the mountain building. The top of Akchagylian marine deposits is situated at the height of 1600 – 1700 m a.s.l., and they are covered by Apscheronian deposits with 1906 m maximum height (Mt. Big. Suval). Thus, taking into account the rise of the sea level in Apscheronian time, the amplitude of deformations of the Gusar plateau can be estimated at 1500 m for the period after the end of Apscheronian sedimentation (about 1 Ma). The rate of uplifting of the plateau, based on these data, is 1.5 mm per year and correlate with the rates of uplift of the Shirak depression of the Armenian Highland (1.3 – 1.8 mm per year; Trifonov et al., 2017).

In the future comparative analysis of the Gusar Plateau deposits (Mt. Big. Suval) with the Lateral Range (Chereke massif) deposits will allow to confirm or deny their similar genesis and age and calculate the rates of the uplift of the latter.

The work is supported by grants of RSF (18-00-00977), and RFBR-18-00-00977 (geoarcheology).

**P-3613**

## **Calibrating the timing of the Thera eruption: A new annual radiocarbon record**

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### **Abstract**

One of the largest volcanic eruptions in the past 10000 years - the Minoan eruption of Thera (also called 'Santorini' eruption) is an important event in many fields of research.

A variety of environmental and paleoclimate archives utilize the physical markers left by the eruption for synchronizing timescales of ice cores, sediment records and speleothems. The eruption of Thera also leaves a chronological marker in archaeological archives, tying together the Aegean and Near Eastern chronologies.

To date, the precise timing of the event is being debated. Archaeological evidence and physical evidence in the form of radiocarbon dates show large discrepancies. Archaeological data place the eruption in the mid-16th century BC the earliest while radiocarbon dates point toward the late 17th century BC.

The accuracy of the radiocarbon calibration data has recently been explored by other researchers as a possible reason for the discrepancies. High-resolution tree-ring data indicate a possible offset to the calibration data included in IntCal13.

We present an additional dataset of annual radiocarbon results from a German oak tree covering the period 1625 to 1510 BC. A subsection of the dataset was analyzed in multiple laboratories to examine laboratory offsets and for quality assurance purposes. We will explore offsets to the calibration data and compare the new dataset to other recently published tree-ring data as well as its impact to radiocarbon calibration around the eruption of Thera.

**P-3614**

## **Chronological synchronization using annual $^{14}\text{C}$ data - possibilities from the mid-second millennium BC**

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### **Abstract**

Long sequences of annual  $^{14}\text{C}$  data created from measurements of securely dated annual tree-rings offer a number of prospects to improve and synchronize multiple lines of dating evidence. This can be especially important during periods where chronological discrepancies exist and where there is debate over the possible impact of natural events on human societies. Here we present 420 years of continuous annual  $^{14}\text{C}$  data from the early to mid-second millennium BC. We explore the reproducibility of certain features within this annually based sequence using a number of different tree-ring species including oak from Ireland (Timahoe, Co. Kildare, latitude 53.3450) and bristlecone pine from the USA (White Mountains, California, latitude 37.5327). Data produced by two radiocarbon laboratories are presented to explore inter-laboratory differences on analyses of the same tree. We discuss prospects for improved calibration and chronological synchronization on the basis of these new results.

P-3615

## Temporal evolution of Norwegian Sea radiocarbon content during the last deglaciation, towards a regional $^{14}\text{C}$ calibration curve

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### Abstract

The marine radiocarbon reservoir age effect in the Norwegian Sea is known to have been highly variable during the last glacial period, and at times considerable larger than the modern value of approximately 400 years. Nevertheless, marine  $^{14}\text{C}$  chronologies have typically assumed a marine radiocarbon reservoir age similar to the modern value, typically around 400 to 440 yr. Although the uncertainty of this assumption is commonly acknowledged, a lack of constraints on the temporal evolution of the reservoir age in the Norwegian Sea during the deglaciation has prevented a more accurate calibration of marine conventional  $^{14}\text{C}$  ages.

We present a new reconstruction of the deglacial (12.5-19 ka) (near) surface  $^{14}\text{C}$  reservoir ages in Norwegian Sea. We have compiled ~100 new and previously published  $^{14}\text{C}$  dates from four sediment cores and placed them in a new chronological framework based on correlation to proxy records sensitive to North Atlantic climate from Greenland ice cores and a radiometrically dated speleothem record from Hulu Cave, China. The alignment was corroborated by a tephra marker bed found both in the Norwegian Sea sediments and Greenland ice cores. The new chronology enables us to directly compare our Norwegian Sea  $^{14}\text{C}$  time-series to the atmospheric  $^{14}\text{C}$  content represented by the Intcal13 calibration curve and to reconstruct the reservoir ages. Our results show that the deglacial reservoir ages deviated substantially from modern values, and had considerable variability, which needs to be taken into account when working with marine  $^{14}\text{C}$  chronologies. We discuss implications of the new reservoir age reconstruction on chronologies of marine ice sheet and paleoclimate reconstructions.

**P-3616**

## **The Glacier Peak ash in Scotland**

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### **Abstract**

The Lateglacial period (~14.7 – 11.7 cal. ka BP) eruptive stage of Glacier Peak in the northern Cascade Range deposited a number of ash layers (tephras) in quick succession, forming visible event-stratigraphic marker layers (isochrons) across much of western North America. Geochemically distinctive microscopic glass shards from the most explosive eruptions of this stage remain detectable in a 'cryptotephra' layer (not visible in stratigraphy to the naked eye) of rhyolitic composition in lake sediments on the NE Atlantic Seaboard, where it is dated to 13.74 – 13.45 cal. ka BP ( $2\sigma$ ).

Here, we report the first trans-Atlantic detection of Glacier Peak cryptotephra (set G) in a Lateglacial lake site in western Scotland, ~7000 km from source. At this location (Loch Ashik, Isle of Skye), Glacier Peak shares a crowded tephrostratigraphy with two well-documented cryptotephra layers of likely Icelandic origin: the Borrobol Tephra (14.19–14.00 cal. ka BP;  $2\sigma$ ) and the geochemically equivalent Penifiler Tephra (14.06–13.81 cal. ka BP;  $2\sigma$ ) which occur singly or together in a number of terrestrial Lateglacial sequences in Scotland and Scandinavia.

Previous tephra work at this site, as well as other localities, has not identified shards of Glacier Peak composition. This may be due to masking of such ultra-distal layers by the relatively greater concentrations of the closely preceding, and thus stratigraphically overshadowing, Penifiler and Borrobol tephtras which often exhibit reworked post-peak shard distributions. However, the use of higher resolution 0.5 cm contiguous stratigraphic sampling and off-peak geochemical analysis in this study resolves previously unseen shard concentration variations within these distribution tails which are consistent with additional tephra layers and which are shown to contain a relatively greater proportion of Glacier Peak composition.

It is likely that other sedimentary sequences with faster accumulation rates will allow better stratigraphic distinction of the Glacier Peak layer from the Penifiler tephra. Additionally, Glacier Peak may be present elsewhere in the European tephrostratigraphy in sequences where the Borrobol and Penifiler tephtras were not deposited, and consequently where it will be less obscured.

The introduction of the well-dated Glacier Peak isochron into the regional tephrostratigraphy of Scotland should aid in constraining local age models. It will also permit direct trans-Atlantic correlation of sedimentary sequences for the mid-Lateglacial period, which was characterised by abrupt and short-lived climate oscillations. Accurate assessment of the relative timings of such palaeoclimate events is key to determining causal forcing mechanisms throughout the North Atlantic region.

**P-3617**

## **Millennial-scale tephra reworking: distinguishing "pseudo" tephra isochron from genuine one**

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### **Abstract**

Primary tephra deposits have been believed as isochronous marker beds in a stratigraphic sequence. Such tephra deposits and even invisible crypto-tephra have been widely applied for geology, geomorphology, archaeology and palaeo-environmental studies. The concept of tephra isochron is based on a hypothesis that all tephra are derived from primary (often of airborne nature) depositional origin. However, wind, water, and gravity processes can rework tephra in both time and space. Resedimentation of tephra can form a new discrete layer later in the depositional sequence, or it can be distributed as crypto-tephra over a range of different stratigraphic horizons. Without considering detailed transport and depositional processes involved in individual tephra layers/grains, any state-of-the-art petrological and geochemical analyses cannot evaluate a true tephra isochron.

The present study aims at understanding the duration and persistence of reworking and resedimentation of tephra based on sedimentological, petrographical, and geochemical analyses of tephra from the Holocene fluvial and deltaic sequences in northeast Japan. The examples presented here are 1) visible discrete tephra beds occurring in different stratigraphic horizons; however, the material itself is sourced by a single eruption, and 2) crypto-tephra composed of glass shards from multiple volcanic and sedimentary sources with different ages.

In the Niigata Plain, four sediment cores (KN-1, SN-1, MZ-1 and TA-1 cores) located progressively seawards of the coastline yield discrete and visible (or some cryptic) pumice concentrated layers derived from the 5.4 cal ka Numazawako tephra from Numazawa volcano at almost the similar depth (15-20 m below the ground level) of the delta front facies. The <sup>14</sup>C ages of the pumice concentrated layers show that each pumice layer formed at KN1520 = 5.7-3.0 cal ka; SN1636 = 4.8-1.7 ka; MZ1832 = post 3.0 ka; and TA1930 = 1.2-0.3 ka. This indicates that the Numazawako tephra continued to be reworked for > 4000 years after the eruption with delta progradation. In addition, geochemical data indicates that tephra materials originating from an earlier eruption of Numazawa volcano and from other calderas were incorporated into the deposits.

In the Tsugaru Plain, the post-2.5 ka subsurface deposits have 10 to 80 % glass shards content (in 1/8 mm-1/16 mm size) throughout the sequence. Geochemistry of glass shards points to different sources such as those from 1) the most recent AD 915 eruption of Towada volcano, 2) earlier caldera forming eruptions (30 ka, 15 ka), and 3) erosion of the Pliocene pyroclastic bedrock. These results clearly signify the fact that tephra reworking processes can continue long after an eruption has ended, and can persist even during the background sedimentation period. Furthermore, regarding the glass shards chemistry, if the numbers analyzed grains are too small, it can result in a misleading interpretation of tephra from a single eruption.

P-3618

## Developing a tephrochronological framework and assessing tephra delivery within the Atlantic sector of the Southern Ocean between 10-40 kyr BP

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### Abstract

Tephrochronology is a powerful technique for the correlation of disparate palaeoclimatic sequences from a range of depositional environments and is underpinned by frameworks of isochronous ash deposits. A regional tephra framework for the Atlantic sector of the Southern Ocean and Antarctica, both downwind from several volcanic systems, could facilitate the correlation of important marine and ice-core palaeoclimatic archives. Such correlations could be used to explore the phasing of climatic changes between the ocean and atmosphere, improve existing chronological models and assess the magnitude of the marine reservoir effect. In addition, the Southern Ocean is thought to be a key area for the outgassing of CO<sub>2</sub> via deep-water ventilation during the last deglaciation. Establishing tighter constraints on the phasing between sedimentary evidence for deep-water ventilation, and ice-core evidence for past atmospheric CO<sub>2</sub> variations could help in testing models of past relationships between climate and CO<sub>2</sub>. While there is an emerging tephra framework for the Antarctic ice-cores, limited investigations have been conducted on Southern Ocean marine records, particularly studies focused on the identification of cryptotephra, ash horizons not visible upon core inspection.

Here we report on high-resolution tephrochronological investigations of two marine cores from the Atlantic sector of the Southern Ocean (MD07-3076 and TN057-21). These cores have been investigated using recently developed methods for the identification of marine cryptotephra, which have focussed on finer grained material than prior investigations. Within the MD07-3076CQ record a peak in colourless glass shards only present in the 25-63 µm grain-size fraction and with a profile indicative of isochronous deposition has been identified. This deposit has an age of ~25.3 ka BP and ongoing geochemical analysis will determine the source of the eruption and permit a comparison with tephra horizons in the Antarctic tephra framework. Within both records several zones of elevated green/brown (dacitic/basaltic) glass shard concentrations, most clearly resolved in the 25-63 µm fraction, and with profiles indicative of non-isochronous or secondary deposition can be observed. The shard concentration, peak form and duration of these zones differs between the cores, however, there is a general similarity in their timing with events centred around ~17.5, ~24, ~31 and ~36 ka BP. These periods of tephra deposition are consistent with past studies of the coarse fraction of cores from the region, which attributed their occurrence to either Antarctic ice sheet instability or fluctuations in sea-ice transportation of ash. Ongoing geochemical work to identify the source of the deposits and comparisons to palaeoceanographic proxies will contribute to the debate regarding the mode of tephra delivery to these sites.

**P-3619**

## **Quantitative geochemical fingerprinting: machine learning to trace tephra to source**

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### **Abstract**

Cross-correlating unknown tephtras to reference samples of known origin requires exhaustive data archives of glass geochemical data, and, typically, extensive manual searching and digital plotting of glass data. Expert interpretation, combined with prior knowledge and numerous plotting permutations is a well-established method to discriminate and identify tephtras. However, quantitative methods of discrimination have the potential to expedite the parsing of likely reference sources and to remove a level of subjectivity from geochemical analysis.

Here we explore how machine learning algorithms can be employed to source unknown tephtra layers to volcanoes from Alaska's Aleutian Arc-Alaska Peninsula and Wrangell volcanic field. A series of supervised classification algorithms including neural networks, support vector machines, decision trees, and random forests among others, have been trialed to predict the origin of tephtras from 10 sources. The models were trained on nearly 2,000 electron microprobe analysis (EMPA) glass measurements from the University of Alberta Earth and Atmospheric Science's Tephtra Collection and Geochemical Database and the Alaska Volcano Observatory. Performance was evaluated internally (via cross-validation on training data) and externally (using held-out data from the source dataset and literature).

All classifiers tested performed well. Random forests and artificial neural networks and their combination as an average ensemble were consistently among the best performing algorithms, with accuracy >96% and kappa scores >0.96 on unseen data on a point-by-point basis. They were 100% accurate when individual analyses were averaged per sample. As a test case, geochemical data representing 15 tephtras from sediment cores of Eklutna Lake, south-central Alaska, USA, were tested using the best performing algorithms. The source predictions of the models were directly comparable to those gleaned from traditional plot-based correlations, but were produced in a fraction of the time, and returned quantitative pseudo-probabilities of source volcano correlations to each tephtra.

Combined with stratigraphic and chronologic data, as in the case of Eklutna Lake, machine learning methods are a boon to tephrochronologists. We are now able to rapidly parse vast geochemical datasets in a systematic and quantifiable fashion, even when mixed populations are present. Unknown tephtras that would historically be time-consuming to correlate can now be quickly focused to source, permitting further identification, ideally to eruption. However, just as is the case with traditional plotting methods, to make these new tools most useful, complete high-quality databases of reference glass geochemistry are required. Any model is only as good as the data upon which it is trained. Fortunately, glass geochemical data archives and their critical metadata are growing worldwide. As new data is produced and made available, analytical tools that leverage this information must be co-developed. This work is but one such adaptation to the "big data" of modern tephrochronology.

P-3620

## Cryptotephra investigation in the Carpathian Mountains

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### Abstract

Understanding of the timing and mechanisms of past abrupt climate change can be increased with the integration of palaeoclimatic records. However, chronological uncertainty associated with dating errors on individual past records prevents the full investigation of synchronies and asynchronies within the climate system. The application of cryptotephra (non-visible volcanic ash) allows palaeoenvironmental records to be precisely correlated across potentially thousands of kilometres in addition to building and improving local chronological models.

Here, we present the first, distal cryptotephra record from two sites in the Southern Carpathian Mountains (Romania). Our crypto-tephrostratigraphic investigations concentrate on the Late-glacial portions of the Lake Lia and Lake Brazi sedimentary sequences. We have identified several discrete tephra layers within these two records. Major and minor element volcanic glass chemistry (Electron microprobe analysis and LA-ICP-MS) reveals that the cryptotephra layers derive from various volcanic sources (e.g. Aeolian Islands, wider Mediterranean, Central Anatolia, Icelandic).

One significant finding of this investigation is the ultra-distal occurrence of the Askja-S tephra in both records, dramatically extending the known south-eastern dispersal of this ash from the Plinian eruption date refining the age of the eruption to 10,824±97 cal yrs BP (Kearney et al., 2018). Crucially, the Askja-S now offers a precise chronological tie-point facilitating the alignment of climate archives from NW Europe through into Eastern Europe immediately after the Preboreal climatic oscillation. Additional new cryptotephra include a largely unknown Late-glacial period eruption from Lipari in the Aeolian Islands, an eruption recorded from Ischia in the Tyrrhenian Sea and numerous previously unknown eruptions originating from central Anatolia. These cryptotephra investigations clearly illustrate that the central Carpathian Mountains offer an ideal location to integrate the tephrostratigraphic frameworks of disparate volcanic regions, and in doing so, provide a more robust chronological framework for palaeoclimate records in the region and further afield.

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P-3621

## Tephra layer refining Middle Pleistocene chronology of Serbian loess

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### Abstract

An accurate chronology is one of the critical premises of reconstructing past climate variability from Quaternary loess archive. However, beyond the upper limit of OSL (~100 kyr) and radiocarbon dating (~40 kyr), chronology of middle Pleistocene loess mainly relies on orbital tuning, with the most recent independent age control of the Brunhes-Matuyama boundary, which hardly meets the requirements of further paleoclimatic investigations in higher resolution and precision. Fortunately, in Serbian part of Danube loess, which is considered to be the most complete loess-paleosol sequences over the past million years over Europe, several primary tephra layers interbedded may provide valuable age anchors for better constraining loess chronology in middle Pleistocene interval.

We here focused on a tephra layer interbedded in the loess unit V-L4, estimated corresponding to MIS 10. The tephra was 1-2 cm thick in yellowish brown color, mainly consists of coarse-silt-sized grains. Glass shards were orange to brown in color, with thick-walled, cusped and pumiceous shards morphology. The mineral assemblage was made up of clinopyroxene, plagioclase, sanidine, biotite and apatite. To determine its origin and age, we conducted *in situ* major elements electron microprobe analyses (EMPA) of glass shards, clinopyroxene and feldspar grains, and <sup>87</sup>Sr/<sup>86</sup>Sr, <sup>143</sup>Nd/<sup>144</sup>Nd analyses of glass shards by a thermal ionization mass spectrometry (TIMS), and compared the results with potentially linked eruption materials.

Except for the glass shards showed low oxide totals (76-87%) and depletion of alkalis, which was incapable of any correlation, the composition of clinopyroxene and feldspar, and isotope ratio of glass shards showed consistency with Villa Senni eruption, dated to 351-357ka, from Alban Hills, Italy.

The clinopyroxene composition of this tephra layer also coincides with that of the Bag Tephra, a widespread tephra interbedded in Quaternary loess along the Danubian valley of Hungary and Slovakia, suggesting they might be isochronous deposits. The Bag Tephra was speculated to be product of Villa Senni eruption, which however lacks geochemical evidence. Our study proved this linkage, and might contribute to unifying loess strati-chronology frame over the Danube region.

The age of tephra layer in V-L4 provides a solid anchor for the chronology of Serbian loess. According to the estimated sedimentation rates, the bottom age of Serbian loess V-L4 was restricted to ~355-364ka, which coincides with the long-lasting warm climate of MIS 11 in east Asia, revealed by Chinese loess records. Our study further confirmed the pedostratigraphic and climatostratigraphic coherence between Serbian and Chinese loess, shedding new lights in future land-sea correlation and environment dynamics study.

P-3622

## Correlating cryptotephra layers: data visualisation or a statistical challenge?

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### Abstract

The successful application of tephrostratigraphic research relies on the robust characterisation and correlation of ash layers. This is most typically conducted by utilising stratigraphic, sedimentological, textural, and chemical data. However, in distal and ultra-distal regions, which are frequently the focus of cryptotephra investigations, these data are restricted and therefore characterisation and correlation of tephra layers relies upon small amounts of glass chemical data. Further complexity in interpreting ash layers in distal regions is derived from: repeating chemical signatures; taphonomic considerations; chemical degradation of tephra; bi-modal and non-normal chemical populations; and the discovery of far travelled tephra layers derived from volcanic centres 1000 kilometres from the study region. These additional factors, alongside the small amount of chemical data available, means that miscorrelation of ash layers is possible and in order to minimise the impact of this, secure correlations should be based on rigorous and objective criteria.

At present the major-element classification of tephra layers is carried out via variations of the Total Alkalis - Silica plot and this provides uniform information about the properties of the ash layer. This visual matching approach to set criteria is a robust way of classifying the layers identified but the approach is frequently extended to support correlations between layers. Visual correlations via bi-plots are embedded in cryptotephra research but are prone to subjective assessments with operator preferred element oxides plotted against raw reference data or more usually manually defined chemical 'fields'.

More robust approaches to correlation using statistical measures of distance are available but due to the small amounts of data and the complexities explained above these have not been uniformly adopted by cryptotephra researchers. This may, in part, reflect the often violated or untested assumption of Gaussian data distribution for each class that these suite of techniques require i.e. the low numbers of analyses available from potentially non-normal data sets mean that distance measures between populations that uses centroids are unlikely to provide robust correlations.

This research suggests alternative approaches to both the visualisation and correlation of tephra glass chemical data from cryptotephra layers identified in NW Europe. This poster explores the uses of techniques that either relax the requirements of Gaussian data distribution or provide non-parametric alternatives, these are: (1) kernel density estimates; (2) flexible discriminant analysis<sup>1</sup>; and discriminant analysis using Gaussian mixtures<sup>2</sup>. The effectiveness of each approach is considered alongside more traditional linear discriminant techniques.

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P-3623

## Towards a tephrochronological framework for Finland

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### Abstract

Tephrochronological frameworks are an excellent tool for dating and correlating sedimentary archives, archaeological sites and landforms both in proximal as well as distal areas. This is reflected in the rapid increase in routine tephrochronological studies across Northern Europe during past decades. However, very little tephrochronological work has been carried out so far in Finland. The main aim of our research is therefore to assess the possibilities of using tephrochronology as a dating method in Finnish climate and environmental research and to construct a robust tephrochronological framework for Finland.

We searched for cryptotephra in materials forming the palaeoenvironmental archives most commonly used in Finnish environmental studies: both peat sequences as well as homogeneous and varved lacustrine sediments. Our research sites cover southern and central Finland from the Åland Islands in the west to the Russian border in the east. Additionally, two subarctic lakes in northern Finland were included in the study. Tephra shards were extracted using acid digestion and heavy liquid separation, which resulted in detection of cryptotephra in 17 of our 34 sites. Due to low shard concentrations, the shards were enriched by using a micromanipulator when preparing mounts for electron probe microanalysis (EPMA), performed at either the University of Edinburgh or the University of Iceland. Despite applying rigorous laboratory methods to concentrate the shards, and using a narrow 3 – 5 µm beam during analysis, robust geochemical results could not be obtained from all the layers, due to small size and high vesicularity of the shards. Out of the 37 detected tephra deposits 18 have been geochemically fingerprinted this far.

A majority of the identified tephra originate from historical Hekla eruptions (e.g. Hekla 1845 and Hekla 1510). This is different from what has been recorded in Swedish sequences. Tephra from the large mid-Holocene Hekla eruptions forms the backbone of the Swedish tephrochronology and historical products of Hekla are largely absent in Sweden (Wastegård, 2005). The seemingly scarce occurrence of mid-Holocene Hekla tephra in Finland could partly be explained by low shard concentrations impeding geochemical fingerprinting or possible poor preservation of thin and vesicular shards in acid peat bogs. Presence of Hekla 1845 and 1510 tephra in Finland, as well as the fall-out of Hekla 1947 tephra in southern Finland (Salmi, 1948), reveals a similarity between the tephra historical records in Britain, Ireland and Finland, indicating a similar meandering tephra transport pathway during each of these eruptions. As our research is on-going, we expect the tephrochronological framework for Finland to significantly improve in the near future.

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P-3624

## **Towards a comprehensive tephrostratigraphic framework for Quaternary rhyolitic volcanism in New Zealand: employing cryptotephra methods to find the hidden eruptions.**

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### **Abstract**

The Taupo Volcanic Zone (TVZ), located in the central North Island, New Zealand, is currently one of the most active volcanic systems on Earth. Thought to have initiated ca. 1.6 Ma, it has produced numerous supervolcanic eruptions including Earth's youngest, the Kawakawa/Oruanui at 25.4 ka. However, our understanding of the eruptions from this system are skewed towards the last 61,000 years due to the preservation bias of proximal, younger, larger deposits. This means that a high percentage of the TVZ eruptive history is unknown; thus, existing magnitude-frequency models may underestimate the recurrence of the TVZ eruptions. Macro- and crypto-tephra deposits situated downwind of the TVZ (onshore and offshore eastern New Zealand, ~50 – 200 km from source) offer the potential of augmenting the existing record of volcanism. However, the disjointed nature of tephra horizons in the terrestrial record, coupled with large uncertainties in dating methods (e.g. Hopkins and Seward 2019), mean that producing a comprehensive record from onshore deposits is challenging. In addition, existing offshore marine cores are either proximal ( $\leq 250$  km) and short ( $<6$  m,  $\leq 30$  ka), or long but distal and therefore only preserve the largest events. To resolve these limitations, we present preliminary results from a new, combined onshore- and offshore-study.

Macroscopic tephra deposits from within 6 new proximal (ca. 200 km offshore) and long (ca. 2 Ma) cores were analysed and cross correlated using major and trace elements and mineral assemblages. These macroscopic deposits, coupled with well-defined onshore marker horizons, provide a robust chronological framework within which the cryptotephra deposits will be identified. The time consuming and laborious method of subsampling throughout a core for cryptotephra is not viable in this study where the cores are numerous and long (totalling  $>300$  m). We therefore propose identification methods using novel core scanning techniques (photographic and X-ray density imagery, magnetic susceptibility and density measurements, and elemental profiles by X-ray Fluorescence). We aim to identify the components of the scan data that highlight the macroscopic tephra horizons, then use these and semiquantitative petrography to locate potential cryptotephra horizons. These will then be analysed for major, and where possible trace element compositions, to allow correlations to be made. This will produce a comprehensive overview of the eruptions from the TVZ, and result in a database of geochemically referenceable, stratigraphically constrained tephra marker horizons for Quaternary eruptions in New Zealand.

P-3625

## Reinvestigation of the Bag Tephra, an important Middle Pleistocene marker horizon in the Carpathian Basin – composition and chronostratigraphy

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### Abstract

Two tephra horizons are used as marker horizons in the Hungarian loess stratigraphy to support the correlation between different loess-paleosol sequences. The older is described at twelve locations in the Carpathian Basin and termed 'Bag Tephra' after one of its type locality. This volcanic ash layer is supposed to be related to the eruption of the Monte Vulture (Central Italy) about 351 ka ago. After detailed investigations of the Bag tephra at many localities the same origin and/or age of Bag Tephra became questionable due to its different physical properties and unclear stratigraphical position (Sági et al., 2008).

Four loess successions, Basaharc, Hévízgyörk, Isaszeg and Pásztó, were dated and petrographically investigated, to get more information about the age and chemical composition of these tephra horizons. Luminescence dating (post-IR IRSL-290 method) and Amino Acid Racemization technique were applied to make age constrains for the deposition and formation of loess layers. Scanning Electron Microscope investigations were elaborated to gain petrographic information about the tephra horizons.

Luminescence and AAR results are in agreement at Basaharc, but some discrepancy was found at Hévízgyörk. Based on pIRIR-290 minimum ages and luminescence properties of the investigated samples the Bag tephra horizon could be divided into two groups (Basaharc, Isaszeg – Pásztó, Hévízgyörk). The two types of the 'Bag tephra' were confirmed by petrographic properties of the investigated tephtras. The same magmatic province (Central Italy) is assumed for both groups, however the same eruption center is not sure. Petrographical differences imply that either the eruption centers and/or the eruption times were different which produced the two types of tephra horizons.

Thanks to the Leibniz Institute for Applied Geophysics, Hannover and to the Hungarian NRDIO projects K119366 and 100315. This research was also funded by the Bolyai János Research Scholarship and the ÚNKP-18-4 New National Excellence Program of the Ministry of Human Capacities.

P-3626

## Potential of tephrostratigraphy to constrain the sequence of glacial-retreat and sea-level change during the Last Glacial Termination in north-western Scotland

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### Abstract

The precise pattern and timing of ice retreat and sea-level change in north-western Scotland since the LGM is not yet fully understood, with some interpretations proving controversial. This is, at least in part, due to the lack of chronological precision available in studies during this period. It is important to resolve these issues, as the behaviour of the ice sheet in Scotland during this period reflects a response to several environmental variables.

This study aims to investigate key sites that have the potential to refine the chronology of deglaciation in north-western Scotland during the period c. 17 - 11 ka BP and to clarify the temporal and spatial complexities of this period. The focus is on the extent to which tephra layers can provide a more robust chronological framework for the established patterns of deglaciation and associated isostatic adjustment e.g. Ballantyne (2010), Ballantyne & Stone (2012), Ballantyne & Small (2018), Bradwell et al. (2008) and Shennan et al. (2000).

The field area extends between 58 - 56° N, from the Summer Isles to Ardnamurchan, an area in which isolation basins offer particular advantage, due to their near-field location with respect to retreat stages of the Dimlington and subsequent re-advance of the Loch Lomond ice sheets. This poster will present stratigraphic and tephrochronological data from a series of new and previously investigated palaeolake basins in the study region.

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P-3627

## The Laacher See Tephra discovered in the Bohemian Forest lakes, east of the eruption

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### Abstract

In Central Europe, the Late Glacial period (~14700-11650 cal. BP) was characterized by dynamic environmental changes. 12,900 years ago, the cataclysmic Laacher See volcanic event (VEI = 6; 6.3 km<sup>3</sup> of magma) occurred in western Germany 40 km south of Bonn. The eruption devastated the surrounding late Allerød landscape and caused substantial lahar-like flood waves in the Lower Rhine and English Channel area. The interaction of magma with groundwater resulted in a highly explosive phreatomagmatic discharge, exceptionally long-distance transport of volcanic shards, and a climate deterioration. The Laacher See Tephra (LST) is found over much of western Central Europe and forms the most important stratigraphic marker in Late-glacial deposits. We assume that, contrary to many published works, the LST ash cloud traveled also directly east from the volcano. Therefore, we have studied lake sediment cores from three sites located in the Bohemian Forest Mts., Czech Republic-Germany-Austria border area (distance of 450 – 470 km from the volcanic crater). The characteristic LST particles were documented in all the cores using X-Ray Fluorescence scanning, magnetic susceptibility measurements, and direct observation by scanning electron microscopy. Subsequently, we used the TESCAN Integrated Mineral Analyzer (TIMA) for automated volcanic shard counting and precise identification of the cryptotephra depth range. Our geochemical results show the closest match with MLST-B phreatomagmatic phase of the eruption. Moreover, a significant amount of LST related phosphorus, often the limiting nutrient in both terrestrial and freshwater ecosystems, was found in the sediments. In this regard, we also assessed the potential effect of the tephra deposition on the vegetation cover and lake communities using pollen, charcoal, diatom, cladoceran, and chironomid analyses. Our first results suggest no significant impact on composition of terrestrial vegetation contrasting with a distinct change in diatom, cladoceran, and chironomid assemblages. The discovery of the LST in the Bohemian Forest opens the potential of tephrochronologically supported research of Late-glacial sites in eastern Central Europe. The study is supported by the Czech Grant Foundation (17-05935S – LAYERS).

P-3628

## Evaluating post-depositional disturbance of distal tephra records and potential precursor eruptions from Laacher-See Volcano through multidisciplinary investigations at Paddenluch, Germany

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### Abstract

The Plinian eruption of Laacher See Volcano deposited a widespread phonolitic tephra bed across much of Europe. Its wide dispersal and distinct geochemical signature make the Laacher See Tephra (LST) an important isochrone for the Allerød interstadial/GI-1, especially for connecting the tephrochronological records of Central Europe with the North Atlantic and the Mediterranean.

While distal LST generally occurs in chronologically consistent stratigraphic contexts, it does exhibit variations in sedimentological characteristics between locations, such as thickness, contacts, scatter, and bedding, and in the compositional range of glass shards. Some sites even record multiple ash layers, at times interpreted as the result of post-depositional processes but at others as indicating potential precursor eruptions, thus re-igniting previous debates of multiple eruptions from this volcano.

Given the importance of the LST as chronostratigraphic marker, resolving these competing interpretations is crucial. Yet, with outcrop profiles displaying distal tephra beds being extremely rare, most tephrochronological studies rely on bore cores, usually few in number from a given site, making comprehensive assessments of post-depositional dynamics difficult. In an effort to assess core sampling representativity, we carried out a comprehensive field study at the Paddenluch outcrop near Berlin, where distal LST is visible in the cross-sectional exposure of an infilled glacial melt-water channel. We used a combination of high-resolution sedimentological, tephrochronological, geochemical and palynological methods to test strategies for effective sampling of distal LST, characterise the main marker horizon, identify potential secondary LST beds, and classify post-depositional processes.

A core taken from the relatively undisturbed edge of the channel was subjected to the same macro- and micro-scale analysis as targeted open-profile sediment columns from the channel centre, including a part of the section where slumping has evidently deformed the sequence resulting in a wavy appearance and repetition of the ash layer. Micro XRF scans clearly displayed the microstructure of the deformed sediments while core scans highlighted the duplicated LST beds. Fine-scale pollen and cryptotephra analysis, complemented by radiocarbon dating, proved further useful tools to reveal the repetitive nature of the slumped sequence within small-scale sediment-column samples. It also helped identify two significant erosion events in the Younger Dryas that are represented as intervals rich in reworked LST. However, no secondary LST beds were found below the marker horizon.

Our study suggests that, when relying on bore core data for tephrochronological studies, it is crucial to collect multiple cores from each location and to apply a combination of micro-analytical methods in order to carefully assess potential variations with respect to primary and post-depositional processes. Our results also imply that suggestions of precursor eruptions from Laacher See Volcano based on distal tephra occurrence should be treated with utmost caution.

P-3629

## Can apatites be used to correlate tephra deposits?

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### Abstract

Evaluation of the magnitude, dispersal and tempo of explosive eruptions relies on building robust event stratigraphies by correlating proximal and distal tephra sequences. In the distal environment, the physical characteristics of these sequences are not distinctive enough to allow for robust correlations. Since the 1980s, major element glass chemistry has been employed to make correlations allowing distal and proximal records to be integrated. However, some volcanic centres produce eruption deposits with similar major element glass chemistries over thousands of years and thus it is difficult to correlate distal occurrences to their proximal equivalents. This has been largely circumvented by acquiring trace element compositions of the glass shards but sometimes the problem of not having a unique glass chemical fingerprint still exists. Some crystal phases (e.g., Fe-Ti oxides and biotite) are useful for correlating tephra deposits when the glass compositions are similar, or if the glasses are too microlite-rich or altered, but these phases are not always present. Apatite is a common accessory phase in evolved eruption deposits. It can incorporate both volatiles and trace elements (e.g., rare earth elements) into its crystal structure, and has been shown to be useful in correlating K-bentonites of altered, Ordovician tephra deposits in North America (e.g., Carey et al., 2009), and some other studies have suggested that apatite compositions can be used to correlate tephra (e.g., Sell & Samson, 2011; Takashima et al., 2017). However, detailed studies that show whether apatite compositions can be used to distinguish successive eruption deposits from the same volcano are lacking. To address this problem, we have extracted apatite microphenocrysts from eruption sequences comprising multiple eruption events (including large caldera-forming and smaller explosive events) from various volcanoes around the world and analysed the major, volatile and trace element compositions of the apatites to determine which elements are the most reliable for correlating the eruption deposits. These data show that the compositions of apatite in successive eruption deposits are often indistinguishable and sometimes similar to those from different volcanoes. These results indicate that apatite compositions cannot be used to correlate tephra deposits.

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**P-3630**

## **Paleomagnetic secular variation and relative paleointensity during the Holocene in South China – Huguangyan Maar Lake revisited**

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### **Abstract**

The scarcity of reliable paleomagnetic secular variation (PSV) records from East Asia especially from low-latitude regions impedes better understanding of global PSV mechanisms. Here we report on a high-resolution PSV record during the Holocene from a composite 10.6 m long core with high-sedimentation rates from Huguangyan Maar Lake (HML) in subtropical-tropical South China (21°9'N, 110°17'E). Detailed rock magnetic results demonstrate that the natural remanent magnetization resides in single-domain and pseudo single domain magnetite. Alternating field demagnetization of natural remanent magnetization of u-channel samples yields six distinct inclination highs at ~7500 BC, ~5100 BC, ~4600 BC, ~3600-3400 BC, ~1600-1200 BC and 600-800 AD, three inclination lows at ~4800 BC, ~600-300 BC and ~1000-1300 AD and three eastward declination trends at ~3600-3200 BC, ~2600-2400 BC and 400 BC-200 AD. The similarity between the HML PSV record and other independently-dated records from East Asia and geomagnetic field models corroborates the robustness of our age model and Holocene PSV record. Strikingly, centennial- to millennial-scale PSV features of the HML are correlatable, within age uncertainties, with other Holocene records from Europe, North America and Canada, suggesting that such directional patterns are likely to be hemispheric in scale. Although relative paleointensity data of HML are affected by environmental factors (e.g., diagenetic alteration), the record still provides a regionally-important new PSV reference curve whose conspicuous features may serve as stratigraphic markers for East Asian paleo-records.

P-3631

## SR-XRF analyses of varved sediments in Altay and Caucasus as a source of high-resolution paleoclimatic information

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### Abstract

Varve sediments are among the most promising proxies for high-resolution paleoclimatic reconstructions. In this study, we present the results of the bottom sediment microanalysis performed with Scanning X-ray fluorescence method in the “Siberian Synchrotron and Terahertz Radiation Centre” (BINP SB RAS, Novosibirsk). The sediment of the two lakes located in the periglacial zone in the Altay (lake Kucherla, 49°52'33"N, E 86°24'52"E, 1790 m asl, ) and the Caucasus (lake Donguz-Orun, 43°13'26" N; 42°29'35"E, 2500 m asl) with vaguely discernible annual layers were scanned with the step of 100 µm to obtain the profiles of more than 20 chemical elements. These results were combined with the photographs of the investigated sediment cores in order to identify the elements (or elemental ratios) that would mark the annual boundaries and delimit the layers more confidently. We found out that the best markers recording the annual changes in grain-size are Rb/Sr and Zr/Rb ratios. After establishing the precise sediment chronologies with the annual resolution, we compared them with the meteorological records. The varve thickness chronology in Kucherla and terrigenous elements chronology (annually averaged values of Fe, Ti, Zn and Mn) in Donguz-Orun are positively correlated with annual precipitation at the local meteorological stations (both with the same coefficient of correlation equal to 0.44,  $p < 0.01$ ). We also found out that the content of bromine in Donguz-Orun sediment is positively correlated with annual temperature ( $r = 0.41$ ,  $p < 0.01$ ). Statistically significant negative relationship observed between the concentrations of terrigenous elements in the sediment of Lake Donguz-Orun and tree-ring width of local pine chronology ( $r = -0.56$ ,  $p < 0.01$ ), as well as the age control with <sup>137</sup>Cs and <sup>210</sup>Pb independently confirm the accurate dating of the sediment sequence. These findings open opportunities for high-resolution multiproxy climate reconstructions in both Caucasus and Altay – relatively poorly studied regions with low anthropogenic stress. The studies were supported: Kucherla - by the Grant 18-55-53016 ГФЕН\_a, Donguz-Orun by the Grant 17-05-01170

P-3802

## Emerging hypotheses about the Holocene palaeoclimate in the Sahara: landscape response, biome continuity, and termination of wet and arid phases

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### Abstract

In the Sahara, the Early and Middle Holocene (ca. 11–5.5 ka) are marked by northward expansion of the Afro-African monsoon across the southern and central Sahara, causing higher precipitation and a more abundant plant cover. This phase is generally defined as African Humid Period (AHP) and it is commonly considered to be a ubiquitous wet phase. A number of studies describe the effects of Holocene climate changes over the region at medium to high resolution, but today, field-based studies are very limited due to geopolitical instability. This limits our full understanding of the true extent and the dynamic of environmental changes over the Sahara and how different regions – and different landscape units within a same region – have reacted to climatic changes and climatic instability. In a patchwork of sometimes old-fashioned studies, new hypotheses are emerging, many of which are based upon land-sea correlations informed by analyses of offshore cores. Some conclusions, anyway, contrast with field-based palaeoclimatic and geoarchaeological evidence. In this contribution, we will pose some questions that remain still unsolved or poorly investigated and we will discuss some hypotheses in context of new and published data. Key questions concern the duration and termination of the AHP: was it an abrupt or gradual process? And, was the AHP continuous or interrupted by rapid climatic events (RCCs)? Finally, when was the beginning of the Anthropocene in the Sahara? A fresh look at field-based geomorphological and geoarchaeological data from different regions of the Sahara suggest that the duration and termination of humid conditions associated with the AHP were not the same everywhere, and were influenced by local physiographic factors in addition to climatic forcing. Continental archives also suggest the occurrence of at least a major break of humid conditions during the AHP at the transition between the Greenlandian and the Northgrippian stages of the Holocene. This break was possibly triggered by the global cooling at ca. 8.2 ka BP, and lasted a few centuries in North Africa. This transition likely had some significant consequences on the populations within the region. Another question of interest for the Sahara involves the timing of the shift from a natural to a human-dominated landscape. Emerging evidence from key sites in the Sahara suggests an early beginning of human activities characteristic of the Anthropocene, driven by the early diffusion of Neolithic herders, and later influences that included attempts at cultivating within the oases in the context of a progressive aridification of the region.

P-3803

## Millennial-scale fluctuations in Saharan dust supply across the decline of the African Humid Period

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### Abstract

The Sahara is the world's largest dust source with significant impacts on trans-Atlantic terrestrial and large-scale marine ecosystems. Contested views about a gradual or abrupt onset of Saharan aridity at the end of the African Humid Period dominate the current scientific debate about the Holocene Saharan desiccation. In this study, we present a 19.63 m sediment core sequence from Lake Sidi Ali (Middle Atlas, Morocco) at the North African desert margin. We reconstruct the interaction between Saharan dust supply and Western Mediterranean hydro-climatic variability during the last 12,000 yr based on analyses of lithogenic grain-sizes, XRF geochemistry and stable isotopes of ostracod shells. A robust chronological model based on AMS <sup>14</sup>C dated pollen concentrates supports our multi-proxy study. At orbital-scale there is an overall increase in southern dust supply from the Early Holocene to the Late Holocene, but our Northern Saharan dust record indicates that a gradual Saharan desiccation was interrupted by multiple abrupt dust increases before the 'southern dust mode' was finally established at 4.7 cal ka BP. The Sidi Ali record features millennial peaks in Saharan dust increase at about 11.1, 10.2, 9.4, 8.2, 7.3, 6.6, 6.0, and 5.0 cal ka BP. Early Holocene Saharan dust peaks coincide with Western Mediterranean winter rain minima and North Atlantic cooling events. In contrast, Late Holocene dust peaks might correspond with positive phases of the North Atlantic Oscillation. By comparing with other North African records, we suggest that increases in Northern Saharan dust supply do not solely indicate sub-regional to regional aridity in Mediterranean Northwest Africa but might reflect aridity at a trans-Saharan scale. In particular, our findings support major bimillennial phases of trans-Saharan aridity at 10.2, 8.2, 6.0 and 4.2 cal ka BP. These phases coincide with North Atlantic cooling and a weak African monsoon.

P-3804

## Multiproxy reconstruction of Pleistocene paleoclimatic/paleoenvironmental changes in the Aalat pedostratigraphic succession (Eritrea). A focus on paleosols and stable isotopes

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### Abstract

The climatic changes during the Early-Middle Pleistocene transition are a key to understand the ecosystem dynamics that involved the *Homo erectus-ergaster* distribution. The Aalat pedostratigraphic succession represents a continental archive in the African Rift Valley (Dandiero basin, Danakil depression, Eritrea), where remains of *Homo* around 1 Ma were identified. High-resolution magnetostratigraphy and some tephra layers at the top and the bottom gave good chronological constraints to this succession, dated between the base of the Jaramillo subchron and the lower Brunhes chron. Despite the present-day arid, desert climate, the Aalat section records a persistence of water-driven, fluvio-lacustrine environments over more than 250 ka, which suggests a major tectonic control on sedimentation, although climate changes are clearly overprinted. Macro- and micromorphological features, along with physico-chemical, mineralogical and geochemical data, up to now poorly available for Pleistocene paleosols in East Africa, depict a poor to moderate degree of paleosol development, in line with high rates of sedimentation around 0.8 mm/a. Nonetheless, cyclical pauses of aggradation led to major geomorphic stability, which permitted the development of calcic, petrocalcic and petrogypsic horizons at different stratigraphic heights (likely developed during 10<sup>2</sup>-10<sup>3</sup> years to some ten thousand years), alternated with Fe-oxide-stained, reddish to yellowish paleosol horizons. This alternation suggests cyclical changes from dry to wet environmental conditions, which fit well with aeolian dust fluxes and marine isotope stages of glacials and interglacials at higher latitudes. This pattern is also consistent with that of the  $\delta^{13}\text{C}$  obtained from the carbonate concretions and limestones, which depicts a prevalence of C4 plants during more arid stages, alternated with C3/C4 ecosystems during wetter phases. The  $\delta^{18}\text{O}$  signature is more complex, showing a noticeable pattern change from the lower to the upper-intermediate part of the Aalat succession. This shift can be linked to an episodic distribution of rainfall events and/or changes in basin hydrology, at least partly controlled by tectonic activity, which in turn promoted changes in water availability of sedimentary processes.

The *Homo erectus* settlement lasted apparently for a short time span, because of the onset of a prolonged, high-discharge fluvial sedimentation lasted about 125 ka, following more than 50 ka characterized by lacustrine and deltaic sedimentation, or an aridity phase which led to the development of thick, complex carbonate hardpans at the base of the fluvial facies. These events could have made the area less suitable for human settling and could have hindered preservation of fossils and artifacts.

Based on climofunctions available in the literature, mean annual precipitation and temperature were estimated for some reference pedogenic horizons, such as a well-developed calcrete hardpan and the most mature red paleosol. These values can be assumed as tentative reference values for Pleistocene glacials and interglacials in this area.

P-3805

## Diatom assemblages from Chew Bahir, Ethiopia: High-resolution snapshots of Late Pleistocene and Holocene climate variability in a ~600 ka sequence

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### Abstract

Chew Bahir (4°40'N, 36°50'E; 600 m asl) is a playa basin in southern Ethiopia located between the Main Ethiopian and Kenyan rifts. It is classified as an 'amplifier' lake, with a seasonally inundated basin floor covering an area ~ 30 km E-W and 70 km N-S. Palaeo-shorelines indicate profound hydrological changes occurred during the Late Quaternary, hypothesised to be linked to changes in the location of the principal wind systems and air masses (ie. Intertropical Convergence Zone and the Congo Air Boundary). The sedimentary archive from this basin provides an opportunity to develop a continuous record of terrestrial tropical climatic variability through multiple glacial cycles and to explore the links between climate and human evolution and dispersal in eastern Africa.

In December 2014, parallel sedimentary cores were drilled as part of the Hominin Sites and Paleolakes Drilling Project through the International Continental Drilling Program, with a composite splice sequence ~ 290 m in depth developed. A chronological framework based on a combination of optically stimulated luminescence, argon-argon and radiocarbon dating, further supported by tephrochronology, indicates the palaeoenvironmental record extends back more than 600 kyr. The diatom record from Chew Bahir would be expected to highlight changes in salinity and water chemistry in response to hydroclimatic fluctuations and provide an important component of the multi-proxy record. Initial assessment of core material revealed a lack of biological remains and that diatoms were not preserved through most of the sequence, except for three short (~1 - 3 m) sections of core, centred around ~2 m, ~70 m and ~85 m composite depth. The Chew Bahir palaeoenvironmental record is therefore reliant on geochemical and physical proxies throughout much of the sequence. The three short sections of well-preserved diatoms do however provide valuable supporting evidence for palaeoenvironmental interpretations of more continuous proxy data such as the oxygen isotope record from carbonates. Furthermore, analysis of diatom assemblages from contiguous 2 cm samples through well-preserved sections provides high-resolution snapshots of climatic variability during the three intervals.

In the uppermost, Holocene section, there is a clear shift from a freshwater, planktonic assemblage dominated by *Stephanodiscus* and *Aulacoseira* species to more saline lake conditions represented by *Nitzschia fonticola* and



subsequently *Thalassiosira cf. faurii*. This increase in salinity charts the end of the African Humid Period and progressive lake level lowering. The earlier phases of good diatom preservation in the Late Pleistocene reveal fluctuating lake levels with more diverse assemblages including some freshwater benthic species as well as some intervals rich in planktonic taxa of moderate salinity such as *Cylotella meneghiniana*. The diatom data from Chew Bahir, where present, indicate that the basin responded rapidly to changing moisture availability with distinct changes in salinity of lake waters.

P-3806

## Late-Holocene palaeohydrology of the central Sahara, inferred from desert oasis lakes in northern Chad

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### Abstract

The UNESCO-listed Ounianga basin in northeastern Chad hosts two clusters of unique desert oasis lakes, which range from hypersaline to fresh. Continuous inflow of fossil groundwater from the Nubian Sandstone Aquifer (NSA) sustains these lakes against the strong climatic moisture deficit. Palaeoenvironmental proxies in the continuous sediment archive of Lake Yoa - the deepest (26m) lake located in Ounianga Kebir - have constrained the transition from the early-Holocene African Humid Period towards the current hyperarid climate regime (Kröpelin et al. 2008, Francus et al. 2013), but showed limited hydrological response to Late-Holocene climate variability (Eggermont et al. 2008).

We present multi-proxy work on Late-Holocene sediment records from three shallow (<6m) lakes in the lake cluster at Ounianga Serir. Our proxies include magnetic susceptibility, x-ray fluorescence, loss-on-ignition sediment composition, charcoal and invertebrate remains. Our combined evidence indicates that these three lakes experienced site-specific but broadly synchronous palaeohydrological shifts. Some of these events broadly match known episodes of widespread hydroclimatic change documented from other records in the central Sahara and elsewhere. We conclude that variation in evaporation linked to changes in temperature and/or wind strength must have resulted in basin-wide lake-level shifts, notwithstanding most likely fairly constant groundwater input from the NSA. This work shows that the iconic freshwater lakes of Ounianga Serir, generally thought to be hydrologically stable 'relict' lakes, are more dynamic and climate-responsive than previously evaluated.

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P-3807

## The speleothem perspective on past African hydroclimates: a SISAL contribution

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### Abstract

Understanding the past variability in African hydroclimates is important in studies into the earth's climate system, paleoanthropology and future climate change. Speleothems provide one of the highest-resolution, precisely-dated archives of past hydroclimate change. The Past Global Changes (PAGES) working group Speleothem Isotopes Synthesis and Analysis (SISAL) brings speleothem records together in a single easily accessible database. The database can be used to analyse multiple datasets together rather than in isolation. This big data approach allows for better spatial analysis of past hydroclimate variability and better integration with climate models. Here we detail the progress of the Africa working group, highlighting the spatial and temporal coverage provided by the SISAL database, and providing initial analysis into past speleothem isotope variability across the continent.

Speleothem deposition at the southern and northern extremities of the present day ITCZ migration appears to be more common during late Pleistocene interglacials than during glacial phases suggesting an overall increased latitudinal range of ITCZ migration or a widening of the tropical rainfall belt during interglacials. During glacial phases speleothem deposition is recorded mainly in the hemisphere that has higher summer insolation. In northwestern and southern Africa precession and eccentricity influence speleothem growth, largely through changing synoptic storm activity. Comparison of recent speleothem stable isotopes with modern isoscapes suggest speleothem  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  approximate modern precipitation  $\delta^{18}\text{O}$  and vegetation  $\delta^{13}\text{C}$ . We assess the spatial variability of speleothem  $\delta^{18}\text{O}$  over the last 12,000 years as an example of database use. Due to restrictive bedrock geology and dry climate African speleothem records are spatially and temporally flashy, but hotspots of cave records still provide great insight into regional climatology. Continued research should combine the high-resolution snapshots they provide with other longer term, low resolution hydroclimate records already available, such as sediment cores from lakes and near shore marine environments.

P-3808

## Dust accumulation variability in the Chinese Loess Plateau since the LGM with implications to dust sources and emission dynamics

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### Abstract

Loess deposits in the Chinese Loess Plateau (CLP) are valuable terrestrial archives widely used to reconstruct past dust and East Asian monsoon dynamics. High sampling resolution chronological studies have revealed significant site-specific variations in loess sedimentation. In this study, we investigated on the spatial and temporal variability of loess sedimentation in the CLP during the past twenty thousand years (ka), by synthesizing new records from the desert margin and loess sites from the central CLP. We found that strong dust accumulation at the desert margin after about 15 ka is synchronous broadly with reduced dust accumulation or less preservation in the main plateau. This spatial inhomogeneity of loess sedimentation is controlled by various dust transportation, trapping, and postdepositional processes in different geographic settings, and is related to past monsoon climate change. Our study further implies that the boundary between the dust depositional region and the source region shifted during glacial-interglacial cycles, because dust was trapped at the desert margin when it became vegetated during the humid and warm interglacial period. During the glacial period, however, this region was strongly eroded and dominated by the extension of sand dunes. We propose that the desert margin serves as a transition zone that accumulates dust during interglacials and emits dust during glacials. This provides an important dust transport and recycling pathway that carries dust from the source region to the depositional region over glacial-interglacial cycles.

To further investigate the dynamics of dust emission from the source area, we recently applied the PI-SWERL (Portable In-Situ Wind Erosion Laboratory) to measure in the field the potential of sand dunes and other desert landforms to emit dust in the deserts in northern China. The preliminary results revealed different dust emission processes and mechanisms between different geomorphic units. Both geological reconstruction and field observations indicate that loess covering by sand dunes could emit dust efficiently.

P-3809

## Different approaches for dust source determination – two case studies from Iran

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### Abstract

Iran, like most of its neighboring countries, is part of the northern hemisphere subtropical dryland belt and thus a relatively high percentage of the country's area is covered by semi-deserts and deserts. These areas – inside and outside of Iran – are very effective dust sources. The aeolian processes are further promoted by high wind speeds supported by the nearby Persian and Oman Seas. Dust and sand storms are a widespread problem throughout Iran, but identifying the exact dust sources is, due to the outlined complex geographical structure, challenging. The study presented here uses two different approaches to determine the dust sources of samples collected in Eastern and South-Western Iran.

The Eastern Iranian case study, which was carried out in the Iranian Sistan region and the adjacent Registan region in Afghanistan, utilizes the fact that emission, transport and deposition of dust are predominately controlled by wind. This approach calculated the Drift Potential (DP), the Resultant Drift Direction (RDD), the Resultant Drift Potential (RDP), and the RDP/DP ratio using the Fryberger (1979) method based on data from 16 meteorological stations for the period 1999-2015. Together with wind regime determination, satellite based mapping and field campaigns in the Iranian part of the study area, the temporal variation of the wind systems and the spatial distribution of the dune systems were determined.

The second case study used the chemical characteristics of dust collected in the South-Western provinces of Iran to determine the dust sources, which were expected to lie outside of Iran. The concentrations ( $\mu\text{g/g}$ ) of Be, Na, Mg, Al, Si, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Cd, Ba, and Pb, retrieved from ten passive dust deposition samplers were analyzed using ICP-MS (Inductively Coupled Plasma Mass Spectrometry). Acid digestion (HCl: HNO<sub>3</sub>) using *Aqua Regia* (ISO/DIS 17294-2:2014 conc.1:50) were employed for the total elemental analysis. Correlations between daily dust event data and the elemental composition of the dust samples over a four year sampling period allowed the determination of the dust sources with the help of key indicating elements (according to Geiger and Cooper 2015).

As main sources of dust, desiccated ephemeral lakes (Hamoun and Hoor) have been identified in the East-Iranian study area. Besides dry lakes and salt marshes, especially in Khuzestan, also other dust sources, both natural (c.f. weathering crusts, marine aerosols) and anthropogenic (cf. vegetative burning) were determined in the South-Western study area.

**P-3810**

## **The Ponte Crispiero Late Pleistocene Loess/Palosols succession (central Apennine, Italy): insight on dust origin and transport**

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### **Abstract**

There is an increasing detailed documentation on the loess succession in central Italy, in particular at the margins of the Po plain (e.g. Cremaschi et al. 2015). However, the origin of the loess deposits inside the central Apennine is still debated (e.g. Giraudi et al., 2013; Boretto et al., 2017). In this poster, we present mineralogical and geochemical (major, minor, trace element and <sup>87</sup>Sr/<sup>86</sup>Sr ratio) data of the Loess/Paleosols succession outcropping at Ponte Crispiero (Chiesa et al., 1990, central Apennine). The Ponte Crispiero loess chemistry is clearly distinguishable from other European loess, and shows both affinity with sediments of some central Italian rivers and in particular some (even if not complete) similarity with the Po alluvial plain deposits. This suggests that during low stand sea level there was a dust transport from the Adriatic margin toward the central Apennine valley.

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Cremaschi M., et al. 2015 Age, soil-forming processes, and archaeology of the loess deposits at the Apennine margin of the Po plain (northern Italy): New insights from the Ghiardo area. *Quaternary International* 376, 173-188.

Giraudi C., et al. 2013. A Late-Pleistocene phase of Saharan dust deposition in the high Apennine mountains (Italy). *Alpine and Mediterranean Quaternary*, 26, 110 – 122.

**P-3811**

## **Multi-scale microstructure and mineral grain size distribution of paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> on Luochuan, China**

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### **Abstract**

Scanning electron microscopy was commonly used on microstructure study of loess and paleosol for changes of the Quaternary paleoclimatic environment. However, there are at least three deficiencies on the previous research. First, the SEM sample surface is usually not smooth enough to accurately reflect internal structures. Second, the scanning area is too small to make a statistics. Third, mineral components cannot be identified in a large scale at one time and the spatial distribution of minerals, except for quartz, in loess and paleosol was seldom studied.

In this paper, a method by BSE/EDX associated with a new sampling tool and image processing technology is presented to overcome three shortcomings above mentioned. With the method, minerals in loess and paleosol sample can be identified through comparing the chromatic value difference between unknown mineral and [standard](#) mineral in a patented color database. Six samples were taken from paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> separately on Luochuan, China. 320 SEM/EDX images with magnification 500 times the original size for each sample were obtained, including 40 base map images and 280 dots mapping images representing the distribution of 7 elements as Si, Al, Ca, K, Fe, Mg and Na separately. We replace the white dots on dots mapping images with 7 different colors according to 7 different elements and change the image background to transparent. After overlaying and stitching 320 images together, the micromorphological characteristics in more than one square [millimeter](#)s of sample surface were analyzed and grain size distribution of three kinds of mineral, quartz, silicate minerals, especially carbonate minerals, with different deposition thickness, were also provided separately.

The results show that: (1) Obvious peak fluctuation on particle size distribution of silicate and carbonate minerals existed between the grain size fraction of 1-3 $\mu$ m of paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> sample. (2) Many evenly distributed elongated and flaky particles with size fraction of 60~100 $\mu$ m in paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> sample were observed, including not only quartz, but also kaolinite and mica. (3) It is also observed that both silicate mineral particles coated with carbonate mineral cutans and carbonate mineral particles coated with silicate mineral cutans exist a lot at the same time on paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> sample.

The observations infer that the origin particle size of paleosol S<sub>0</sub>, S<sub>1</sub> and loess L<sub>1</sub> could be more uniform or coarser than previously thought and carbonate in them could be delivered in clastic form by aeolian processes.

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**P-3812**

## **Stepwise shifts in Asian dust provenance and East Asian winter monsoon intensification since ~7.2 Ma revealed by detrital zircon age**

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### **Abstract**

The evolution and forcing mechanisms of the East Asian winter monsoon during the late Cenozoic are unclear, largely because appropriate proxy indicators for reconstructing variations in this long-established wind system are lacking. In this study, we used a compilation of detailed zircon U-Pb age spectra of a continuous eolian sedimentary sequence in the northern and southern Chinese Loess Plateau to reveal changes in dust provenance, which are closely associated with the evolution of the East Asian winter Monsoon (EAWM). The detrital zircon dating results for the 47 analyzed levels with detailed age constraints indicate that the EAWM strengthened stepwise at ~7.2 Ma, ~2.6 Ma, 1.2-0.9 Ma and at the Last Glacial Maximum. These changes are synchronous with global cooling and ice cover expansion in the Northern Hemisphere. Our reconstruction of the dust provenance and wind strength suggests that the strengthening of the East Asian winter monsoon was probably driven by global cooling, which caused an increasing temperature gradient between the North Pole and the tropics, resulting in outflowing anticyclonic winds. The growth of Himalayan-Tibetan Plateau has less impact on the stepwise EAWM evolution since the late Miocene.

P-3813

## Geochemical evidence for the provenance of loess deposits in the eastern Qinling Mountains, central China

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### Abstract

Determination of provenance of the loess deposits in the eastern Qinling Mountains, central China, is important for improving our understanding of the dust emission, transportation and deposition in the Asia region. It has long been a controversial issue whether the widespread *Xiashu* loess in southern China was derived from the northern Asian interior deserts or aridified local fluvial/flood plains in southern China during the glacial. The eastern Qinling Mountains lie between the Chinese Loess Plateau (CLP) and subtropical China, and consequently on the transportation pathway of the East Asian Winter Monsoon carrying dust from the northwest to southeast. In this study, four sections from the two major basins in the eastern Qinling Mountains were investigated. Among these sections, Liuwan (34.143°N, 110.137°E) and Shipo (34.183°N, 110.250°E) sections are located in Luonan Basin, and Shangluo (33.885°N, 109.914°E) and Dabozi (33.719°N, 110.237°E) sections, in Shangdan Basin. The grain-size distribution of 39 bulk samples, and the major and trace element compositions of the <20 μm fraction of 23 samples mainly from the first loess layer of the four sections were analyzed and compared with the Xifeng loess which is of typical in the CLP. The geochemical composition of Xifeng loess samples is used to characterize the average geochemical composition of the northern deserts. The results show that the grain-size distribution of the bulk samples from the eastern Qinling Mountains is similar to that of the Xifeng loess, indicating the four studied loess sections are of typical eolian origin. The immobile element ratios of the <20 μm fraction (e.g.  $TiO_2/Al_2O_3$ ,  $La_N/Sm_N$ ,  $Gd_N/Yb_N$ ,  $La_N/Yb_N$ ,  $Eu/Eu^*$ ,  $Zr/Nb$ ,  $Hf/Nb$ ,  $Y/Nb$ ,  $La/Nb$ ,  $Th/Nb$ ,  $Ta/Zr$ ,  $Zr/Hf$ ) in the loess deposits from the eastern Qinling Mountains are different from those of loess from the CLP. According to the aerodynamic property of aeolian dust, only dust particles finer than 20 μm can transport a few tens to a few hundred kilometers under typical windstorm conditions. The clear distinction in immobile element ratios of <20 μm fraction between samples from the two regions indicates that the loess deposits in the two regions have different provenances, and the loess on the eastern Qinling Mountains did not primarily come from northern deserts. We suggest that the adjacent alluvial deposits and clastic sediments from the weathered bedrocks are the dominant dust sources of the loess deposits from the Eastern Qinling Mountains. This study therefore provides new evidence supporting our previous conclusion that *Xiashu* loess in southern China is not mainly derived from the northern deserts and the role of the East Asian winter monsoon in transporting the dust the northern deserts to southern China have been overestimated.

**P-3814**

## **The origin of large depressions of eastern Azov region plain (southern Russia)**

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### **Abstract**

On the watersheds of the eastern Azov region, there are dozens of large depressions. Their sizes can reach tens of square kilometers. The outlines of these depressions are like a drop or an egg. The vast majority of large depressions are oriented approximately north. To date, the problem of the origin of large depressions in the eastern Azov region does not have an unambiguous solution. The following hypotheses were put forward: paleothermoclast, erosion-suffusion, subsidence-loess, estuary-lake. Yet, none of them is not finally confirmed and not refuted. This is due to the lack of correct data on their geological and geomorphological structure. Also, the problem of these large depressions evolution in the future remains unclear. Is their extensive growth possible or will they remain stable? The goal is to find at and identify the mechanisms for the formation of large depressions.

As a result of the morphometric analysis of large depressions, a unity of their origin was revealed. For geological and geomorphological research, we chose a key object. It is a typical large depression - "Chervonaya pad". The material for the study was obtained by hand drilling and outcrop investigation on the coast of the Taganrog Bay. As a result of the research, we obtained a new data on the geological structure and morphology of large depressions. Two types of sediments were distinguished in the structure of large depressions and interfluves. At the top lays the loess cover with paleosols developed in it. Sub-aqueous deposits lie beneath the loess cover. The thickness of the loess inside the depressions is less than on watersheds and the number of paleosols is also less. The roof of the underlying sub-aqueous deposits lies sub-horizontally. Traces of lake sediments, cryogenesis, and tectonic faults were not found in the structure of large depressions. The new data allow us to make some important conclusions on the origin and mechanisms of formation of large depressions in the eastern Azov region:

- 1) Large depressions of eastern Azov region were formed by a directional flow.
- 2) These depressions were formed with not water-related processes.
- 3) They were formed by denudation in the loess.
- 4) The position of the buried soil complexes allowed us to estimate the age of the studied depressions. According to the obtained data, depressions were already formed by the beginning of the Eemian inter-glacial.
- 5) As a result of the study, we proposed an eolian denudation mechanism for the formation of large depressions.

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**P-3815**

## **Aggravation of summer monsoon rainfall over south-western India by the dust entrainment in Middle East**

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### **Abstract**

Owing to the global importance of deserts for understanding climate change and biogeochemical cycles, there has been an increasing studies on arid regions since three decades. It has been identified recently that the desert dust entrained from Middle East and North Africa can aggravates rainfall over the north-western India and the adjoining countries through processes, such as, enhanced heat pumping, short-term modulation of monsoon rainfall as well as eastward advancing westerly wind in the temperate zone. The west coast of India and the adjacent Western Ghat is the second largest watershed areas for the Peninsular rivers. A glance through the data needed to test the above processes in the high monsoon rainfall regions, like the coastal Karnataka, indicates that dust raised from the Middle East can enhance rainfall even in the core of the summer monsoonal air flow, particularly during the years of "excess rainfall" as compared to long-term average of the years - 1951 to 2000. Satellite images and data from NOAA and other organizations suggest that the desert dust related data, like RGB images, aerosol optical depth, back-air mass trajectory computations, outgoing long-term radiation indicate that a close association of these parameters with the dense monsoon clouds, that yielded high rainfall during the monsoon 2013. The annual and monsoon rainfall of the Coastal Karnataka compiled by the Climate Monitoring and Analysis of the Indian Meteorological Department, Pune, were 15% and 17% higher than the long-term average climatology of 1971-2000. However, this was not the situation during the year- 2018, although intense dust-entrainment in the Middle East and North Western India, triggered heavy rains in Northern India as well as south-western India during the pre-monsoon and beginning of the monsoon season, rainfall substantially reduced during the August and September months, leading to a drought-like situation where the seasonal and annual rainfall were much below the long-term average. In the current scenario, deserts, particularly in the Middle East are under the influence of westerlies with scanty rainfall have a greater impact on the desiccation of inland water bodies and water budget, particularly for the West Asia, Middle East and North East African countries. It appears that the scenario will worsen in the event of global warming.

**P-3816**

## **Accelerated volume loss in glacier ablation zones of NE Greenland, Little Ice Age to present**

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### **Abstract**

Mountain glaciers at the periphery of the Greenland ice sheet are a crucial freshwater and sediment source to the North Atlantic and strongly impact Arctic terrestrial, fjord and coastal biogeochemical cycles. In this study we mapped the extent of 1848 mountain glaciers in NE Greenland at the Little Ice Age (LIA). We determined area and volume changes for the time periods LIA to 1980s and 1980s to 2014 and ELAs. There was at least  $172.76 \pm 34.55$  km<sup>3</sup> volume lost between 1910 and 1980s, i.e. a rate of  $2.61 \pm 0.52$  km<sup>3</sup> yr<sup>-1</sup>. Between 1980s and 2014 the volume lost was  $90.55 \pm 18.11$  km<sup>3</sup>, i.e. a rate of  $3.22 \pm 0.64$  km<sup>3</sup> yr<sup>-1</sup>, implying an increase of  $\sim 23$  % in the rate of ice volume loss. Overall, at least  $\sim 7$  % of mass loss from Greenland mountain glaciers and ice caps has come from the NE sector.

P-3817

## Late Pleistocene moraine geochronology of the Dinaric mountain karst in Bosnia and Herzegovina; Insights from $^{36}\text{Cl}$ cosmogenic nuclides

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### Abstract

The highest parts of the Dinaric Mountains (northeastern Mediterranean region), known for their karst-dominated landscape and humid climate, were glaciated during the late Pleistocene. Bosnia and Herzegovina is considered as one of the main black spots in the Dinaric Mountains from the glacial chronological point of view, as quantitative age data were completely missing. In this work, we present the first attempt to date moraines in the Dinaric Mountains using cosmogenic  $^{36}\text{Cl}$  surface exposure dating method, and evaluate the ages in the light of regional geomorphological and climatic context. We focus on three areas in southern Bosnia and Herzegovina, i.e. Velež (1969 m asl), Crvanj (1920 m asl) and Čvrsnica (2226 m asl) mountains. Thirty-two samples were collected from moraine boulders from the lowest and largest lateral moraines and hummocky moraines on these three mountain massifs. The moraine boulders, corrected for  $40 \text{ mm ka}^{-1}$  bedrock erosion age, yielded  $^{36}\text{Cl}$  ages of Last Glacial Maximum ( $22.7 \pm 3.8 \text{ ka}$ ) for Čvrsnica, Oldest Dryas ( $14.9 \pm 1.1 \text{ ka}$ ) for Velež, and Younger Dryas ( $11.9 \pm 0.9 \text{ ka}$  and  $13.2 \pm 1.8 \text{ ka}$ ) for Crvanj and Čvrsnica respectively, considering the oldest boulder age obtained from each moraine as the most representative time of moraine emplacement. The dated moraines mark the largest extent of glaciers in the study areas, which have been reconstructed to  $\sim 28 \text{ km}^2$  for Velež and  $\sim 24 \text{ km}^2$  for Crvanj, having a mean equilibrium line altitude at 1388 m and 1541 m, respectively. The magnitude of glaciation along with the equilibrium line altitudes is exceptional in terms of the Lateglacial evidence elsewhere in the northeastern Mediterranean region. It is very likely that the boulder ages reflect complex exhumation and denudation histories; therefore future work is needed to better understand these processes and their influence on the cosmogenic exposure dating approach in a karstic landscape. As the entire country of Bosnia and Herzegovina lack any previous knowledge on the timing of glaciations, the correlation of the age data are quasi impossible. However, our results provide a new dataset, and present a relevant contribution towards a better understanding of the glacial chronologies of the Dinaric Mountains. This work was supported by TUBITAK 118Y052 and Istanbul Technical University (MGA-2017-40540) projects.

**P-3818**

## **The structural glaciology of the Svínafellsjökull snout: Implications for ice dynamics and debris transfer**

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### **Abstract**

Since the Little Ice Age (LIA) the overall retreat of Svínafellsjökull has been punctuated by several readvances resulting in the development of a complex suite of large to small-scale, concentric to saw-tooth moraines on the foreland. Between c. 1970 and 2000, the position of the margin has remained relatively stable, with retreat being dominated by downwasting and a lowering of the glacier surface. However, since 2000 the recession of Svínafellsjökull has been occurring at an accelerated rate resulting in a pronounced thinning of its terminal zone. This research presents data to investigate the structural response to this pronounced thinning of the terminal zone both spatially and temporal, and the impact this has on the glaciological landform record.

The structural architecture of Svínafellsjökull has been investigated by detailed mapping and analysis of the deformation structures (fractures, banding) exposed on the glacier surface using historical vertical aerial photographs, supplemented by field survey and unmanned aerial vehicle aerial photography. Variation in the orientation, length, density and morphology of the crevasses has revealed that Svínafellsjökull can be divided into two main zones: (i) an extensive upper zone which exhibits a relatively simple radiating/fan shaped fracture pattern, a locally well-developed network of supraglacial meltwater channels and a prominent light and dark coloured ogive/Forbes banding; and (ii) a structurally more complex lower zone occupying the lower reaches of the glacier. The regular view of the movement of non-surging valley glaciers is that they move as a single 'plug flow' with the entire glacier body moving 'en-masse' down valley. Although initial results suggest that the structure of the upper part of Svínafellsjökull can be interpreted in this way, the complex lobate morphology of its marginal zone does not fit with simple radiating crevasse pattern typically associated with the spreading of a single piedmont lobe. The structurally complex nature of the marginal zone of Svínafellsjökull indicates that it comprises of three independent, lobate flow units.

Changes in the structural configuration of the lower reaches of Svínafellsjökull have an impact on the landform record preserved within its forefield. The most recently formed moraines at Svínafellsjökull display saw tooth or crenulated pattern in plan form. Geomorphological mapping of the forefield reveals that the pre-LIA limits are arcuate in shape with the switch to a saw tooth pattern of moraine crests having occurred during the 1980-90s (c.f. Everest *et al.*, 2017). This could suggest that the lobate style of flow at the margin of Svínafellsjökull was established during the late 1980s as the glacier retreated from this major readvance limit. To conclude, this research demonstrates that the landform record within Svínafellsjökull's forefield reflects changes in the structural architecture of the marginal zone of the glacier.

P-3819

## Insights into the influence of stepped topography on glacier retreat rates from an abandoned lobe of Skálafellsjökull, SE Iceland

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### Abstract

Glaciers do not retreat at a uniform rate dictated solely by climate. Climate signals are interspersed with more location-specific signals, which may be influenced by factors including (but not limited to) glacier hypsometry, underlying geology, ice albedo and underlying topography. We use detailed Unmanned Aerial Vehicle imagery to produce a high resolution Digital Elevation Model and aerial orthophoto to map the glacial geomorphology of the abandoned foreland of a former high elevation secondary lobe of Skálafellsjökull, an active temperate outlet glacier of the Vatnajökull Ice Cap in SE Iceland. We combine this mapping with lichenometric dating and sedimentology to provide insights into the effect of stepped upland topography on glacier retreat rates.

Many of the glaciers in SE Iceland have been intensively studied over the last 50-100 years and numerous publications document their retreat in response to climate warming. However, most of this work has concentrated on the piedmont lobe termini which flow(ed) onto the somewhat flat outwash plains produced during the Holocene. The response of glaciers in more topographically complex areas is less well understood, but is important because many glacierized areas that are undergoing retreat, such as glaciers around the periphery of Greenland and Svalbard, lie over such terrain.

Skálafellsjökull provides a useful analogue because the glacier sits over a series of dyke-controlled bedrock steps. Whilst the main snout of Skálafellsjökull has retreated across a flat outwash plain, a subsidiary lobe of the glacier previously extended over part of the higher-altitude stepped topography during the Little Ice Age, and has now almost completely disappeared from this area. The lobe flowed over four relatively uniform topographic steps. We reveal the detailed geomorphology of this abandoned lobe, which comprises arcuate and saw-tooth moraine ridges at the distal ends of the steps, and flutings at the proximal ends, and we provide lichenometric ages for the retreat of the glacier from 1890 to 1945, and historical margin positions from a series of aerial photographs and satellite imagery from 1945 to the present day.

**P-3820**

## **Topographic controls on plateau icefield recession: insights from the Younger Dryas Monadhliath Icefield, Scotland**

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### **Abstract**

Plateau icefields are a common form of mountain ice mass, frequently found in mid-latitude to high-arctic regions and increasingly recognised in the Quaternary record. Their top-heavy hypsometry makes them highly sensitive to changes in climate when the ELA lies above the plateau edge, allowing ice to expand significantly as regional ELAs decrease, and causing rapid recession as climate warms. In light of predicted future climate warming, it is important to understand the controls on plateau icefield response to climate change in order to better predict recession rates, with implications for water resources and sea-level rise. Improving knowledge of controls on glacier recession also has the potential to enable palaeoclimatic information to be extracted from the Quaternary glacial record. We use the distribution of moraines in a formerly glaciated setting to examine how topographic controls augment the response of a former icefield to climatic amelioration towards the end of the Younger Dryas. We find that overall valley morphology influences the style of recession, through microclimatic and geometric controls, with bed gradient affecting moraine spacing. In addition, ice masses reconfigure as recession progresses, because transection valleys and ice divide migration could alter the expected response based on hypsometric distribution. We also identify the potential for thresholds or tipping points during recession, resulting in a non-linear and spatially variable ice mass response to changes in climate.

**P-3821**

## **The geomorphology of Svínafellsjökull and Virkisjökull-Falljökull glacier forelands, southeast Iceland**

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We present a detailed, 1:10,500-scale, surficial geology and glacial geomorphology map of Svínafellsjökull and Virkisjökull-Falljökull glacier forelands in southeast Iceland. The map depicts the landsystem imprint of Holocene glacier fluctuations, volcanogenic outburst floods, and recent (post-1990) climate-induced rapid ice-front retreat. The map is based on field survey data in combination with 2012 airborne LiDAR data, 2009-2012 terrestrial LiDAR data and 2007 colour aerial photography. The base DEM for the glacial and topographic information is compiled from an ice-cap wide airborne LiDAR dataset. The mapped glacial landforms are dominated by sequences of recessional moraines laid down in the mid Holocene, the Little Ice Age, and the last ~100 years; the state of landform preservation generally decreasing with age. In addition, expansive glaciofluvial outwash plains (sandar) stretch from the glacier margins to the present-day coastline. Interspersed with glaciofluvial sedimentation associated with typical ice-marginal retreat sequences is key geomorphological evidence of high-magnitude volcanogenic outburst floods (jökulhlaups) associated with the eruptions of Öraefajökull in 1362 and 1727 CE. Other notable geomorphic features include saw-tooth moraines at Svínafellsjökull; flutes at both glaciers; and a large, recent, supraglacial rockfall at Virkisjökull-Falljökull. Ice-front retreat from a prominent re-advance moraine in ~1990 has accelerated since ~2005 leaving a rapidly evolving buried-ice landscape in front of Virkisjökull-Falljökull – including an ice-cored esker, a large ice-floored (supraglacial) lake, numerous actively forming kettle holes and subterranean ice caverns. This map could act as a 'reference frame' for geomorphologists studying the temporal evolution of glacial landform-sediment assemblages – the products of currently rapid deglaciation in southeast Iceland.

P-3822

## **Pervasive cold-ice within a temperate glacier - implications for glacier thermal regime, sediment transport and foreland geomorphology**

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### **Abstract**

This study suggests that cold-ice processes may be more widespread than previously assumed, even within temperate glacial systems. We present the first systematic mapping of cold-ice at the snout of the temperate glacier Midtdalsbreen (Norway) using ground penetrating radar data. Results show a 40 m-wide cold-ice zone within the majority of the glacier snout. We interpret ice to be cold-based across this zone, consistent with basal freeze-on processes involved in the deposition of moraines. We also find at least two zones of cold-ice up to 15 m thick within the ablation area, occasionally extending to the glacier bed. There are two further zones of cold-ice up to 30 m thick in the accumulation area, also extending to the glacier bed. Cold-ice zones in the ablation area tend to correspond to areas of the glacier that are covered by late-lying seasonal snow patches that reoccur over multiple years. Subglacial topography and the location of the freezing isotherm within the glacier and underlying subglacial strata likely influence transport and supply of supraglacial debris and formation of controlled moraines. The wider implication of this study is the possibility that with continued climate warming, temperate environments with primarily temperate glaciers could become polythermal in forthcoming decades with i) persisting thinning and ii) retreat to higher altitudes where subglacial permafrost could be and/or become more widespread. Adversely, the number and size of late-lying snow patches in ablation areas may decrease and thereby reduce the extent of cold-ice, reinforcing the postulated change of thermal regime.

P-3823

## Assessing the erosivity and deglacial thinning history of the southeastern Laurentide Ice Sheet using *in-situ* cosmogenic $^{10}\text{Be}$ and $^{14}\text{C}$

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### Abstract

A lack of empirical data constraining the thinning history and erosion patterns of the Laurentide Ice Sheet has resulted in uncertainty about volume changes and dynamics – information critical to understanding its contribution to sea level rise, influence on paleoclimate, and response to the changing climate of the deglacial period. To provide insight about ice sheet history and behavior, we collected 120 samples for *in-situ*  $^{10}\text{Be}$  and 10 samples for *in-situ*  $^{14}\text{C}$  cosmogenic exposure dating from various elevations at numerous mountains in the northeastern United States and southern Quebec, Canada. By calculating ages of exposure at different elevations across this region, we will reconstruct the lowering paleo-ice surface of the southeastern Laurentide Ice Sheet. Using radionuclide pairs at critical locations, we will also investigate the erosion that took place during glaciation.

Presently, we have processed 62 samples for  $^{10}\text{Be}$  concentrations. Mountain-top exposure ages located within 150 km of the southeastern Laurentide Ice Sheet terminal moraine indicate that near-margin thinning began early in the deglacial period (~19.5 to 17.5 ka), coincident with the slow initial margin retreat indicated by varve records. Exposure ages from several mountains further inland (>400 km north of terminal moraine) were collected over ~1000 m elevation spans and record ice thinning between 14.5 and 13 ka. Ages within each of these vertical transects are similar within  $1\sigma$  internal uncertainty, indicating that ice thinning was rapid. This rapid thinning occurred at approximately the same time that varve records indicate accelerated ice retreat during the Bølling-Allerød warm period (14.6–12.9 ka), providing evidence of substantial ice volume loss during this period from the southeastern Laurentide Ice Sheet.

Higher elevation (>1200 m a.s.l.) samples contain high  $^{10}\text{Be}$  concentrations that yield simple exposure ages older than the LGM. *In-situ*  $^{14}\text{C}$  ages from one of the high-elevation locations yield younger exposure ages, indicating that these high  $^{10}\text{Be}$  concentrations are likely due to  $^{10}\text{Be}$  inherited from previous periods of exposure rather than continuous exposure. At the highest elevations (>1600 m a.s.l.), samples contained high  $^{10}\text{Be}$  concentrations (simple exposure ages ~33 – 75 ka) and *in-situ*  $^{14}\text{C}$  concentrations at or near saturation, possibly indicating early exposure (>25 ka) following cover by non-erosive ice. The lack of summit erosion suggests that the paleo-ice surface of the Laurentide Ice Sheet was never significantly higher in elevation than the tops of these mountains, inhibiting meltwater formation and basal sliding above ~1200 m a.s.l.

P-3824

## Cosmogenic surface exposure dating of the deglaciation of Finnmark and northern Finland

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### Abstract

The northern coast of Finnmark county, northern Norway, forms the northernmost edge of mainland Europe. During the Last Glacial Maximum (LGM) this region was covered by the Fennoscandian Ice Sheet (FIS), which coalesced with the Barents Sea Ice Sheet (BSIS) off the coast. The region is thus important for our understanding of the dynamic interactions between the BSIS and the FIS, but despite this it remains one of the least dated regions covered by the FIS.

We present 23 cosmogenic surface exposure ages (<sup>10</sup>Be) from eight localities sampled along a 240 km long north-south transect ranging from the outer coast of the Nordkinn peninsula (Norway) to Lake Inarijärvi (Finland). Based on these we discuss implications for the pattern and timing of ice sheet retreat in the region. The samples were prepared at the Institute of Geological Sciences, University of Bern and were the first geological <sup>10</sup>Be samples measured at the National Laboratory for Age Determination, Trondheim (Seiler et al. 2018).

We were particularly interested in the deglaciation age at the outer coast, where the previously suggested deglaciation ages have varied widely. Seven of the samples were therefore taken at the outer coast of the Nordkinn peninsula. After excluding three questionable samples (two outlier ages at 55.1±5.1 ka and 19.5±1.8 ka and one sample taken below the marine limit), the remaining samples gave a mean age of 14.5±0.4 ka, which we consider the best estimate of the deglaciation at the outer coast of Nordkinn. For the southernmost part of the transect, three samples from the streamlined terrain around Lake Inarijärvi indicate a deglaciation 11-10 ka ago.

### Highlights

- Twenty-three cosmogenic surface exposure ages (<sup>10</sup>Be) from eight localities in northernmost Norway and Finland.
- For the outer coast, our new exposure ages suggest a deglaciation around 15-14 ka, which fits with a deglaciation during early Bølling.
- The study presents the first geological <sup>10</sup>Be samples measured at the National Laboratory for Age Determination, Trondheim.

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P-3825

## The impact of glacial lake-outburst floods on the meltwater-drainage system of northern central Europe during the Middle Pleistocene glaciations

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### Abstract

The formation and drainage of ice-dammed lakes along the southwestern margin of the Middle Pleistocene (Saalian) Fennoscandian ice sheet had a major impact on the regional meltwater-drainage system and the landscape evolution. The advances of the Middle Pleistocene ice sheets repeatedly led to the blockage of the fluvial- and meltwater-drainage systems and the formation of extensive ice-dammed lakes. The drainage of the meltwater along the southwestern margin of the Middle Pleistocene ice sheets was controlled by the ice-dammed lakes in river valleys and lowland areas from the Lower Rhine Embayment in the west to the continental drainage divide between the Atlantic and the Black Sea in eastern Poland. The location and extent of these lakes depended on local topography and the presence of ice dams. The retreat of the ice margin changed the lake configuration and opened lake overflows, leading to a successive drainage of the lakes. Glacial lake-outburst floods occurred when large overflows were suddenly opened. The restoration of the drainage routes towards the west and northwest required the successive opening of the ice dams and the drainage of the ice-dammed lakes.

At least three major outburst floods from different ice-dammed lakes in northwestern and central Germany have been reconstructed. These floods were triggered by the failure of ice dams in bedrock-outlet channels and released ~20 to ~200 km<sup>3</sup> of water. The drainage routes are characterised by erosional features like plunge pools, trench-like channels, megaflutes, scour pools and streamlined hills. Depositional features include large sand and gravel bars, and fields of sandy bedforms deposited by supercritical to transcritical flows.

Numerical flood simulations were conducted to better understand flood inundation and quantify the flow characteristics. Reconstructed flood hydrographs indicate peak discharges between 166,000 and 673,000 m<sup>3</sup>s<sup>-1</sup>. 2D numerical simulations of the flood inundation provide estimates of the spatial and temporal evolution of flow depth, velocity and bed-shear stress.

The incision of deep and broad channels by the glacial-lake outburst floods strongly impacted the meltwater-drainage system by providing an efficient drainage network. The channels initiated by the lake-outburst floods became a crucial part of the ice-marginal drainage system during the decay of the Saalian ice sheet and subsequent re-advances. Some of the flood-related channels became part of the fluvial drainage system after deglaciation.

**P-3826**

## **Run-up sediments as (palaeo-)hydraulic indicator**

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Run-up sediments can be found in river channels and floodplains in front of local obstacles like trees trunks, bridge piers or bedrock cliffs. Upstream of the obstacle, the flow velocity of the current decreases resulting in a locally elevated water surface due to the transfer of energy from kinetic to potential energy. Transported suspension load might be deposited at a higher level in front of the obstacle or mark the higher water level to one side or either side of the obstacle.

Run-up effects as special feature of flood debris lines were first mentioned by Costa in the context of debris flows, but were not investigated in detail. Along the pathway of the Pleistocene ice-dammed lake outburst floods in the Altai-Mountains, Siberia, run-up sediments are located at numerous valley obstructions in front of local bedrock ridges. The clue of the interpretation is not their sedimentological structure or texture, but the configuration of their deposition and especially their elevation in relation to undisturbed flood stage indicators upstream of the obstruction. Typically, they generate a relatively thin layer of deposited suspension load in front of the obstruction.

They indicate the amount of energy transfer and can be used to conclude on the mean flow velocity of the current upstream of the obstruction. According to the energy equation by Bernoulli, energy can only be transferred from kinetic to potential energy as pressure energy is negligible for open channel flow. Hence, once a current is blocked its kinetic is transferred into potential energy indicated by a risen water level. As the amount of the water level differences upstream and in front of the obstruction can be measured in the field – or surveyed of suspension load marks and deposits for palaeofloods – the unknown variable of mean undisturbed flow velocity can be estimated. This principle previously was applied for flow velocity measurements in small channels.

**P-3827**

## **The geomorphological significance of Quaternary fluvial deposits and mega-boulders in the Tamatert Valley, High Atlas, Morocco**

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### **Abstract**

In the Tamatert Valley, near the village of Imlil (1800 m.a.s.l.) in the High Atlas of Morocco, a defining feature of the valley floor is a spread of enormous boulders pointing to the occurrence of a catastrophic geomorphological event (or events) in the recent geological past. The headwaters of this catchment were glaciated during the Pleistocene. Mega-boulders are present on the bed of the steep active channel and within exposed Quaternary fluvial and colluvial deposits. Fieldwork has been carried out to establish the spatial distribution, lithology, size, and geomorphological context of these boulders. Key aims are to determine their age, provenance, and the processes responsible for their transport and present disposition. The largest boulders are not derived from the local bedrock in the lower valley. The timing of emplacement will be established through optically stimulated luminescence dating of associated deposits and via cosmogenic dating of the boulders themselves.

The Tamatert Valley and adjacent valleys were glaciated periodically during the Quaternary. The timing and extent of the glaciation has been well constrained with over 50 cosmogenic isotope dates. Optically stimulated luminescence dating of the Quaternary fluvial and colluvial deposits near the village of Imlil will shine a light on the influence of glaciation, as well as the catastrophic events, on the river record in this steepland setting.

More broadly, understanding the specific impact of glaciation, as part of cold stage climate, may be key to a better understanding of landscape evolution and contemporary fluvial system behaviour in steep mountain settings and must therefore be an important part of fluvial geomorphological research in the Mediterranean and North Africa.

P-3828

## New geochemistry evidence for the Yellow River intrusion into the Huaihe River (east China)

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### Abstract

The sediments of the Huaibei Plain in semi-humid mid-eastern China represent valuable geological records with respect to eolian–fluvial interactions, depositional environments, and climate change in east China. The lower course of Yellow River has flooded many times throughout history with documented recordings of more than 1000 floods over the past 4000 years and at times has invaded the Huaibei Plain. However, the existence of prehistoric incursions of the Yellow River into the Huaihe River drainage basin is still poorly understood. This is a significant scientific question for understanding the evolution of Huaibei Plain and Yellow River.

In this study, an 8-m core from Huainan (HN, 32°50.123'N, 116°30.167'E) in the center Huaibei Plain and a set of loess samples from northern and southern China were analyzed for major, trace, and rare earth elements (REEs). Results were compared to determine the samples' provenance. The major, trace, rare earth elements contents, and grain size distribution were found to fluctuate widely in the 2–8 m section of the Huainan core and more narrowly closer to the surface (0–2 m). This suggests a provenance shift at a depth of 2 m. The  $TiO_2/Al_2O_3$ ,  $SiO_2/Al_2O_3$ , Th/Nb, La/Nb values and REE patterns in the upper core (0–2 m) are similar to those found in samples from the Chinese Loess Plateau (CLP). These results suggest that the CLP in northern China is likely to be the primary origin of the upper part (0–2 m) of the Huainan core. And the upper part (0–2 m) is Yellow River flood sediments. According to the <sup>14</sup>C dating, the age is ~13.2 ka at 2 m depth in the HN core. The sediments may have been transported from the CLP to Huainan as Yellow River flood events, probably during the last deglaciation (~13.2 ka) as a result of increased precipitation, along with glacier and snow melt in the upper reaches of the Yellow River catchment during this period. This suggests that the Yellow River may have migrated into the Huaihe River catchment much earlier than the earliest historical records (361 BCE) suggest. This result significantly improves our understanding of the influence of the Yellow River in the formation and shaping of the Huaibei Plain.

P-3829

## Development of the north-central Nile Delta in the Holocene, based on examination of the barrier Blorus Lake sediments, Egypt

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### Abstract

Development of the Nile Delta in the Holocene was dependent on three major factors: sea level fluctuation, Nile sedimentary activity and subsidence of the delta front. In turn, landscape and accretion of the delta itself had a great impact on the ancient Egyptian state, especially in the pharaonic times. The modern Blorus (Burullus) Lake is located in a north-central part of the Nile Delta, east of the Rosetta branch. It is the second largest natural lagoon in Egypt, characteristic for its numerous environments including salt marshes, mudflats and sand plains, with high sand dunes on the shores. The lake is about 54 km long, 6-21 km wide and to 2 m deep, longer axis runs parallel to the delta sea-front and its area is about 462 km<sup>2</sup>. The western part the lake is deeper and mostly freshwater, the eastern sector is more shallow and saline due to the Bughaz Canal that connects the lake with the sea. The Blorus Lake was fed in the Holocene by the Sebennytic branch of the Nile and its transformations stimulated predynastic settlements, laying foundations of the ancient Egyptian civilisation.

A drilling BO-1 was done in 2014 at the northern shore of the Blorus Lake within the frames of the project funded by the National Science Centre in Poland (decision no. DEC-2012/05/B/ST10/00558). The collected core, 11 m long, was sampled for high resolution lithological, sedimentological and faunal analyses, including also microscopic studies (SEM/EDS), magnetic susceptibility measurements, radiocarbon dating and correlation with geoarchaeological data. The basal fine-grained sand (11.0 – 10.7 m depth) of the Late Pleistocene Mit Ghamr Formation was deposited by the Nile in a dry climate. It is overlain by well-sorted sand with interbeds of silty clay, inserts of organic matter and mollusc shells deposited in a brackish lake with water-level fluctuations and varied interaction of fluvial and marine environments in the Early Holocene. A sea ingression at ca 6.9 – 6.5 cal kyr BP in a shallow brackish lagoon is indicated by a silty clay with water-soluble ions and organic matter. Since that time, the predominant angular quartz grains in the sediments are replaced by the subrounded ones. It is followed by periodical input of the Nile and a sea ingression at ca 2.9 – 2.7 cal kyr BP, reflected by sand deposited in a shallow brackish lagoon with a marsh margin. Since ca 2.5 cal kyr BP there were numerous short sea ingressions and after 2.0 cal kyr BP the lagoon was generally cut off from the Nile but more grains of sand gained the aeolian sculpture.

**P-3830**

## **Physical property characterization of Quaternary sediments in the vicinity of the paleo-Seomjin River, the South Sea, Korea**

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### **Abstract**

Thirty-two core samples were collected from the continental shelf area of the South Sea, Korea. They have been used to characterize physical properties in relation to sedimentary units (interpreted from seismic and core data) and to interpret physical property variation as a function of burial depth. The physical property data were readily classified into sedimentary units: Units S1, S2, S3, S4, and S5, in descending order. The variations in physical properties reflect well the relative characteristics of sedimentary units (equivalent to seismic units). Moreover, the relationships between physical properties are well grouped by each sedimentary unit. In addition, the distributions of physical properties match well with the grain size distribution and bathymetry of the study area. In particular, the lithology (e.g., grain size) plays an important role in the variation of physical properties. These results suggest that the physical properties of these sediments are mainly controlled by depositional processes in the vicinity of the paleo-Seomjin River, and that sea-level change specifically was a dominant sedimentary processes in the study area during the Quaternary. In particular, the physical properties of Unit S2 do not show transitional characteristics between Units S1 and S3, although it belongs to the transition zone in sequence order. This finding is attributed to the fact that compared with the sediments of Units S1 and S3, Unit S2 is composed of more coarse-grained sediments with abundant shell fragments.

**P-3831**

## **The geomorphic and climatic affinity of Holocene mega-floods in the western Himalaya, India**

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### **Abstract**

Sedimentological evidence of Holocene mega floods are investigated in the Satluj river valley and its trans-Himalayan tributaries. The idea is to understand the geomorphic and climatic processes responsible for the generation of the mega floods in the western Himalaya. Based on the sedimentological and textural criteria ~16 flood events of increasing magnitude are dated which cluster in two major time domains. The older phase (seven events) occurred before ~11 ka while the younger phase (nine events) is dated between ~8 and 6 ka. The younger flood phase is regional in nature (catchment wide) but does not overtop the older flood phase (>11 ka) in the para-glacial zone of the Spiti river implying that the former were either of lesser magnitude or did not originate in the trans-Himalayan region. The former seems to be the likely possibility as indicated by the <sup>87/86</sup>Sr ratio and major element data suggesting dominance of higher Himalayan crystallines in the flood sediment. Climatically, we ascribe the younger phase to the phases of negative Arctic Oscillation (-AO) and negative North Atlantic Oscillation (-NAO) during which a coupling between the moisture-laden monsoon circulation and southward penetrating mid-latitude westerly troughs occurred. As a consequence, the floods were triggered by the extreme precipitation events causing slope instability leading to the Landslide Lake Outburst Floods (LLOFs) particularly in the higher Himalaya (orographic barrier)- a conducive geomorphic setting for cloud condensation and torrential precipitation. On the other hand the events in older phase seems to be triggered by melting of glaciers/rain on snow and GLOFs generated thereof by rising temperatures in early Holocene.

**P-3832**

## **Late Holocene Environmental Change at Math-Pimpri: A New Ancient settlement discover on the Sina River Valley in Deccan region, India**

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### **Abstract**

Math-Pimpri, the ancient settlement town of Satavahanas dynasty, is a key site for understanding the complex alluvial environment of the upper Sina River valley which is located in the semi-arid parts of the Deccan Trap region, western part India. The beginning of the Satavahana rule is dated variously from 271 BCE to 30 BCE. Satavahanas dominated the Deccan region from the 1st century BCE to the 3rd century CE. The dynasty reached its zenith under the rule of Gautamiputra Satakarni and his successor Vasisthiputra Pulamavi. The Puranas and inscriptions remain important sources for the history of Satavahanas. Among the inscriptions, the Nasik and Naneghat inscriptions throw much light on the reign of Gautamiputra Satakarni. Renewed archaeological excavations (2013-14) allied to geomorphological works on the ancient river environment are attempting to establish the nature of the local and regional landscape before, during, and after the occupation of the settlement. For the first time, Optically-Stimulated Luminescence (OSL) and archaeological datings have been combined on the fluvial archives. This database helps us to understand better the chronostratigraphy and the evolution of the palaeo-environments. A complete bankfull cross-section of the Math-pimpri branch has been obtained. Thus, we get 3 important characteristics of the main branch: the width, the depth, and the palaeo-discharge records. In order to get an idea of the palaeo-processes information provides additional insights into the nature of the local environment during the period of occupation.

P-3833

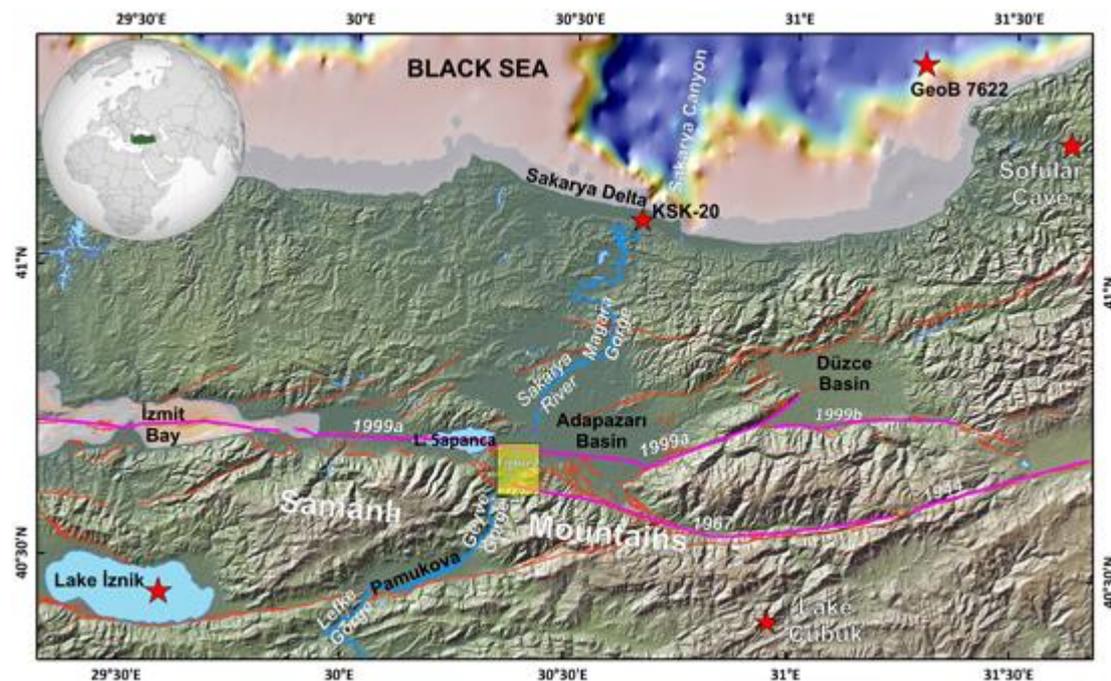
## Investigation of Holocene palaeo-hydrological changes using fluvial archives: A case study for Sakarya River terraces, NW Anatolia.

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### Abstract

Holocene climate changes of the NW Anatolia is well-resolved by means of high resolution speleothem (Sofular Cave) and sedimentary (Iznik, Çubuk Lakes and Black Sea) records. The Sakarya River, the major fluvial system of the region, comprise 3 stepped depositional terrace staircases located just to the south of the North Anatolian Fault at the Adapazarı Basin. These terraces provide sedimentary record from 9-1.8 ka (T2), 1.2-1 ka (T1) and 0.7 ka-recent (T0) evidenced by luminescence and radiocarbon dating.



Physiographic map of NW Turkey and the location of the study area (yellow shaded area). Pink lines represent surface ruptures along the North Anatolian Fault during the last 100 years. Stars present the locations of the adjacent climate records

The sections are fully exposed due to excessive sand-mining, and formed of fine grained flood plain deposits exhibiting a layered stratigraphy. Despite the hiatus(s), these deposits have a potential to record and reflect the hydrological changes at the Sakarya River throughout the Holocene.

In order to construct an event stratigraphy, we detail the sections exposed at the terrace steps and map the changes in grain size, geochemistry and charcoal percent etc. By using this multi-proxy approach, we aim to detect the rapid climate changes (such as 8.2 and 4.2 ka events) evidenced in regional paleoclimatic records and also the critical hydrological events (such as frequent flooding periods) for the region.

This study is supported by TUBITAK 115Y132 and 117Y426 grants.

**P-3834**

## **Luminescence Chronology of Late Holocene Palaeofloods records in the Upper Kaveri Basin, India: Flood-Climate relationship**

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### **Abstract**

Palaeoflood records from upper Kaveri were identified and provided with Optically Stimulated Luminescence (OSL) dates to reconstruct the past flooding events generally associated with climatic transitions. The river gauge data from the Kaveri basin were substantiated with the preserved sedimentary records, emphasizing on the importance of sedimentary records in climate studies. Rainfall record of 100 years (1901-2002) is also considered to understand the flood dynamics of the study region. The objective is to look for palaeoflood records and ascertain their periodicities on decadal to millennium scale and to observe the association of extreme flood events with climatic changes. Upper Kaveri receives Indian summer monsoon and flows through rocky terrain. It is joined by many tributaries on its way, thus, is expected to carry mixed sediments coming from weathering of local host rocks. Therefore, extent of bleaching and thus feasibility of OSL dating in such environment was checked. Age models were applied to compute the ages successfully, complemented by existing flood records. The study shows changes in the climatic pattern can be associated with more frequent occurrences of extreme flood events. The flood clusters (~50 years BP, ~90 years BP, 160-220 years BP, ~700 years BP, ~2.1 ka and ~2.3 ka) are observed during major climatic shifts. No high magnitude floods are observed when the monsoon climate was relatively consistent for a long time. The study throws light on luminescence characteristics, bleaching status and helps to reconstruct the past fluvial history of the upper Kaveri river, generally associated with climatic transitions.

**P-3835**

## **Geomorphologic indications of the Mediterranean and Black Seas capturing presently the endorheic plains and plateaus of Central Anatolia**

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### **Abstract**

Since Late Miocene in Anatolia, uplift, faulting and sliding have generated the encircling of a central zone limited south by the Taurus highlands with summits reaching today 3000 m to >4000 m along the Mediterranean sea. Meantime, the uplift of the central zone reached 1000-1500 m asl while major strike-slip fault zones, sheared and faulted block systems. Uplift of the highlands encircling Anatolia caused the incision of valleys and deep canyons radiating from the highlands in direction of the seas surrounding the peninsula, while central Anatolia formed a more or less high depression at 1000-1500m asl. This central zone presents today patches of (i) plateaus and low hills corresponding to remains of erosion and structural surfaces truncating carbonate deposits, and (iii) volcanic massifs constructed after Late Miocene.

During and after uplift, thick series of emerged carbonates were subjected to dissolution producing a high variety of surface and underground karstic features. In the highlands, stages in the deepening of the underground karst (eg. forming stepped floors separated by sloped to vertical tunnels) record slowing phases in the uplift. In parallel, the slower uplift of central Anatolia protected the central plateaus from incision, allowing karstic features to remain superficial, with low Plio-Pleistocene limestone plateaus alternating with poljes. As a result, the hydrography of central Anatolia is mostly endhoreic (ie. no outflow to the sea) with depressions often corresponding to faulted poljes in which water occurrences mostly occur as karstic springs, and freshwater to salty marshes and lakes.

Recent interpretation of three large depressions bordering the northern slopes of the Taurus from the Isparta Angle (Beydağları poljes and Burdur to Beyşehir-Suğla poljes) to the Aladağlar range (Konya-Ereğli, Tuz Gölü and Sultansazlığı plains) evidence, together with hydrogeologic monitoring of underground water, that these closed depressions are being captured today by Mediterranean and Black Sea exhoreic drainage. This capturing is controlled by both the tectonic regimes that has affected Anatolia during Pleistocene, and by the karstic processes dissolving the carbonates. The result of these observations is that the combination of tectonics and karstic dynamics is opening a new stage in the dismantling of the endhoreic central Anatolia. In eastern Anatolia where the uplift is more recent and active, connections between underground and surface erosion processes are not as much developed. In this latter region, "capture-to-be" locations exist where (i) tectonically-controlled lines concentrate surface erosion in limestones (fault lines, canyons), and (ii) surface and deep karst features develop actively in limestone massifs separating tectonically mobile watersheds.

P-3836

## Holocene and historical morphodynamics of the Lower Mesopotamian waterscape: a multi-sensor remote sensing approach

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### Abstract

During the Holocene the Tigris-Euphrates river system, at the lower sector of the Mesopotamian Plain (Iraq), has been characterized by a complex morphodynamics in response to climate fluctuations and the extensive construction of artificial canals, dug since the first River Valley Civilizations. During the early Holocene, the sea-level rise caused a general and rapid northward shifting of the Persian Gulf shoreline, after which the general progradation of the Tigris and Euphrates delta system accounted for the shoreline regression up to the present position. Several studies focused on the Mesopotamian waterscape to identify, among others: i) the position of the shoreline during the maximum Holocene marine ingression (i.e., 6,000 yr BP); ii) the effect of the Tigris and Euphrates paleo-delta progradation during mid and late Holocene; iii) key features useful for distinguishing natural river channels from anthropogenic canals. In this context, this study aims to enhance the knowledge on the Holocene and historical morphodynamics of the Lower Mesopotamian waterscape and, specifically, on the paleo-hydrology of the ancient fluvial system. This study provides new geomorphological data useful for better comprehending the mechanisms and rates of the complex interactions between the dynamics of the natural waterscape and the distribution, shifting and abandonment of historical settlements and artificial canals.

A multi-sensor remote sensing approach has been adopted to identify the main geomorphological features and describe the associated morphogenetic processes. Optical and multi-spectral Landsat 8 satellite images have been processed for computing NDVI and Clay Index, as well as to extract Regions of Interest (ROIs). The spectral signatures of the ROIs have been extracted and compared among them. This analysis has been integrated with the investigation of the micro-topography obtained through the re-classification of different DEM sources: i) C-band interferometric SRTM and Sentinel-1 (ground resolution of 30 and 15 m); ii) optical ALOS datasets (ground resolution 30 m).

Remote sensing multi-spectral analysis revealed useful to identify and delineate the geomorphological features associated to the Holocene progradation of the ancient Tigris and Euphrates delta system, past flood-events along the main distributary channels, surficial effects of channel migrations and marshes distribution. Especially, past flood-events have been identified by depositional and erosive landforms due to avulsion processes and the associated crevasse splays, other than by the position and planar pattern of artificial canals. In fact, these latter were essential for managing hydrological extreme events and, on the other hand, to take advantage from them (i.e. field irrigation system). Micro-topography analysis, integrated by the study of distribution of ancient settlements and the planar configuration of ancient distributary channels and artificial canals, allow to preliminary discern the geomorphological effects of the Holocene sea-level variations and the associated variations of the river morphodynamics.

P-3837

## Improving the understanding of the lower Guadalhorce fluvial landscape development: first dates on the river terrace staircase and alluvial fans

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### Abstract

Quaternary fluvial archives such as river terraces and alluvial fans are the most important, potentially to be dated, landforms in the unravelling of quaternary landscape development and climate changes. This is even more true for the western Mediterranean where terrestrial climate records are not abundant. One of the so far poorly studied areas is the around 160 km long Guadalhorce river is situated in the province of Malaga, Andalucía in the south of Spain. Its source is located in the Sierra de Alhama and it dominantly flows west, draining the Antequera tectonic basin before turning south in the El chorro area towards the Mediterranean - Alboran Sea, having its mouth near the town of Malaga. The catchment has undergone a complex geologic – tectonic development history, and shows evidence of an extensive human occupation history.

The principal investigated area is the Lower Guadalhorce valley with a flight of terraces situated between the El Chorro canyon and the beginning of the Malaga Basin. In this area a total of 10 terrace levels can be distinguished, from T0 (current river bed) to T9 (supposing the highest and oldest terrace level). A total of 11 locations were sampled in vertical exposures of fluvial terraces or alluvial fan settings ranging from 1 to 20 meter above present day river level. Sampled sediments of the sand fraction were analysed with the latest quartz OSL techniques and IRSL feldspar methods.

The results indicate burial ages, inferred as important aggradation phases, in MIS 4, 5d and 6. The same holds true for the 2 sampled alluvial fans, indicating fan buildup activity, interfingering with fluvial activity in MIS 4 and 6. Consequently, fluvial aggradation seems, in analogue to NW Europe, to be linked to the so called cold stages, although there is no direct evidence for real (peri)glacial conditions in the Western Mediterranean lower river basins. The mechanism therefor is probably linked to wetter conditions (can be in both precipitation amounts and lower temperatures, evaporation conditions). Remarkably, there is no terrace level found yet for the MIS 2 cold stage. Finally, the lowest and youngest terrace level, although with poor reliability, points towards a historical aggradation phase of only 600-100 years ago. Not surprising, the incision that formed these lowest - youngest terrace levels is clearly linked to the installation of the reservoir lakes just upstream of the El Chorro area, trapping the upstream sediments and providing more controlled clean water discharge.

P-3838

## Sediment provenance indicated by magnetic susceptibility and inorganic geochemistry in the Baker-Martínez fjord system (Chile, 48°S)

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### Abstract

Patagonian fjord sediments are increasingly used as high-resolution archives of past climate and environmental change, including variations in glacier mass balance, flood frequency, and seismic activity. To accurately interpret these proxy records, it is crucial to comprehend modern day sedimentation processes and determine the provenance of the sediments. With this in mind, the main objective of this study is to identify parameters that can be used to reconstruct sediment provenance in the fjords of Chilean Patagonia. We focus on the Baker-Martínez fjord system, which is located between the Northern and Southern Patagonian Icefields and seems particularly sensitive to climate change. This fjord system connects the terrestrial ecosystems of Patagonia with the SE Pacific Ocean, and most of its sediment originates from glacier-fed rivers draining either the Patagonian Batholith (PB; Baker and Huemules rivers) to the north, or the Eastern Andes Metamorphic Complex (EAMC; Bravo and Pascua rivers) to the south. Eighteen surface sediment samples from across the Baker-Martínez fjord system and 44 suspended sediment samples from two sequential (Baker fjord) and one continuous (Steffen fjord) sediment trap were investigated. In addition, we analyzed suspended sediment samples collected at the mouths of the four main rivers that drain the PB and EAMC to define end-members. We focus on mass-specific magnetic susceptibility (MS) and inorganic geochemistry, which seem to be particularly promising in this fjord system dominated by lithogenic sediments (97–85 wt%). Our results indicate that sediments derived from the PB are characterized by high MS, Ti/Al, and Fe/Al values, reflecting the granodioritic nature of the batholith (rich in pyroxene and amphibole). In contrast, sediments from the southern EAMC-derived rivers have significantly lower MS, Ti/Al, and Fe/Al values. The sediment trap results reveal MS values that increase with increasing Baker river discharge, either during the summer melt season, or during high precipitation events (rain-on-snow) in winter. Likewise, the MS, Ti/Al and Fe/Al values of the fjord surface sediments are also directly related to sediment provenance. In fjords fed by only one river (e.g., Martínez channel), however, the MS is significantly correlated with mean grain size ( $r = 0.90$ ;  $p < 0.01$ ) and with the proportion of lithogenic particles ( $r = 0.73$ ;  $p < 0.05$ ). The latter observation means that future research is needed to correct the MS and geochemical data for grain-size before using them as quantitative provenance indicators. This study suggests that, after grain-size correction, MS and inorganic geochemistry (Ti/Al and Fe/Al) can be used to reconstruct sediment provenance within the Baker-Martínez fjord system. Ultimately, applying these provenance indicators to long sediment cores from the same fjord system will allow us to reconstruct variations in the behavior of outlet glaciers from both icefields independently.

**P-3839**

## **Sub-annual flood dynamics during the last Saharan humid period: clues from a laminated record from the Nile deep-sea fan**

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### **Abstract**

Paleoenvironmental reconstructions have revealed the occurrence of large-scale changes in precipitation dynamics in North Africa during the Holocene. Evidence from modelling approaches and sedimentary records suggests that these changes were linked to modifications of rainfall seasonality, which likely exerted direct control on fluvial dynamics. There are, however, few continuous records of changes in seasonality, which hinders our understanding of underlying forcing factors.

Here we propose to use a unique 5 m-thick section of finely laminated sediments deposited on the Nile deep-sea fan during the last Saharan Humid Period. The core was retrieved at 700 m water-depth and sedimentation rates during sapropel deposition are in the order of several mm per year. Microfacies analysis and elemental micro-XRF scanning indicate that couplets of alternating dark- and light-coloured layers represent seasonal deposits of Nile discharge and marine hemipelagic sedimentation, respectively. Preliminary lamination counts suggest that couplets were deposited at an annual rate for most of the record, except during a short interval of bi-annual deposition between 9 and 8.8 ka (i.e., 2 couplets/yr). Increases in layer thickness is observed around 9.5 and 9.1 ka BP, followed by a gradual decrease until 8 ka. Careful examination of lamination structure and time-series analysis of layer counts will permit to further explore sub-annual changes in flood dynamics during the Saharan Humid Period. Finally, due to its high temporal resolution, our record has the potential to link reconstructions of Nile discharge to other regional archives of hydrological changes (e.g., speleothems, lakes) and thereby identify overarching forcing mechanisms.

P-3840

## Late Holocene Glacial Lake Outburst Floods (GLOFs) in Chilean Patagonia: evidence from Valle Grande floodplain sediments (47 °S)

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### Abstract

Glacial Lake Outburst Floods (GLOFs) constitute a major threat in glacierized regions. These catastrophic events occur when a lake dammed by a glacier or moraine empties, resulting in abrupt flooding. In Patagonia, this issue is particularly pronounced in the Baker region (47–48°S), where 21 GLOFs have been documented in the last decade. All recent GLOFs resulted from the emptying of Cachet 2 Lake into Colonia River, a tributary of the Baker River. During such events, Baker River, which is the largest in Chile draining most of the eastern side of the Northern Patagonian Icefield, triples in discharge. Due to backwater flooding, the water level in the Valle Grande floodplain, which is located along Baker river immediately upstream of Colonia River, rises by 4 to 6 meters, resulting in its complete inundation. Although GLOF frequency seems to have increased worldwide in the last decades, there is currently no reliable scientific evidence supporting this claim, largely due to a lack of flood records on timescales that extend beyond gauged river-flow datasets. To examine changes in GLOF frequency in Patagonia, four sediment cores were collected in the Valle Grande floodplain. The cores were scanned on a Geotek MSCL at 2 mm resolution for magnetic susceptibility (MS), gamma density, and sediment color (spectrophotometry). Loss-on-ignition was measured continuously at 5 mm resolution and radiocarbon ages, <sup>210</sup>Pb concentrations, and charcoal counts were obtained to establish a core chronology. All cores indicate the occurrence of fine-grained organic-poor material with high MS and density values, alternating with organic-rich deposits. It is hypothesized that the fine-grained material is deposited during floods, whereas the organic-rich soils represent periods of quiescence. The records seem to display three periods rich in floods during the last 2500 years. Once precise age depth models are constructed, the results will be compared to historical records of climate and glacier variability to assess the possible relationship between GLOFs and climate change.

P-3841

## Geochemical Study of Holocene Sediments of The Mahi River Estuary, Implications To Palaeoweathering and Depositional Environment

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### Abstract

The Mahi River (~600km long) is one of the major west flowing rivers in India. The Mahi basin lies in horst segment and host 300 m Quaternary sediments, which is sitting over the tertiary rocks (Mehr 1993, Maurya et al 1995). The Mahi River originates in Madhya Pradesh and starts flowing, initially in NW direction and takes a southwesterly turn in Rajasthan and finally debouches in the Cambay Gulf. In lower reaches, where the river forms an estuary, the sediment package preserves signatures of the complex interplay of fluvial and estuarine processes, sea level changes and tectonics. In the present study a 17.28 m long sediment profile was taken from Chokari village to delineate different depositional environments and weathering in the sediments. The upper ~8 m sediments of the profile are estuarine in nature, whereas the lower part is fluvial and intercalated by 1 m thick gravel bed. The upper part is moderately sorted; unimodal and silt dominated indicating that it is formed under very low energy depositional environment which is also supported by the Herring-bone structure as noticed by earlier workers also (Maurya et al. 2000). Low carbonate content (4.2%) and dominance of smectite clay mineral in the sediments further support that the upper facies sediments are most likely deposited in the estuarine environment. The CIA value in the upper part varies from 53 – 60, and in lower part it range between 59-65 indicating that the upper part sediments are chemically immature compared to the lower part sediments. All these attributes reinforce that estuarine sediments may have deposited due to marine intrusion in the drowned river valley on account of sea level increase during the early Holocene time. The ~ 2 ka age deduced by the OSL dating technique in the upper part of section also suggests that sea level must have been more compared to the present and area was submerged (Maurya et al. 2002). Contrary to this, the sediments of lower part are poorly sorted and bimodal with alternate sand-silt layering. The occasional occurrence of cross bedding indicates fluvial deposition (Maurya et al. 2000). Relatively higher carbonate values (~12%) in lower part also indicates oxidizing conditions and relatively higher CIA (59-65) values suggest that the sediments are chemically more mature and may be linked to the terrestrial environmental conditions. A 1 m thick gravel bed (CIA- 44) sandwiched between the upper and the lower sections indicate enhanced precipitation or tectonic activity in the catchment area. The lower CIA (~44) and geochemical composition of sediments indicate tholite dominance also indicates that the Deccan basalt is the main source of sediments as also observed by Sharma et al. (2013).

**Keyword:** Sea level change, tectonics, chemical weathering, sediment texture.

P-3842

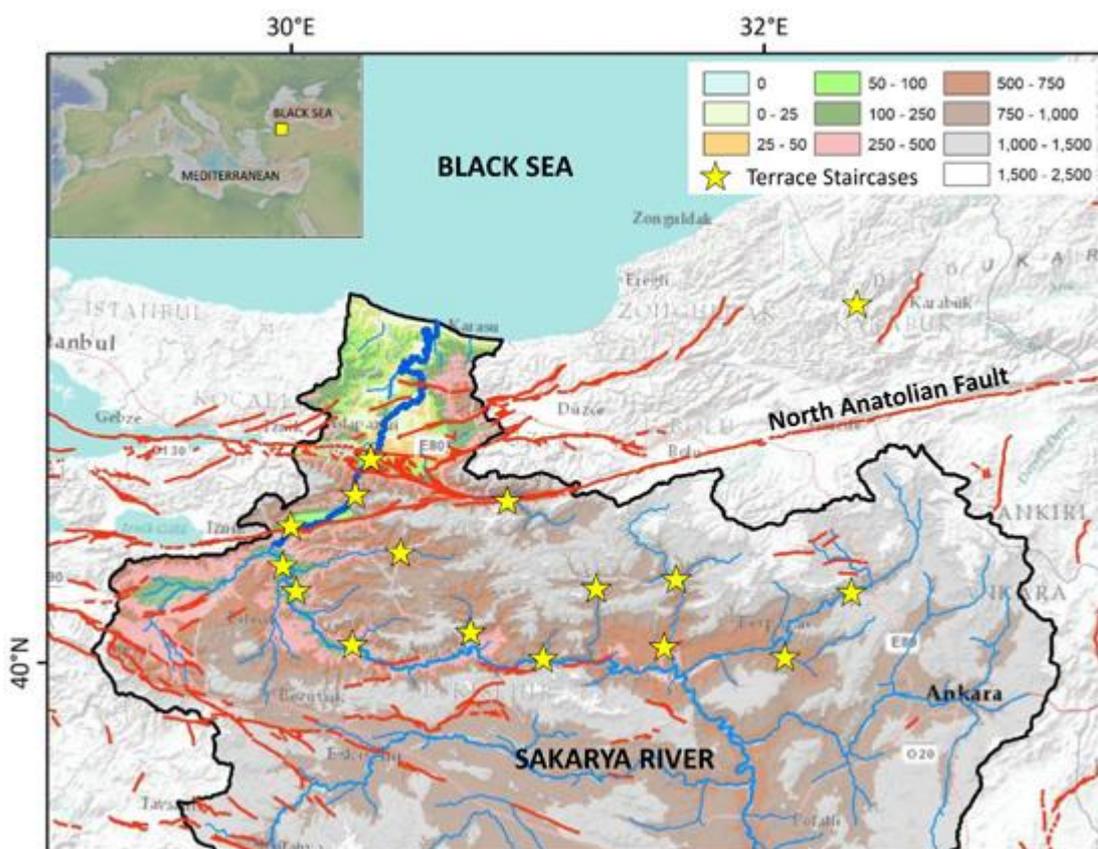
## Chronology of the Sakarya River Terraces: Fluvial response to climate change, tectonic uplift and to the Black Sea level changes

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### Abstract

Sakarya River forms a prominent river system draining a large portion of Anatolia (~63544 km<sup>2</sup>) to the Black Sea. Along its 824 km course, the river runs through the high relief of the Pontide Mountain range and as well as the North Anatolian Shear Zone (NASZ).



The Sakarya River Basin and the distribution of studied terrace staircases. We studied the terrace staircases formed within the Sakarya River Basin (40-40.45°N and 30-32.15° E) by means of mapping, high resolution measurement surveys and systematic luminescence dating. The spatially scattered terrace formation has a potential to reveal interaction of various forces of the Earth, such as climatic events during the glacial and interglacial periods (such as extreme/rapid or long duration) leading to flow regime and sea level changes and also differential tectonic uplift observed along the southern block of the NAFZ.

We aim to reveal the initiation and termination of depositional/erosional periods, calculation of the vertical uplift rate and finally the timing and extend of the fluvial response to the Black Sea level changes. Each terrace staircases



exhibit at least four steps, enhancing our interpretation through time, from Holocene to late Pleistocene and beyond.

This study is supported by TUBITAK 115Y132 and 117Y426 grants.

**P-3843**

## **Settlements in a dynamic fluvial environment – a multi-proxy approach to investigate the landscape history around Kom el-Gir (Nile Delta, Egypt)**

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### **Abstract**

Settlement activity in the Nile Delta is strongly linked with the shifting of branches of the river Nile. Nearly all major ancient settlements were founded in close relationship to waterways. The constant shifting of these Nile branches - coming either too close or moving too far away – was a fundamental challenge for settlements.

This holds especially true for Kom el-Gir situated in the north-western Nile Delta and settled between Late Ptolemaic and Late Roman times (2<sup>nd</sup> century BC – 7<sup>th</sup> century AD). Remains of a temple, most likely founded in the Ptolemaic period, a late Roman fort, and the proximity to Tell Buto (Tell el-Fara'in), which has a much longer settlement history (with interruptions between 4<sup>th</sup> millennium BC to 7<sup>th</sup> century AD), made this site worth to be studied. The reasons for this comparatively short settlement period remain unclear so far. Did the general environmental conditions prevent settlers from populating this spot and how did these conditions change over time? How far was the distance to the nearest river arm? Had shifting river branches eroded an older settlement? Therefore, the questions on the proximity and the layout of the nearby river system are essential ones for deciphering the story of Kom el-Gir.

The region around Kom el-Gir was intensively investigated by a multi-disciplinary team under the umbrella of the German Archaeological Institute Cairo, in cooperation with the Goethe-University Frankfurt and the Ludwig-Maximilians-University of Munich and included the analyses of historic maps and satellite images, surface surveying, magnetic prospection, electric-resistivity measurements, auger core drilling, geochemical analyses of sediment samples, and the creation of a digital terrain model based on TandemX data.

Based on these applied methods, this paper presents first results dealing with the landscape evolution of the area and allows to: (1) deciphering the fluctuations of river arms in the surroundings of the Tell (especially in the eastern part); (2) detecting possible artificial channel systems for freshwater supply and drainage; (3) detecting the palaeorelief at Kom el-Gir itself to finally; (4) approach an answer to the question why we do not find settlement remains of the periods before the 2<sup>nd</sup> century BC in contrast to Tell Buto.

**P-3844**

## **Floods of the Adige River and community resilience in the Venetian Plain (Italy) between the Medieval Climate Anomaly and LIA**

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### **Abstract**

Analyzing the interaction between settlements and floods of the past allows relevant insights on the dynamic behavior of communities that face critical climatic phases and/or adjustments of the fluvial network to changing environmental conditions and human impact. More specifically, it can provide clues to test the long-term capability of an urban system or community to adapt to flood hazard through “resisting or changing in order to reach an acceptable level of functioning, organization and structure” (Batista and Gourbesville, 2016), i.e., to develop and maintain an effective resilience to floods. Building societal resilience to flood hazard is central in the development of risk mitigation strategies in Climate Change scenarios of the future (Jeroen et al., 2014).

Here we present a case of resilience to flood hazard and floodplain silting-up in the city of Adria and along the Adige River, between the southern margin of the Venetian Plain and the northern Po River delta. Between the 10<sup>th</sup> and 15<sup>th</sup> century AD, recurrent floods hit the Adria and led to the burial of its 9<sup>th</sup> century church by overbank sediments (Corrò et al., 2017). The church now lies at about 2 m depth under the modern city cathedral. These floods were due to the opening of two crevasse channels on the right bank of the Adige River, the Castagnaro and Malopera rivers, that funneled sediments along the Tartaro River down to Adria (Mozzi et al., 2018). A first major event of floodplain aggradation clusters around the 10<sup>th</sup> century AD, during the Medieval Climate Anomaly, in a period of enhanced flooding recorded in Northern Italy, in the Alps and the Mediterranean basin. Extensive peat sedimentation followed between the 11<sup>th</sup> and 14<sup>th</sup> century AD, indicating a decrease of overbank flooding and silting by the Tartaro River due to early management of the crevasses, more proximal sediment accumulation, and better regional climatic conditions. Following events of floodplain sedimentation took place in the early 15<sup>th</sup> century due to the reactivation of the Castagnaro and Malopera crevasses. This was possibly related to the climatic deterioration of the Little Ice Age but also to the artificial deepening and enlargement of the channel for allowing small-boat navigation.

A more efficient management of the crevasses was actuated by the Venetian Republic during the 16<sup>th</sup> and 17<sup>th</sup> century, through the building of wooden and earth sluices. This resulted in a drastic decrease of floods in Adria. However, flood hazard along the Adige River kept on being very high, as documented by the occurrence of more than 80 events of channel overflow, embankment infiltration and formation of fountains at the foot of the levees on an 80-km long river tract between 1604 and 1882 (Bondesan et al., 2003).

**P-3845**

## **The post-LGM incised valley of Concordia: a fluvial archive of the alluvial plain of Tagliamento River (NE Italy)**

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### **Abstract**

The Tagliamento River is one of the major alluvial systems in the Venetian-Friulian Plain (NE Italy) and its megafan is characterized by several incised valleys formed since the Late Glacial and now almost completely filled. Among these features, the most investigated is the one identified in a first time near the city of Concordia Sagittaria.

A dataset consisting of almost 2000 cores, integrated with several geotechnical tests and a lidar topography, was used in order to characterize this incised valley. In particular, more than 1500 cores were realized with hand augers since 2012 by the Physical Geography students of the Utrecht University during a series of fieldwork activities organized in the area.

Our dataset allowed to reconstruct the buried morphology of this incised valley, which can be traced for a length of almost 25 km and was characterized by a width up to 1.2 km and a maximum depth of about 20 m below the top surface of the LGM alluvial plain.

A detailed characterization of the infilling led to the recognition of three main depositional units.

The lower one is the result of the direct activity of the paleo Tagliamento River within the valley. It consists of a 10 m thick gravelly unit, deposited after 19.5 ka cal BP and capped by an organic-rich layer with an age ranging from ca. 9.5 to 6.5 ka cal BP.

The middle unit can be linked to the Holocene marine transgression, which led to the formation of a lagoon environment within the incised valley and the consequent deposition of a 15 m thick unit of muds between ca. 8.0 and 2.0 ka cal BP. The absence of an evident riverine input suggests an upstream diversion of the paleo Tagliamento River. The presence of some peat horizons within this unit indicates a pulsating freshening of the lagoon, which may be the consequence of phases of enhanced freshwater discharge. Nevertheless, whether the peat formation was fostered by fluvial (upstream) rather than marine (downstream) controls is still matter of debate.

The upper unit is represented by alluvial sediments deposited by the Tagliamento River in a renewed phase of activity in the area. The formation of this unit started after ca. 2.0 ka cal BP, but some major floods occurred between 6<sup>th</sup> and 8<sup>th</sup> century AD and deposited up to 6 m of sediments that sealed the incised valley.

This study provides a detailed description of a fluvial archive that encompasses almost the entire post-LGM history of the Tagliamento River, allowing the paleoenvironmental reconstruction of the area and providing new data on the fluvial evolution and on its interplay with the marine processes that occurred in the Venetian-Friulian Plain during the Holocene.

P-3846

## Obtaining extreme flood series by the combination of flow data and historical floods reconstruction: the Upper Garonne River (Spain-France)

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### Abstract

Traditionally, the Val d'Aran (Spain) has been considered the headwaters of the Garonne River, a river that flows through Spain, goes into France and heads towards its mouth in the Atlantic Ocean after a journey of more than 647 km. Flow data of the Garonne River are recorded in Bossost, near the outlet of the Aran Valley (647 km<sup>2</sup> of the basin), but the series cover a relatively short period (from 1965 to the present) and prudence must be exercised when extrapolating flows associated to high return periods. One possibility to reduce the uncertainty when carrying out the frequency analysis is to complement the flow data series with data obtained from the reconstruction of historical floods.

In the French town of Saint Béat (Haute-Garonne), about 19 km downstream of the town of Bossost (Val d'Aran) and in the French part of the basin, the marks reached by the waters in different episodes are available for different floods (flood marks) since the year 1778. This information is not available in the Spanish territory of the Garonne. Therefore, the maximum discharges of the historical floods were obtained by the reconstruction of these episodes using the flood marks registered in Saint Béat. In each historical flood, the role of the snowmelting in the headwater as a contributory mechanism to the precipitation in the flood runoff generation has been analyzed simultaneously.

The peak flows of the historical floods in the town of Saint-Béat (673 km<sup>2</sup> of the basin) have been reconstructed with the help of the hydraulic model HEC-RAS v. 4.1.0 on a DTM with a resolution of 1m x 1m, in which the morphological changes of the bed and the floodplains and their roughness from the old cartography have been considered. Also cadastral plans and detail photographs were used to reconstruct the land uses and the vegetation occupation of the flooded areas in each period.

The historical reconstructed peak flows from the floods of the last 250 years clearly surpass those obtained in the flow systematic series of the last 50 years, indicating the lack of extreme values contained in these series. Its inclusion in flood frequency analysis allows reducing the uncertainty of an insufficient time series and improving the prediction of low recurrence quantiles in flood risk planning.

P-3847

## Provenance of western Patagonian river sediments (44–48°S): A critical evaluation of mineralogical, geochemical and isotopic tracers

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### Abstract

Western Patagonian rivers supply a considerable amount of sediments to the eastern South Pacific via adjacent channels and fjords. Sediments deposited in those basins are increasingly used to reconstruct Quaternary paleoclimate, paleoceanographic and paleoenvironmental changes. To improve our interpretation of the regional sediment records, we evaluate the efficacy of four commonly used provenance tracers including bulk mineralogy, major and rare earth element (REE) geochemistry, and  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\epsilon\text{Nd}$ . Our results demonstrate that the ability of the investigated tracers to differentiate sediment sources varies widely. Bulk mineralogy is a powerful tool to distinguish volcanic soils from the batholith, but its ability to differentiate metamorphic and volcanic bedrock lithologies is limited, largely due to lack of mineralogical data on the source rocks. In contrast, the major element composition of the source materials in Northern Patagonia is abundantly documented. Major elements however suffer from compositional overlap between different sources and their use for provenance reconstruction is therefore very restricted. The REE patterns normalized to the Upper Continental Crust clearly allow distinguishing volcanic soil materials from the bedrock, but they are inadequate to distinguish among lithologies. Among the investigated tracers,  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\epsilon\text{Nd}$  are the most suited to reconstruct provenance. They are well differentiated among potential sources since all source materials have different ages.  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\epsilon\text{Nd}$  were therefore used to estimate the relative contributions of volcanic soils and various types of bedrock lithologies in sediment samples from the six rivers that reach the Pacific Ocean in northern Chilean Patagonia (44–48°S). Isotope-based mixing model results suggest various degrees of contribution from the bedrock compared to the regional volcanic ash soils, which we interpret as different vulnerabilities of soils covered by deciduous and evergreen forest to erosion. This study constitutes a strong basis for the interpretation of sediment archives from the eastern South Pacific. Our results should be particularly useful to test the different postglacial drainage routes that have been proposed in the recent literature.

**P-3848**

## **Understanding the long-term flood variability in Western Mediterranean: A view from spanish lake records**

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### **Abstract**

Society is becoming more vulnerable to extreme climate events through increasing exposure of people and infrastructure. Notably, floods are among the most destructive natural disasters, and robust knowledge about their future trends is therefore crucial for the sustainable development of societies worldwide, particularly in sensitive areas such as Western Mediterranean. FLOODARC MSCA project (2019-2021) aims to provide a more comprehensive understanding of the long-term variability of hazardous (high-impact) floods at different temporal and spatial scales. Preliminary results show large dissimilarities in flood-related sediment yield in different Western Mediterranean areas highlighting a large spatio-temporal flood variability during the last millennia. These dissimilarities seem to be controlled by the hydroclimate variability at the regional scale as well as by land use changes in different areas of the Iberian Peninsula. Future state-of-the-art statistical tools applied to the flood database will allow us i) to evaluate, for the first time, the causes of non-stationarity in the long-term flood pattern evolution at a sub-continental scale ii) to decouple the climate vs anthropogenic signal in the lacustrine flood record and; iii) to investigate the role of the climate variability on the high-impact flood patterns at centennial to millennial time-scales in Western Mediterranean.

P-3849

## Mid-Infrared spectroscopic analysis of fine alluvial sediments: insights for provenance determination of palaeochannel infillings

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### Abstract

The sedimentary provenance investigations contribute to improve the understanding of fluvial palaeo-dynamics at different spatial and temporal scales. Conventional approaches for source to sink studies are usually based on the physical, mineralogical, geochemical, magnetic or isotopic properties of sediments. Efficient, accurate and relatively less time-consuming than the conventional fingerprinting techniques, Mid-Infrared Spectroscopy (MIRS) is an alternative method for tracing the origin of fine sediments. The research objectives of this study are (i) to use the MIRS method to discriminate the origin of fine alluvial sediments, by using multivariate statistics on a large set of reference samples from three different sedimentary basins (Rhine, Ill, Vosges tributaries) in the Upper Rhine area, (ii) to verify whether the IR spectra signatures of sediments are influenced by the geomorphological deposition context (bars *versus* banks), and, to some extent, by high organic matter content in the samples and thereafter (iii) to apply the MIRS method to study the fluvial palaeo-dynamics and to determine the source of palaeo-channel infillings in the Upper Rhine alluvial plain. The three sedimentary basins have been characterized by 196 reference samples of sub-recent alluvial deposits from 78 collecting sites. Discriminant analysis revealed a strong discriminating capacity by classifying correctly the samples by their origin without any inter-groups overlap, independently from the geomorphological context (bars *versus* banks), slight changes in organic matter contents or sediment texture. Combining MIRS technique and multivariate statistics for palaeo-channel infilling determination, complemented by radiocarbon <sup>14</sup>C dating and mineralogical data, allowed to understand local morpho-sedimentary dynamics over the last ca.12 millennia.

Keywords: Fine sediment provenance, Mid-Infrared Spectroscopy, Discriminant analysis, palaeochannel filling evolution.

P-3850

## Palaeoflood records for adaptation of infrastructure and civil engineering design in ephemeral rivers with scarce hydrological data: Ugab River, Namibia.

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### Abstract

Palaeoflood investigation provides valuable data for designing the upgrade of a MR76 road bridge on the large (21,500 km<sup>2</sup>) Ugab River, northwest Namibia. A review of the regional road network requires this road to be upgraded to asphalt surfaced road standards with a double lane bridge, able to accommodate a 1% exceedance probability flood without overtopping.

Hydraulic modelling indicates that the current bridge can only accommodate a 2000 m<sup>3</sup>sec<sup>-1</sup> flood without overtopping. Local flood models predict the 1% flood between 3000- 5000 m<sup>3</sup>s<sup>-1</sup>. However, in the Kuiseb River, 300 km south of the Ugab River, similar procedures are thought to overestimate flood peaks. Given the size of the investment for upgrading the road and bridge, a simple comparison between the two catchments could not be justified. Based on the available flood model results, the existing bridge needed to be demolished and replaced with a larger structure at a cost of N\$50 million (€ 3 million). As this is a data poor area and doubts were put on the estimations, a palaeoflood study was sponsored by the Roads Authority to determine the actual flood peaks at the bridge. The reason for this study was simple; if the bridge could accommodate the 100 year flood based on the additional data and analyses, the existing structure would be sufficient with a significant cost saving.

Palaeoflood studies were performed at two reaches with preserved sedimentary evidence: one site 20 km upstream, and another 7 km downstream from the bridge. As expected in this arid region with little bioturbation, evidence of floods, up to 1260 years old, are well preserved. Evidences were also obtained from tree log lines defining high-water marks. The oldest (and highest) was emplaced at AD 1135. The composited and better palaeoflood evidence is from the downstream site. It shows 14 palaeofloods since AD 757. The largest flood reaches a minimum discharge of 1130 m<sup>3</sup>s<sup>-1</sup>.

A flood frequency analysis for the Ugab River at the bridge, based on palaeoflood data spanning 1300 years, indicates that the 100-year flood is 820 m<sup>3</sup>s<sup>-1</sup>. This is much lower than the estimations by other procedures based on sparse data that proved overestimations. This outcome brings about a significant cost saving to the Roads Authority since the existing bridge complies with the standards for flood risk.

**P-3851**

## **Atmospheric variability related to large summer floods in the upper Hasli-Aare catchment (Swiss Alps) from AD 1300 to 2010**

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### **Abstract**

The paper explores the summer paleoflood variability in the alpine Hasli-Aare catchment (Swiss Alps), regarding the external forcing (e.g. Total Solar Irradiance – TSI) and atmospheric variability from the AD 1300 to 2010. Paleoflood series were recorded from alluvial sedimentary records and documentary sources. Paleoclimate modelling was applied to the sea level pressure anomalies (SLP). The grid database for modelling was provided by the CESM Paleoclimate Working Group at NCAR, which processed the experimental series of the Last Millennium Ensemble Project (LME).

Paleoflood series shows fourteen flood pulses since AD 1300. Ten flood pulses occurred during periods of negative anomalies of TSI/cold climatic phases: around AD 1310, 1390-1400, 1440, 1460, 1560, 1660, 1690, 1720-1730, 1800-1840, and 1920-1930. On the other hand, three flood pulses are related to positive anomalies of TSI/warm climatic phases: around AD 1780, 1860-1890, and 1970 to present. Furthermore, some of these pulses are modulated by volcanic activity. The cooling effect by volcanic forcing is visible during flood periods with positive anomalies of TSI, e.g. around AD 1600, showing the principal divergence between the temperature (negative anomalies) and the TSI (positive anomalies) since AD 1300.

The simulated SLP composites of summer flood clusters related to low-solar activity exhibited an atmospheric circulation pattern close to the negative phase of the summer North Atlantic oscillation (SNAO), with the low-pressure trajectories southward of its habitual location, in a temporal state almost permanent during these pulsations. We propose the name of paleo-SNAO to define this decadal atmospheric variability related to summer floods in the upper Hasli-Aare catchment. However, the results also showed evidences of the atmospheric circulation pattern of the flood clusters during high-solar activity and warm periods (i.e. current global warming), was related to positive phase of SNAO.

The results presented in our study using LME to detect similar interannual patterns of atmospheric variability related to flooding since 1300 in the upper Aare catchment, contribute to the understanding of past and future climates and their impacts. The results also improved the knowledge-base for some aspects of climate change impacts and to reduce the uncertainty about future outcomes. In this way, there are strong evidences that large paleofloods in the upper Aare catchment occurred not only during low solar activity/cold climate pulses but also during high solar activity/climatic warm climate phases. For example, the 1762 climate flood during positive solar activity was equal or even larger in the Hasli-Aare catchment than the 2005-flood (Global Warming), and several cold climate floods except the catastrophic 1480, 1550, or 1831 events. Therefore, the warm pulse 2005 flood is not unprecedented and might not directly connected with the anthropogenic influence on climate, but with pattern of atmospheric variability.

**P-3852**

## **How extreme floods can trigger river avulsion beyond delta plain limits**

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### **Abstract**

In lowland fluvial environments such as delta plains, rivers can create new branches through avulsion. This causes reorganizing of discharge diversion over the delta, in cases breaching former limits of floodplains to annexate new areas. Avulsions show a phased development, beginning with crevasse splay formation during floods, eventually maturing into a new single meandering river channel. This overall process can take several centuries and is affected by the flooding regime of the river. Periods of intensified flooding are thought to initiate avulsions, push ephemeral overflow routes to become permanent, and cause crevasse complexes to evolve into single channels. This means that studies of the pacing of geomorphological change can benefit from palaeohydrological studies focusing on the timing of larger flooding events.

Here we show the role of major flood events in fluvial morphology for the Gelderse IJssel case in the eastern Netherlands. This 100 km long river resulted from a major avulsion in the Rhine delta that occurred in the first millennium AD. It annexed a peat filled brook valley and debouched into the Central Netherlands lagoon. This downstream valley hosts a unique geological dataset to track the phasing of avulsion, while the upstream delta has a complete record of major flood events. These flood events have been independently identified in sedimentary and dendrological palaeohydrological records.

Triggering of the avulsion occurred while increased fine-sediment loads doubled due to deforested hinterland and when flooding intensified from the 6<sup>th</sup> to the 8<sup>th</sup> century AD. From the 7<sup>th</sup> century onwards a crevasse complex had permanently breached the rim of the former floodplain. A final extreme flood (c. AD 784/5) appears to have triggered maturation into a single meandering channel, that by 1000 AD was fully developed. These dates are in agreement with geological data upstream and with abundant archeological and historical evidence along the river, such as the rise of the cities of Deventer and Zutphen. This case highlights the importance of extreme flood events for fluvial morphology, delta-network evolution and the impact on people living in the delta.

P-3853

## Climate Hazards and Extremes (CHEX) – palaeoflood reconstructions from southernmost Norway

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### Abstract

Climate Hazards and Extremes (CHEX) is an interdisciplinary research project within the Bjerknes Centre for Climate Research. CHEX seeks to provide policy-relevant information through improved projections of climate hazards and extremes, by integrating long-term time series from proxy records with numerical model output and Earth observation data. Climate hazards are climatically induced events that may have a significant impact on society, such as strong winds, storm surges, rapid sea level change and floods. Projections for future climate scenarios are typically modeled using observed data and instrumental records as data input. However, such data records are typically no longer than a few decades and hold little information about the most extreme and hazardous events with recurrence intervals for several hundred years. To gain data on these events we have to rely on records obtained from palaeoarchives such as lacustrine sediments.

The hydroclimate of southernmost Norway is highly influenced by changes in the westerly winds and the North Atlantic atmospheric circulation. Holocene flood records from this region may provide an important tool for the prediction of future flood events, and how land use planning should be conducted in light of present and future climate change. As a contribution to the project we, use lacustrine sediment records to investigate palaeoflood activity in lakes in the region. Sediment thickness and distribution have been mapped using Chirp Sonar and Ground Penetrating Radar (GPR). A multi-proxy approach has been applied to fingerprint the sediments, which includes X-ray fluorescence (XRF), computed tomography (CT-scanning) and magnetic susceptibility (MS). This yields high-resolution data of geochemical properties throughout the core, as well as high-resolution 3D X-ray imagery.

Lacustrine sediment records from both western and eastern Norway have been studied quite extensively, whereas no such records have been presented from the southernmost region. Subsequently, this region represents a knowledge gap concerning Holocene climate change and is an important link between the coastal climate of western Norway and the more continental eastern region.

P-3854

## Postglacial incisions-infill cycles in fluvial headwaters of NE Borisoglebsk Upland: base level vs landscape conditions variability signal (Central European Russia)

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### Abstract

Borisoglebsk Upland is one of a number of the Moscow glaciation marginal zone uplands in the Russian Plain center. Evolution of its fluvial network began since the last deglaciation. It is generally accepted that the density of glacialfluvial network and its penetration into interfluves significantly exceeded those of modern fluvial systems. However, our knowledge on the postglacial incision-infill cycles, their drivers and timing is very limited, especially at the local scale. In this study, we attempt to reconstruct the Northeastern Borisoglebsk Upland fluvial systems development over the last 150 ka and determine its past extents at different stages based on palaeoarchives comparison from presently inactive interfluve headwaters, contemporary gullies and small valleys. Interdisciplinary research within the  $\approx 15$  km<sup>2</sup> case study area involved detailed description of cores and sections, analysis of grain size, chemical and organic contents, pedogenic and microstructural properties of associated deposits, dating, investigations of the present-day and buried topography, remote sensing data interpretation, and DGPS survey.

Integrating the available results, at least four distinct fluvial incision stages were determined while network extent has significantly changed through the Late Pleistocene. Three – Late Moscow (Saalian), Late Valdai (Weichselian) and Late Holocene – can be generally associated with the Nero Lake level decrease and accompanying isolation of the 130, 100-105 and 95-98 m ASL terraces respectively. For the late incision, human impact has also been an additional trigger. The Late Moscow and Late Valdai incisions mostly determine general outlines of modern fluvial systems while the latter appears to be most expansive. The Late Valdai gullies cut only middle reaches of the initial fluvial network and eastern slopes of highest hills. In contrast, the Early-Middle Valdai incisions of limited distribution and problematic causes were most likely associated with permafrost degradation impacting surface runoff formation.

Incision stages were separated by landscape stability or aggradation periods. Upper parts of the Late Moscow depressions and fluvial incisions were gradually infilled and smoothed by Valdai lacustrine sediments and Late Valdai-Holocene colluvial deposits. In contrast, in middle parts of the fluvial network, two complex periods included heterogeneous aggradation interrupted by stabilization and smaller but prominent incisions. For the Mikulino (Eemian) interglacial prolonged lacustrine sedimentation was altered by stabilization and incision in the middle (partly eroded peats with tree logs). For the most of Holocene at least some of superimposed colluvial infills and local incisions can be attributed to short-term events as forest fires.

It is particularly important to note that most of the detected incision stages were asynchronous between headwaters and middle reaches and spatially non-uniform. Thalwegs of major Late Moscow incision and local incisions during the Mikulino interglacial generally do not coincide with the following Late Valdai and Late Holocene incisions.

**P-3855**

## **Landscape changes, terraces and deposits of the river Pulvar (Fars, Iran): new perspectives and new chronology derived from OSL dating.**

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### **Abstract**

This work is implemented in the frame of an Iranian-French archaeological project focusing on the area of Pasargades, an Achaemenid capital founded in the middle of the 1<sup>st</sup> mill. BC, located in an intermountaneous flooding plain in the Zagros. The goal of the project is to understand the regional human occupation, consequently deeper study of the large-scale Holocene landscape dynamics is necessary. This project is implemented under the agreement of the of the Iranian Centre for Archaeological Research (ICAR) with the support the Pasargadae World Heritage Site Office, the Shahid Beheshti University, the French National Agency for Research (ANR), and the French Foreign Ministry.

Critical results concerning landscape changes in mountain environment has been produced. Especially for the Holocene river dynamics, three main phases have been characterized corresponding to three alluvial terraces (T1 to T3) mapped and analyzed over the whole studied area.

A large scale phase of alluvial deposits occurred from the beginning of the Holocene until middle or even recent Holocene. It is characterized by a thick fine sediment layer visible throughout the region which fills plains and valleys. This deposit was cuted as terrace 15 meters up to the river (T1). The controlling factors of this accumulation appears to be climate and geological structure. Holocene climatic optimum (8000-5000 BP) increased the erosion of previous levels and especially sandy-marly quaternary deposits. This would explain both the high carbonate content and the fineness of the particles, because the quaternary deposits consist partly on the same type of sediment. Furthermore the increase of the precipitations and the vegetation covering could explain the strong cutting of the T1 terrace. An Achaemenid dam built over the T1 terrace gives a relative date to this phenomena (at least 500 BC). OSL dating (results to be received during the first 2019 semester) will precise this event.

The thickness and granularity of the sediments in T1 are striking, in such an environment. The steepness of the side slopes, the former Pleistocene deposits and the presence of intermountain plains downstream of the studied section (Tang-e-Bolaghi gorge) could have played a decisive role.

The second terrace (T2) is linked to reactivation of the alluvial dynamic, with coarser deposit in a context that seems relatively wet. The obtained C14 dates refer to the Islamic period as also demonstrated by a ceramic sherd found in a sequence in the plain of Pasargades.

Third terrace (T3) is less visible but still present as benches along the present river bed sides. It shows the sub-actual river dynamics, in elevation perhaps due to the excessive puncture of alluvium in the Pulvar bed.

P-3856

## Abandonment of River Chuya valley (South-Eastern Altai) and age constraints for the Altai megafloods

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### Abstract

Russian Altai is known for the traces of the Pleistocene cataclysmic floods ranked within the top ten terrestrial floods in the Earth history (Baker et al., 1993, 2013; Herget, 2005; Carling, 2013; etc.). Floods were generated by the outbursts of large lakes accumulated in the intermountain basins in the upstream area of River Chuya due to the damming by valley glaciers. Flood waves spread through the Chuya and then the Katun' valleys to River Ob'. The main flood has usually been dated to MIS 2 according to few radiocarbon ages from the lacustrine sediments in Katun' tributary valleys (Butvilovskiy, 1993; Herget, 2005) and TCN dating of large clasts transported by the megaflood (Reuter et al., 2006). Direct OSL ages from megaflood and cover deposits point at older times (Baryshnikov et al., 2015; Zol'nikov et al., 2016), however optical dates provide interpretation problems due to the possibility of incomplete bleaching. In this study we make the attempt to constraint the age of the megaflood(s) from the geomorphic features of the Chuya valley.

In the middle course, upstream from the Chibit village, River Chuya leaves its old mature valley and cuts a 20-km-long young canyon through the rocks of the Northern Chuya Ridge. In the abandoned valley reach, numerous evidence exist of its occupation by valley glacier that entered from the Chibitka tributary valley and moved upstream the old Chuya valley. This glacier plugged the Chuya valley and forced the river to cut through the rocks aside. A set of OSL ages from glacio-fluvial deposits allow to date this glacial advance and the valley abandonment at 80-90 ka BP. Another glacial phase was dated at 50-60 ka BP. During this phase, River Chuya was dammed at the confluence of old and young valley reaches, and valley lake was formed, which left lacustrine silts within the young canyon. No traces of this lake were found in the abandoned valley, which was probably filled by ice.

The above events provide constraints for the age of the Chuya megaflood. The megaflood(s) must have occurred before 50-60 ka BP, otherwise the lacustrine silts would not survive in the canyon. Moreover, the abandoned valley and clear glacio-fluvial landforms within it do not bear any traces of the cataclysmic flow, which must have swept away all the sedimentary fill of the old valley. It means that the Chuya megaflood must had occurred before 80-90 ka BP. It could have been associated with the first Late Pleistocene glacial advance in the late MIS 5, or with the Pleistocene maximal glaciation of Altai during MIS 6.

P-3857

## Optically stimulated luminescence dating of lowland floodplain sediments in Ireland towards a floodplain evolution model

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### Abstract

Reconstruction of Late Quaternary floodplain evolution and flood histories requires reliable and robust geochronologies, which in Ireland been hampered by problems presented by radiocarbon dating, including contamination by old carbon sources from eroded peatland, or the lack of suitable dating materials *per se*. Here we present a preliminary evolutionary model for the middle River Nore, Co. Kilkenny, applying integrated morphological, sedimentary and micro-XRF chemostratigraphic methodologies, together the first attempt to employ optically stimulated luminescence (OSL) dating in an Irish fluvial setting.

OSL dating on quartz mineral (150 – 250 microns) was carried out on samples retrieved from recently excavated trenches and exposed bank sections, and analysed using the Single Aliquot Regenerative dose protocol (SAR). Samples were characterised by a dim to very dim luminescence response, typical of sediment in recently glaciated landscapes. As the sedimentary units were rather thin, judicious sampling was performed in order to properly assess the dose rate. Manganese oxide concretions found in the sections and in greater abundance above clay-rich layers, presented a highly elevated activity in radium 226, compared to its parent, uranium 238. This was in contrast to the bulk sediment matrix, which implies that these oxides formed post-sedimentation and are actively absorbing radium. This finding presented further challenges towards devising an OSL chronology, which will be discussed.

The first phase of dating in one reach suggests that only the uppermost 1.5 metres of alluvium are of Holocene age with basal ages dating to the early Holocene (c. 9 ka). Given the sedimentological context and overlying geochronological evidence, an underlying clay is likely to be from a Late Glacial lake system. Geochemical data suggests a dominant detrital rather than biological origin for these sediments, inferring low productivity consistent with a cooler period such as the Younger Dryas. Relatively shallow depths of Holocene sediment may infer low sedimentation rates, but evidence for a non-conformity at the site, together with the cluster of early-Holocene dates towards the base of the Holocene sequence may indicate floodplain stripping and/or an absence of sedimentation during the evolution of the floodplain. Preservation of deposits associated with extreme floods in the Nore was inconclusive.

Errors on the dates reflect the systematic and random uncertainties (e.g. calibration, water content, partial bleaching). Further analysis will provide additional age constraints on the floodplain evolution in the middle Nore. The preliminary results indicate that in minerogenic, sand-rich floodplain sites such as those constituting much of the middle Nore valley, where organic matter for radiocarbon dating is limited, OSL dating presents a viable alternative dating method for reconstructing Holocene alluviation. Moreover, limitations inherent in the properties of sediment from paraglacial landscapes can be overcome using a careful sampling strategy.

**P-3858**

## **Late Holocene channel pattern change from laterally stable to meandering**

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### **Abstract**

River channel patterns may alter due to changes in hydrological regime related to changes in climate and/or land cover. Such changes are well documented for transitions between meandering and braiding rivers, whereas channel pattern changes between laterally stable and meandering rivers are poorly documented and understood. We hypothesize that many low-energy meandering rivers had relatively low peak discharges and were laterally stable during most of the Holocene, when climate was relatively stable and human impact was limited. Our objectives in this work are to identify a Late Holocene channel pattern change for the low-energy Overijsselse Vecht river, to develop and apply a novel methodology to reconstruct discharge as a function of time following a stochastic approach, and to relate this channel pattern change to reconstructed hydrological changes. We established that the Overijsselse Vecht was laterally virtually stable throughout the Holocene until the Late Middle Ages, after which large meanders formed at lateral migration rates of about 2 m yr<sup>-1</sup>. The lateral stability before the Late Middle Ages was constrained using a combination of coring information, ground-penetrating radar (GPR), radiocarbon (<sup>14</sup>C) dating, and optically stimulated luminescence (OSL) dating. We quantified bankfull palaeodischarge as a function of time based on channel dimensions that were reconstructed from the scroll bar sequence and channel cut-offs using coring information and GPR data, combined with chronological constraints from historical maps and OSL dating. We found that the bankfull discharge was significantly greater during the meandering phase compared to the laterally stable phase. Empirical channel and bar pattern models showed that this increase can explain the channel pattern change. The bankfull discharge increase likely reflects climate changes related to the Little Ice Age and/or land use changes in the catchment, in particular as a result of peat reclamation and exploitation.

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### **Acknowledgments**

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**P-3859**

## **Integrating geophysical surveys and drill cores for establishing the subsurface stratigraphic framework of the paleo-Yamuna river, northwest India**

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### **Abstract**

The fluvial landscapes of northwest (NW) India prominently built by a large network of perennial river systems were home to the well-known Bronze Age Indus Civilization. A pronounced change in the distribution pattern (in both time and space) of urban settlements of mature and late Indus Civilization in NW India has been linked to a large river flowing through this region which in turn was influenced by the intensity of the Indian summer monsoon. The role of the paleo-Yamuna river that once flowed through northwest India on the sustenance of the so-called large river and the Indus civilization has been postulated but not established due to the lack of subsurface stratigraphic data. This study focuses on an integrated study using resistivity surveys and drill cores to provide the subsurface stratigraphic framework of the paleo-Yamuna river deposits followed by optically stimulated luminescence based chronology for constraining the chronology of the deposits. We present new data based on vertical electrical resistivity soundings (1D-VES), multi-electrode electrical resistivity tomography (2D-ERT), multi-probe well log surveys and drilling in one of the paleochannels of the Yamuna to map the large-scale geometry and architecture of the valley fills of the paleochannel system in the subsurface. The geophysical signatures recorded as VES on two transects trending NW-SE in Karnal and Kaithal districts of Haryana at 9 and 13 locations respectively, along with continuous ERT reveal the presence of subsurface sand bodies (>20m thick) interbedded with silty clay layers that are laterally stacked. The occurrence of thick and wide sand bodies in the subsurface implies that these are the deposits of a large river system and suggests that the Yamuna was connected to the paleo-Ghaggar River as hypothesized by earlier workers based on remote sensing techniques. Further, these fluvial sand deposits show longitudinal and lateral chronological variation suggesting that the stratigraphic record of the Haryana plain was built by avulsing river systems.

**P-3860**

## **First approach to review Badlands landscape evolution in Quaternary**

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### **Abstract**

Badlands are defined with different criteria: lithological conditions, weathering processes, landform features, agriculture potentiality, and even the difficulty of being crossed by humans (Martínez-Murillo and Nadal-Romero, 2018). The term “badlands” refers to regions that have soft and poorly consolidated material outcrops, limited vegetation, reduced or no human activity, and a wide range of geomorphic processes, such as weathering, erosion, landslides, and piping. These features interact at different spatial and temporal scales to shape these distinct landforms. According to Moreno-De las Heras and Gallart (2018), three general badland initiation patterns can be distinguished: i) first two patterns correspond to the expansion of hillslope gullies initiated at mid-slope sections, caused by within-slope conditions, or at the slope bottom, through a combination of within-slope and basal conditions; ii) the third one to the disruption of a non-channelized hillslope by mass movements that open a bare soil or rock scar to weathering and water erosion. The analysis of these phenomena is particularly relevant in subhumid and humid badlands, where these landforms are relatively small and young, which means that their initiation can be physically examined. Conversely, in semi-arid and arid areas, badlands are usually very extensive and relatively old, so that their initiation factors are frequently obscured by the action of other drivers that control the long-term evolution of these systems.

This study makes a first approach to review already published studies focussed on the Quaternary and landscape evolution in regions with Badlands, giving special attention to the geomorphic process leading to their origin and evolution. A list of publications in these topics was compiled using Scopus, ScienceDirect, and Google Scholar. At this first stage, the searches were conducted using the following codes: “Badlands” AND “Quaternary”, “Badlands” AND “Landscape evolution”, “Badlands” AND “Holocene”, “Badlands” AND “Pleistocene”, “Badlands” AND “Quaternary”, and “Badlands” AND “Anthropocene”. In total, the results showed 67, 52, 79, 99, and 0. The database is analysed with the purpose of shedding light to the question ‘how and why badlands appear and evolve?’ in order to better understand how the current Global Change can influence their future evolution, and their on and off-site effects in the eco-geomorphological system and human activities.

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P-3861

## Wizards, tephrochronology and the evolution of a jökulhlaup sandur in Iceland

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### Abstract

We use tephrochronology tied to the Greenland ice core record to explore the development of a 10<sup>th</sup>-century jökulhlaup in front of Sólheimajökull in southern Iceland. We establish precise links between the geomorphological records and passages in the 12<sup>th</sup>-century Icelandic historical work 'The Book of Settlements' in which wizards are said to be responsible for the flood. In the early 10<sup>th</sup> century the snout of Sólheimajökull stood at the southern limit of its bedrock channel (some 4km beyond current limits). The consequences of this included the absence of an incised floodplain in front of the glacier and the potential for volcanogenic floods to sweep to the east and west. The first elements of the 10<sup>th</sup> century flood spread over the eastern margins of Sólheimasandur and also flowed west. The initial route west can be traced through a coll and onto Skogasandur. On the sandur the flood first flowed further west along the foot of the bedrock escarpment. Where it lapped against the edge of the escarpment pumice gravels from the edge of the flood grade into the airfall deposits of a tenth-century Katla tephra, proving precise dating evidence. As the meltwater flowed west the flood routes evolved. The channel on the sandur at the foot of the escarpment was beheaded, and as the bedrock channel along the western side of the glacier deepened, the water flow through the coll was also cut off. This resulted in a switch of the western floods from an almost due westerly flow towards Skogar to a southerly and easterly flow back towards the present course of the Jökulsá (and the most direct route from the glacier to the sea). As the routes changed so did the geomorphological impacts and sediments laid down by the flood. The westerly flow began rich in pumice, and the flood would have acquired more pumice as it incised the old pumice fan lying over the NE part of Skogasandur. As later stages of the flood incised the bedrock channels to the west, large volumes of palagonite boulders were incorporated into the flow. Thus, the later stages of the flood that swept back towards the east created the terrace units covered in palagonite boulders to both the east and west of the present river course. To the east, this palagonite terrace borders an extensive pumice terrace formed during the initial phase of the flood. This detailed case study illustrates the potential importance of flood routing and timing in determining the sedimentological characteristics of Quaternary flood deposits, as well as examining how such events were preserved in cultural memory in medieval Iceland.

P-3862

## Variable Late Glacial to Holocene seismicity in the Eastern Alps, Austria? First results from a lacustrine paleoseismic study

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### Abstract

Comparison of earthquake frequency in Fennoscandia and Northern Central Europe since the Last Glacial Maximum (LGM) suggests a general seismicity pattern for deglaciated areas, with high seismic activity in the Late Glacial, a rather calm period in the early Holocene and another increase in seismicity during the middle to late Holocene. In these tectonically relatively stable regions, postglacial rebound is believed to be the main contributor to changes in the stress field. However, in formerly glaciated, tectonically active mountain ranges, the role of tectonic stress vs. postglacial rebound on earthquake recurrence is still unclear and further strategically-located paleoseismological studies are needed.

Here, we present preliminary results of a lacustrine paleo-earthquake project in Carinthia, situated at the southeastern rim of the Eastern Alps, Austria. This region, although located in an intraplate setting, has experienced several historically and instrumentally recorded earthquakes of an  $M_w$  up to 7. Eight lakes, all of them remnants of Pleistocene glaciations, were investigated using high-resolution reflection seismics and sediment cores. Our findings show that at least three lakes contain a datable archive of simultaneously-triggered slope failures, for which past seismic activity constitutes the most likely mechanism. By mapping the subaquatic landslides and combining them with analyses on long (~12 - 14 m) sediment cores and bathymetric data, we aim at reconstructing the paleoseismicity and its spatio-temporal distribution in the Carinthian/Friuli area during the last ~14 ky. One of our studied lakes, Klopeiner See, located at the very eastern margin of LGM ice extent, represents an extraordinary archive of deglaciation history. Due to a condensed Holocene section, we can resolve 12 m of Late Glacial history in a sediment core. By geophysical core logging, XRF- & medical CT-scanning as well as detailed core description, we are able to distinguish numerous event deposits from cm- to m-scale and date them accurately using radiocarbon dating, while also gaining insight into landscape evolution during deglaciation.

Our data hints at pulses of enhanced seismicity during the Late Glacial, peaking at the Pleisto- to Holocene transition, with several voluminous landslides covering large parts of all lake basins. Interestingly, the Carinthian lacustrine records show relatively little evidence of seismically triggered landslides in early to mid-Holocene times – a similarity to other paleo-earthquake studies in both the Fennoscandian Peninsula and the Alps. However, other than in the Swiss or French Alps, the tectonic contribution to recent uplift rates in our study area is relatively large. This suggests that seismicity in the Alps was – and maybe still is – rather governed by postglacial rebound than tectonically induced stress.

**P-3863**

## **Lateglacial reactivation of the Harz Boundary Fault (northern Germany) caused by glacial isostatic adjustment**

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### **Abstract**

Seismic activity in northern Germany is rare, but recent earthquakes were recorded e.g., east of Hamburg and in the Halle/Leipzig area. Many of these earthquakes occur at major Cretaceous reverse faults. A possible trigger mechanism is the release of lithospheric stress changes due to glacial isostatic adjustment in response to the decay of the Weichselian ice sheet in the Late Pleistocene (Brandes et al., 2015). The occurrence of recent seismicity and the long record of historic earthquakes require a re-evaluation of the seismicity in northern Germany.

One of these Cretaceous reverse faults, is the NW-SE trending Harz Boundary Fault, which is approximately 100 km long. At this fault, young tectonic activity was observed. A recent sinkhole close to the Harz Boundary Fault exposes a NNE-ward dipping planar fault plane that cuts through unconsolidated debris-flow deposits. To analyse the subsurface structure along the Harz Boundary Fault, high resolution shear-wave seismic and geoelectric (ERT) profiles were acquired, which image the steeply dipping Harz Boundary Fault and give evidence for a splay fault system with back thrusts, directly north of the main fault. Most likely, the NNE-ward dipping fault that is exposed in the sinkhole corresponds to the back thrust imaged with the geophysical methods.

Luminescence dating of feldspar and quartz minerals (IRSL and OSL) of the faulted debris-flow deposits indicates fault movements post dating ~15 ka. The timing of fault movements is supported with numerical simulations of GIA related changes in Coulomb failure stress. Modeling results for a compressional regime, as is assumed for this area, show that the Harz Boundary Fault became unstable between 14.2 to 7.8 ka. This matches with the estimated luminescence ages and supports the assumption of tectonic movements at the Harz Boundary Fault in the Lateglacial. The time window of these fault movements also matches data from the Osning Thrust, where a stress change related to GIA induced fault movements is also documented (Brandes et al., 2012).

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**P-3864**

## **Traces of seismic waves in Pleistocene, glaciolacustrine sediments. Case study from Usedom Island (NE Germany)**

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### **Abstract**

The 3D view of soft-sediment deformation structures in glaciolacustrine fluidized succession from a coastal cliff on Usedom Island (Germany) induced by liquefaction were analyzed in aim to track records left in unconsolidated, laminated sediments by the seismic waves. Based on sediments textural and structural features of sediments, the layers engaged in soft-sediment deformation structures were interpreted by Hoffmann and Reicherter (2012) as seismites caused by liquefaction process induced by seismic waves during Pleistocene glacio-isostatic adjustment. Detailed research on the description of 3D soft-sediment deformation structures was carried out in laboratory where the sediment sample of cuboid sized 40x40x60 cm was cut horizontally slice by slice in every 1.5 cm in aim to take a photo of each of them. Deformation structures visible on every thin-section were contoured to calculate them and determine their size and shift. Next, three types of sediments occurring in each thin-section were distinguished: silt, sand and silty-sand. It was assumed that all observed features were formed in silty background. The adages of the structures were determined in places with clear changes in the color of sediments. Obtained data allowed for probable recognition the places in the sample, where the energy of wave was maximum (the smallest structures, the biggest mixing) or minimum (the biggest structures, minimum mixing). Although, the sample was too small to determine the whole wave period, several most likely scenarios for the wave propagation process were determined based on many possibilities recorded in studied case.

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P-3865

## Complex structure of intraplate Mariánské Lázně fault zone that ruptured in Holocene (Bohemian Massif, central Europe)

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### Abstract

We studied the NNW-SSE trending Mariánské Lázně Fault (MLF) situated in the western part of the Bohemian Massif (Czech Republic, Central Europe). The MLF is morphologically pronounced and controls the eastern limit of the Cheb-Domažlice Graben for a length of about 100 km. In its northern part it borders the Cenozoic Cheb basin towards the Krušné Hory mountain front and intersects with the NE-trending Cenozoic Eger rift. The Cheb basin is famous for abundant occurrences of mantle-derived carbon-dioxide emanations, present-day earthquake swarms with maximum magnitude not exceeding Mw 4.0, and Mid-Pleistocene volcanism. The present-day earthquake swarms are strikingly aligned along a NNW-trending fault known only from the foci at depth with no geological or morphological expression on the surface. This seismogenic fault intersects the NW-trending border fault of the Cheb basin, the northern segment of the MLF, with no present-day associated seismicity. However, our paleoseismic trenching revealed larger prehistorical earthquakes that have resulted in the present-day morphology along the MLF. Because prevailing kinematics of younger events, revealed from the very first trench, appeared to be showing a strike-slip mechanism, we carried out 3D trenching at the Kopanina site to explore horizontal displacements and the structure of the fault zone. We excavated six additional backhoe trenches and six hand-dug trenches, which revealed a complex structural set-up with oblique faults and deformation probably as a result of right-lateral transpression during the Late Quaternary. Also, Holocene colluvia is faulted, which is in agreement with the results from the first trench, and which indicates Holocene surface-rupturing earthquakes on the MLF with possible minimum magnitude of Mw=6.3-6.5. Radiocarbon dating of charcoal sampled from the faulted Holocene layers, followed by OxCal modelling, show that the latest earthquake occurred during the 790 – 1020 AD period. Several candidates for a historical earthquake within that period have been analysed from the historic earthquakes catalogues. The most likely earthquake that would match that period and the related magnitude may be the one reported to have occurred in 998 AD. Further investigation on this correlation is under process. This historical earthquake revealed from trenching appears to be the youngest surface-rupturing earthquake in central Europe and the largest one identified in the Bohemian Massif so far, and has a major implication for seismic hazard for areas with slow-moving faults.

P-3866

## Holocene behavior of the Wasatch Fault Zone, USA, affected by pluvial lake loading/unloading cycles on the hanging wall

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The Wasatch Fault Zone (WFZ) in Utah, USA, is an active normal fault zone separating the Wasatch Range (upthrown block) from the Bonneville Basin (a closed depression on the downthrown block). Throughout the Quaternary large pluvial lakes alternately formed and then desiccated on the hanging wall (HW) of the WFZ. The latest pluvial lake (MIS2, Lake Bonneville) reached a highstand elevation of 1555 m (from 16.8-18.0 ka), and covered an area of 51,200 km<sup>2</sup> with a maximum depth of 300 m (volume 10,300 km<sup>3</sup>). The lake desiccated rapidly between 12-14 ka to approximately the extent of today's Great Salt Lake (volume 19 km<sup>3</sup>). Removal of the 10,281 km<sup>3</sup> of water load caused post-pluvial isostatic rebound of the HW, as reflected in the domal upwarping of highstand shoreline by as much as 70 m in the centroid of Lake Bonneville. Even before the modern era of paleoseismology on the WFZ (1970s-present), geologists speculated about the effect of the HW depression/rebound cycle on the activity of the WFZ. They pointed out that the thick eastern shoreline deposits of Lake Bonneville had buried the pre-MIS2 trace of the WFZ, and that the highstand shoreline lay on the footwall (FW) of the fault. Post-MIS2 fault traces then had to rupture up through the shoreline deposits to reach the ground surface. Over most of the central segments of the WFZ post-MIS2 fault scarps have now grown to 20-25 m high in Bonneville shoreline deposits.

In the past 2 decades technological advances have permitted a more sophisticated analysis of fault-lake interactions. Deep 'megatrenches' have exposed a continuous record of WFZ slip events from the Bonneville highstand (16.8 ka) to the present, a record composing 9 successive paleoearthquakes in the northern Salt Lake City segment but only 7 in the southern SLC segment. Lidar DEMs (0.5 m resolution) now cover the eastern Bonneville shoreline and WFZ, permitting precise deformation surveys. A major elevation discontinuity in shoreline elevations exists in the center of the SLC segment, between the two megatrench sites. This discontinuity coincides with a 2.5 km-stepover in the WFZ and a buried gravity ridge that separates the deep part of Lake Bonneville from a shallow shelf. It now appears that differences in crustal depression/rebound across this discontinuity created a non-persistent segment boundary in the center of the SLC segment, causing the northern subsegment to rupture with the Weber segment to the north, while the southern subsegment ruptures with the Provo segment to the south. However, that behavior ceased about 9.5 ka as rebound waned. Since then the two subsegments have a very similar paleoseismic record.

P-3867

## High-head dams' construction – replication of the natural "Disturbance regime" of mountainous river valleys' evolution: illustrated by the Kokomeran River valley

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### Abstract

Construction of high-head dams in mountain river valleys raises debates on their environmental acceptability. Indeed, it causes significant changes of the landscape and ecosystem. However, analysis of the evolution of river valleys in various mountainous regions all over the world shows that their blocking by large-scale rockslides – the so-called "Disturbance regime" proposed by Kenneth Hewitt (2006) is a common and rather frequent natural phenomenon. Such blocking can influence river valleys more than interplay of the tectonic and exogenous processes that forms a typical shape of river valleys with narrow gorges and steeper thalwegs where they cross actively growing mountain ranges, and widened valleys filled by fluvial deposits when passing through neotectonic depressions. It can be exemplified by the Kokomeran River in Central Tien Shan that had been blocked by rockslides repeatedly. Its thalweg profile (Fig. 1) can be divided into several sections. In the upper part of the valley, up to the confluence with the Djungal River, profile is steep where river crosses neotectonic uplifts, and flattens within intermontane depressions reflecting the prevailing role of neotectonic deformations in River valley shaping. Three large river-damming rockslides identified in this part of the valley had blocked it in the past, but later they had been incised by the stream completely. In contrast, downstream from the Djungal River mouth, where Kokomeran passes through the V-shape gorge between the Sarykamysh and Kavaktau neotectonic anticlines, stream remains tranquil. Such a profile extends for about 30 km, up to the Late Pleistocene Karachauli breached rockslide dam. It is likely that its base has not been reached by bottom erosion yet so that the Kokomeran River is still incising in the deposits accumulated upstream. One more nick point about 5 km downstream from the breached Karachauli blockage coincides with the breached Lower Kokomeran rockslide dam, most likely of the Holocene age. Recurrent formation of rockslide-dammed lakes and their subsequent breaching are the natural elements of mountain river valleys' evolution. Thus, constructing high-head dams and creating deep reservoirs we just reproduce natural phenomena.

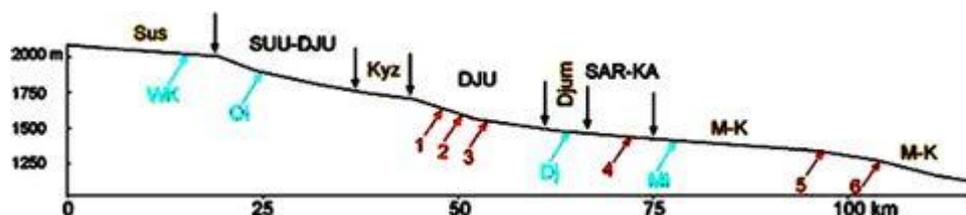


Fig. 1. Thalweg profile of the Kokomeran River based on the 3" SRTM DEM. Red arrows mark river-damming rockslides: 1 – Kokomeran, 2 – Displaced Peneplain, 3 – Mini-Köfels, 4 – Lower Aral, 5 – Karachauli, 6 – Lower Kokomeran; blue arrows – main tributaries: WK – Western Karakol, Oi – Oikaing, Dj – Djungal, Mi – Minkush; brown indices – neotectonic depressions: Sus – Suusamy, Kyz – Kyzyl-Oi, Djum – Djungal, M-K – Minkush-Kokomeran; black indices – neotectonic uplifts crossed by the river: SUU-DJU – connection of the Suusamy Range and of the northern part of Djungal Range; DJU – southern part of the Djungal Range; SAR-KA – connection of the, Sarykamysh and Kavaktau Ranges; black arrows mark conventional boundaries between neotectonic uplifts and depressions.

P-3868

## Sedimentological features on hyperconcentrated flow deposit formed by the 300 years ago slope failure due to Nankai-Trough earthquake, central Japan

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### Abstract

The “Oya-Kuzure” slope failure is located in the source area of Abe River, Shizuoka Prefecture, central Japan. It has been estimated that many failure events had occurred repetitively around the area and that a large-scale failure occurred early 18th century caused by the Hoei Earthquake (M: 8–9), one of the Nankai Trough earthquakes. The landslide slope is 700 m high and 1800 m wide with an estimation of 120 million m<sup>3</sup> in volume and the 18th century slope failure deposits filled the upper reaches of Oya–Abe rivers at least 7km long.

The 40m high and 400m wide cliff is distributed along the river stream ca. 5km downstream from the “Oya-Kuzure” slope failure. Gravelly deposit on the outcrop is characterized by alternation of cobble and pebble layers of 0.5–5 m thick and topographically continued from debris flow deposit caused by the Hoei earthquake. Absence of internal sedimentary structure within each layer and occasional presence of oversized clasts (0.5–5 m long axis) in the cobble layer show that these gravel layers are hyperconcentrated flow deposit. Because of unconsolidated occurrence due to very young (ca. 300 years ago) deposition, gravels are taken easily from the cliff surface and fabric (imbrication and orientation) of them are measured easily.

Imbrication of gravels and distribution of hyperconcentrated flow deposit show southward flow direction. On the other hand, long axis (a-axis) orientation varies parallel–perpendicular to flow direction. In pebble layers, gravels of a-axis parallel (0 to  $\pm 30^\circ$ ) to flow direction are popular (56/122); gravels of a-axis perpendicular ( $\pm 60$  to  $90^\circ$ ) to flow direction are 40/122. In cobble layers, whereas, gravels of a-axis parallel and perpendicular to flow direction show similar abundance (64/172 and 69/172, respectively). Detailed investigation on cobble layers revealed that gravel abundance of a-axis perpendicular to flow direction increase from lower part (11/40) to upper part (23/40). The upward increasing tendency of a-axis perpendicular gravels means upward increase of rolling gravels under the influence of tractional flow. It is expected that comparison of our results with existing models of hyperconcentrated flow will add several knowledges on hyperconcentrated flow and its deposit.

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P-3869

## The role of large-scale rockslides in developing of the top part of Mzymta River (Caucasus, Russia).

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### Abstract

The main objective of these studies was to study large-scale rockslides and rock avalanches in the high (elevation up to 1.5 km) Northern slope of the Aibga Ridge, at the base of which the valley of the Mzymta River is developed.

The geological structure of the slope involves Lower Jurassic terrigenous argillaceous rock strata, overlapping in the upper part of the slope by a series of porphyritic massif formations of Middle Jurassic, and complicated by a series of sub-regional faulting. The studied region is characterized by high seismicity.

The modern valley of the Mzymta River on the considered site has a complex character. The morphology of the valley represents the alternation of narrow linear sections where the channel has sharp differences and V-shaped appearance with a height of more than 20 m sides, and relatively wide areas, with the presence of several terraces above the floodplain. Studies have shown that the modern morphology of the valley of the Mzymta River is associated with wide development on the Northern slope of the Aibga Ridge large-scale rockslides and rock avalanches, the frontal parts of which reached the river.

One of the largest rock avalanche (which called «**Frontier**») had developed at the top of the northern slope of Aibga Ridge with capturing porphyritic series (J<sub>2</sub>pr). As a result of a series of slope collapses, a circus with an escarpment up to 180 meters high and up to 640 meters wide was formed. In the Central part of the circus deposit low-depth glacial which apparently formed as a result of the development (late Pleistocene or Holocene) corrie.

The formation of large-scale slope deformations is probably associated due to the destruction of tuff sandstones and mudstones in the middle part of the slope, which led to the appearance of flaws and caused the subsidence of large blocks of massive porphyrites in the upper part of the slope, their displacement and collapse. The disintegration of landslide blocks in the process of destruction contributed to the formation of an extended rock avalanche in the structure of which the sequence of the primary structure was preserved. In the rear and in the middle parts of the rock avalanche lie large blocks of porphyrites and in the front part mainly blocks of sandstones and tuff sandstones.

Directly in the valley of the Mzymta river, the formations of a stone avalanche overlaps the deposits of the II floodplain terrace of late Pleistocene age. Given that in the landslide circus lie late Neopleistocene and Holocene glacial formations, the age of the studied avalanche can be determined as late Neopleistocene.

**P-3870**

## **Krasnogorsky large-scale rockslide and its role in the development of Kuban river valley middle part (North Caucasus, Russia)**

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### **Abstract**

The river Kuban is the main watercourse collecting surface runoff from the northeast macro-slope of the Caucasus Mountains. Its valley has a width of up to 400-500 m (at the level of the 1st terrace) when reaching the foothill plains. The valley is characterized by significant asymmetry. The left landslide border of the valley is steeper and represented by a cliff up to 50 m high, developed in Jurassic sediments.

Krasnogorsk landslide develops in the left side of the Kuban river valley. The landslide length in the direction of displacement reaches 400 m. The width of the landslide body in the head part is up to 200 m, tapering in the middle part to 120 m. In the lower part the landslide body is divided by a ridge formed by undisplaced rocks up to 30 m wide into two tongues 90 m and 70 m wide. Landslide tongues egress the erosional ledge of the r. Kuban which is up to 45-50 m high. According to drilling data the thickness of the landslide massif is about 15-18 m. The total volume of rocks involved in the displacements is estimated at 1 million cbm.

A detailed study of the general structure of the slope in the Krasnogorsk area showed that the modern landslide body was formed within the ancient landslide massif, involving a fragment of the ancient landslide massif in displacement. An ancient landslide has a length up to 1 km in the direction of displacement with a width of up to 450 m. According to drilling data and geophysical results the ancient landslide body thickness exceeds 30 m. The total volume of rocks involved in the displacement is estimated at 12 million cbm.

The landslide displacements include sediments of the Plinsbach, Aalen and Bayesian stages represented by sandstones and dolomitized sandstones, siltstones with intercalations of limestone.

Activation of landslide displacement will be accompanied by the flow into the river Kuban significant volume of material (approximately up to 0.3 million cbm). With the involvement of ancient landslide body additional parts in the displacement the volume of detrital material will significantly increase. The consequences of the rapid landslide material flow into the river bed will be:

- partial overlap of the river bed with its reformation (formation of additional branches), as the landslide develops on the high erosive side of the valley along which the main water flow goes;
- movement of the main flow of the river to the opposite bank of the valley, which will cause the sudden activation of erosion processes and the retreat of the bank;
- partial flooding of the territories located upstream along the river valley for a time until the river forms a new equilibrium valley.

**P-3871**

## **Scale and formative age of Gunsakot landslide located in central Nepal Himalayas**

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### **Abstract**

Dormant landslides of deep-seated type are densely distributed in the topographic transitional zone from the Midland to the Great Himalaya. Dormant landslides of the deep-seated type are distributed in an area below 3,500m a.s.l., because the mountain slope higher than that was presumably eroded away by valley glacier in the former Ice Age. As to geology, they are predominantly distributed in geological areas of phyllite & augen gneiss areas, considering both landslide area ratio and the number of the landslide site. Most of large landslides are sliding down to northwest, reflecting the geological structure that declines to northwest due to activity of MCT. Consequently, landslides of deep-seated type are also prone to develop on dip-slopes in this area. And landslides usually occur easier on dip slope than on anti-dip slope under same geological condition.

Area per site becomes larger in the area of augen gneiss which is distributed in the hanging wall side along MCT where relief abruptly increases. Aerial-photo interpretation detected a gigantic dormant landslide at Gunsakot locating in the upper course of Indrawati River, Sun Koi watershed, central Nepal Himalayas. Planar scale of the landslide is almost 10km<sup>2</sup> including source and depositional areas. Depositional area of detritus with the thickness of 300m more is 4 km<sup>2</sup> remained on the left bank of Indrawati river. Its volume is estimated to be 0.9 km<sup>3</sup> in the source area and 1.2 km<sup>3</sup> in the depositional area, respectively. The net volume is thought to be 1 km<sup>3</sup> at least. Equivalent coefficient of friction, H/L, is 0.25, that is equal to 14 degree.

Detritus-flow mounds are distributed in the depositional area. Rock masses with long axis of 5 - 10m are scattered on the mounds. The authors got samples from the top part of the rock masses for <sup>10</sup>Be dating to clarify the formative age of the gigantic landslide. The result of the dating varies 2000 and 8000 yrs. B.P. There are some minor scarps below the main scarp in the main source area facing to north-west, consequently a series of large scale landslides occurred several times after 8000 yrs. B.P. However, the rock masses of younger age might come from other scarp facing to south.

Gravitational deformation also has proceeded in the augen gneiss area, forming multiple ridges widely along the top ridge and uphill facing scarplets and linear depressions on its surrounding slope in southern part of Gunsakot. This implies more mega-scale landslide will occur in future.

Acknowledgement: <sup>10</sup>Be dating in this study was carried out at Micro Analysis Laboratory, Tandem Accelerator, the University of Tokyo.

**P-3872**

## **Impact of bedrock landsliding in the Quebrada Arcas alluvial fan system, Atacama Desert, Northern Chile**

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### **Abstract**

The large alluvial fan systems of the Central Depression in the hyper-arid core of the Atacama Desert of Northern Chile provide unique opportunity (through exceptional preservation) to examine landscape evolution processes over geologic time-scales (last 8Ma). We will specifically examine the role that bedrock landsliding plays within the catchment and fan evolution in terms of sediment flux and routing. Today the catchment area (1.7–4.3 km above SL) receives rainfall of ~50 mm pa whilst modern rainfall in the lower elevation (1-1.7km above SL) alluvial fan area is <1mm pa. Evidence from packrat middens suggests that even the wettest periods of the Quaternary were no more than 2 times wetter, thus maintaining a likely arid – hyperarid climate for the deposits and landforms examined in this study.

Quebrada Arcas catchment has an area of 760km<sup>2</sup> which incorporates 2.6km of vertical relief. Within the catchment are a series of deep-seated (100-200m) large bedrock landslides ranging in size from <1km<sup>2</sup> to >22km<sup>2</sup> in area. These can be broadly grouped into older landslides that pre-date a significant inset ignimbrite dated at 5.8 Ma and younger landslides that cross-cut and postdate this surface. The older landslides mostly populate an active NNE-SSW compressional fault structure (W of catchment), and the younger landslides are either associated with steeply tilted (38°) ignimbrite/sedimentary unit discontinuity surfaces (E of catchment) or over-steepened slopes associated with the main ephemeral river gorges. The younger and smaller (0.13km<sup>2</sup>) of these latter landslides is associated upstream with a 40m thick sequence of laminated lacustrine deposits (Salar de Carmen, 0.5km<sup>2</sup> in area) which contains large (m-scale) soft-sediment deformation units indicative of discrete and repeated seismic activity over the life-time of the salar.

Quebrada Arcas alluvial fan covers some 688km<sup>2</sup> and comprises 3 main depositional areas based on relative age and sedimentology. 1) An older depositional lobe to the south which covers 281km<sup>2</sup>, has a probable age of 2-5 Ma and is dominated by clast-rich debris flows ; 2) A relatively younger lobe to the north which covers 244 km<sup>2</sup> and is dominated by clast-rich debris flows. Cosmogenic dating using <sup>21</sup>He suggests surface flows were deposited ~1Ma, and 3) An active clast-poor mudflow dominated lobe which covers 155 km<sup>2</sup> below a fan head trench which extends 10 km from the fan apex. Lobes 1 and 2 demonstrate evidence for repeated large bi-modal debris-flow events. At the surface these are represented by linear chutes (some 1-2km long, 40m wide) lined with oversized (5m) granodiorite boulders, and associated downflow with large boulder-field splay lobes (some 0.3km<sup>2</sup> each). Individual splay lobes represent debris flows of some 3000m<sup>3</sup>/sec. These are thought to represent landslide (flood) related deposits based on geomorphology, sedimentology and provenance.

P-3873

## New data on chronology and paleogeography of late Middle Palaeolithic and Early Upper Palaeolithic (EUP) sites from Odra valley, Poland

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### Abstract

In Central Europe (CE), the Odra Valley, including the Moravian Gate is regarded as one of the most significant corridors allowing people and fauna to migrate during the Upper Pleistocene. This area should be considered as a key region in CE for studies of human subsistence strategies as well as the disappearance of the Middle Palaeolithic and the emergence of transitional industries (Early Upper Palaeolithic, i.e. EUP). Until the beginning of this millennium, only a few chronological and paleoenvironmental records from individual sites have been known.

The aim of this paper is to present the latest results of the chronometric, geomorphological and paleozoological research carried out in archaeological sites located within Odra basin. In terms of taxonomy, the assemblages represent Central European Micoquian and Szeletian.

Age determination of archaeological remains was made with the use of optical dating of feldspar and quartz and accelerator mass spectrometry <sup>14</sup>C. As a result, it was found that the sediments below the archaeological layers of the studied sites are composed of fluvioglacial sediments associated with the Odra glaciation (MIS 6). Based on the chronological records, it is clear that layers with archaeological material lying directly on middle Pleistocene sediments are much younger, corresponding to the time-span between MIS 5a and MIS 3. Middle Palaeolithic sites are associated with MIS 5a-MIS 5d to the beginning of MIS 3, while EUP sites with MIS 3 (48 to 40 kyr BP). It is worth mentioning, that until now, there are no traces of age overlapping of late Middle Palaeolithic and Early Upper Palaeolithic remains.

In the light of geomorphological and sedimentological studies, it seems that human activity covered various parts of the river valley. Sites are known from the elevations surrounding the valleys or from the valley slopes (Lubotyń 11, Pietraszyn 11) as well as from bank and channel zones (Pietraszyn 49a, Haller Av., Wrocław).

The majority of sites yielded Pleistocene faunal remains. The most interesting assemblage is known from site Pietraszyn 11 comprising the remains of small fauna, birds, predators as well as reindeers, horses, and mammoths.



The next site with a large number of remains dominated by Bovidae is Haller Av. in Wrocław, containing also remains of mammoths, rhinoceroses, horses, reindeer, wolf, birds (?) and fish.

Finally, in Pietraszyn 49a, the remains of mammoth, horse and rhinoceros have been recognised.

Recent data contribute an idea that Odra River valley was a theatre of intense and varied activity of archaic humans and anatomically modern human. Most of the data points to the very mobile nature of the occupations. This work was financially supported by the Polish National Centre of Science (grant number 2017/25/B/HS3/00925).

P-3874

## Luminescence chronology of the key-Middle Paleolithic site Khotylevo (Western Russia) – Implications for the timing of occupation and landscape development

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### Abstract

Rich in Paleolithic sites, the Khotylevo region in Western Russia is a crucial data point for deciphering migration patterns to the northernmost latitudes (~53°N) of the Eastern European Plain. Currently there is still a lack of information on geochronology and site formation at the key sites, which impedes our understanding of the driving factors behind occupational phases as well as their regionalization. This ongoing project therefore focusses on the >10m section of the Khotylevo 1.6.2 site at the valley-slope of the river Desna. After extensive geomorphological logging, representative samples have been taken for luminescence dating and grain size analysis. With the quartz already in saturation, dating was conducted on 17 feldspar samples using a pIRIR290 protocol. The results yield information on both (1) the timing of middle Paleolithic occupation and (2) on the entire region's fluvial and landscape development of the Early to Mid-Weichselian.

(1) All the archeological remains are embedded within several sediment layers rich in organic matter, indicative of an interstadial (i.e., a warmer phase). Our dating suggests that these cultural layers cannot be distinguished chronologically and fall within the MIS 5a (82-71ka) period. This contradicts previous <sup>14</sup>C data on charcoals and humic acids which placed these cultural layers between 30 and 55ka calBP. Since these dates were already nearing or even beyond the range of the method, we are confident that our robust and highly defined luminescence chronology is more reliable in this particular case. In accordance with other findings of the area (multiple Khotylevo sites, Betovo), it can be surmised that Neanderthals depopulated the entire region during MIS4 to return in mid-MIS3, thus avoiding the coldest periods.

(2) As implicated by our chronological and geomorphological data, there was a pronounced period of fluvial incision at the beginning of the Weichselian, eradicating Eemian sediments on site. The time of occupation (MIS 5a) mainly saw the deposition of slope sediments, interrupted by brief spells of half-bog formation. With the establishment of permafrost in MIS4, slope sediments dominated again in the form of big solifluction lobes. This caused the uppermost cultural layer to be sheared off, dislocated laterally and being redeposited with a deformation and a 45° tip some distance further downslope. The remainder of MIS4 was characterized by fluvial aggradation on site, with the sediments partly displaying a prominent coarse silt content on account of the simultaneous deposition of the "Khotylevo Loess" in the region. Topping the sequence is an MIS3 flood loam containing an interstadial soil (presumably "Bryansk soil") as evidence for landscape stability at that time.

P-3875

## Evidence of a short Upper Palaeolithic occupation of northern France at Amiens-Renancourt 1 (France) during Greenland Interstadial 3

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### Abstract

Following the discovery in 2013 of a new concentration of the archaeological site of Renancourt (Somme, France), new investigations have been performed to document with great details the stratigraphical, chronological and palaeoenvironmental contexts of this important early Upper Palaeolithic site of northern France and that yielded thousands of Gravettian artefacts, large mammal bone remains and a unique set of ornamental items and several Venus figurines carved in Cretaceous chalk.

The stratigraphic sequence is composed of about 2 m of homogeneous loess including a brown-greyish horizon and, 30 cm above, the tundra gley that yielded the archaeological level. Continuous columns of 5-cm-thick sedimentological and malacological samples have been taken throughout the profile. Both pedogenic horizons yielded molluscan species successions that allow to distinguish (1) a transition phase marked by increasing temperatures and humidity and an increasingly diversified vegetation, (2) a maximum of humidity associated with an impoverished vegetation and (3) an opposite transition to colder temperatures that appears quicker and marked by drier conditions for the brownish horizon than for the tundra gley. Moreover, both successions are accompanied by a decrease in grain size, and thus in eolian dynamics.

These two horizons are bracketed by optically stimulated luminescence ages of about 31 and 27,5 ka. The archaeological layer yielded consistent radiocarbon ages on charcoal, burnt bones and earthworm calcite granules around 27,6 ka cal. BP and the brownish horizon yielded radiocarbon ages on earthworm calcite granules around 28,9 ka cal. BP. These ages allow to validate the attribution of the lithic industry to the Recent-Final Gravettian techno-complex and to correlate these two horizons with Greenland Interstadials 4 and 3. Molluscan successions thus depict intra-interstadial environmental changes and show that the human occupation takes place at the end of the stadial-interstadial transition recorded within the tundra gley. Contrary to expectations, the occupation thus precedes the interstadial optimum characterised by potentially less favorable conditions owing to a water-logged environment resulting from the increased intensity of the annual thaw of the permafrost active layer.

In northern France, recent discoveries demonstrate the discontinuous presence of Human populations in space and time during the Upper Palaeolithic and the rare and short nature of their occupations. Combined with the seasonal character of Human activities at Renancourt, our results demonstrate that this short occupation occurred during a milder climatic phase in an optimal environmental context. Imported shell ornaments and exogenous silex highlight a strong relationship with the center of the Parisian Basin, a possible refuge area during unfavourable climatic phases and seasons. This neighbouring southern area is indeed characterised by a slightly more diversified



vegetation and the absence of cyclical ice-rich permafrost installation. Conversely, only brief incursions would have occurred in northern France during the most favorable periods.

**P-3876**

## **Life in the North -OIS3 adaptations at the northern edge of the habitable world. Case studies from northern Central Europe**

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### **Abstract**

The Early-Upper Palaeolithic open-air sites Lommersum and Breitenbach, both located at the northern foothills of the German *Mittelgebirge*, shed detailed light on the behavioral strategies of anatomically modern humans that enabled them to colonize the northernmost periphery of the Aurignacian oikumene.

Lommersum, which dates into the early, colder part of the Aurignacian is dominated by reindeer and is regarded as a processing camp in the immediate proximity of a kill site. Breitenbach, on the other hand, dates into the final stage of the Aurignacian and has yielded a much wider faunal spectrum. However, its economy, too, is largely based on reindeer hunting. Both sites document the repeated human presence in the tundra-like environments of northern Central Europe during OIS 3.

In contrast to Lommersum, the enormous spatial extent and the richness of the Breitenbach site with various settlement features and a diverse find spectrum indicates repeated and also longer-term occupation(s). It thereby documents that the northern periphery of the Aurignacian oikumene was not merely sporadically exploited, but rather represented an integral part of the regional Aurignacian economic system. It is this intensity of occupation, which appears to foreshadow a type of settlement and site organization which – to some degree – characterizes the succeeding Mid-Upper Palaeolithic, i.e. the 'Gravettian', of eastern Central and Eastern Europe.

The diachronic comparison with the reindeer-dominated Late Middle Palaeolithic faunal assemblage from Salzgitter-Lebenstedt and the Late Palaeolithic Ahrensburgian site of Stellmoor – both located in comparable environments in the northern German lowlands – provides a better understanding of the adaptive advantages underlying reindeer-based economies at the edges of the habitable world.

**P-3877**

## **Red palaeosols in Yunnan Plateau, southwestern China as an evidence of Quaternary landscape evolution and palaeoenvironmental change**

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### **Abstract**

Red palaeosols are widely found in the Yunnan Plateau, southwestern China, of more than 2000 m elevation, which could be used as an evidence of Quaternary landscape evolution and important archive of palaeoenvironmental change. Red palaeosol profiles on the plateau planation surface with elevation of 2200–2400 m were collected from different locations of the Plateau. Pedological, geochemical, magnetic, and mineralogical techniques were used to characterize the palaeopedogenesis of red palaeosols. The morphological features suggest that these red palaeosols were highly weathered soils commonly found in tropical-subtropical climates. The current pedoenvironmental conditions in the plateau are not favorable to the formation of red earth. The red palaeosols contain a larger amount of hematite and exhibit a higher degree of magnetic enhancement. The presence of hematite in red palaeosols is related to stronger weathering intensity under warm and dry soil conditions. Therefore, it is deduced that under the present climate, the highly magnetic red palaeosols could not be developed in the areas with such high elevations of over 2000 m. Pedologically, the red palaeosols are characterized by stronger desilicification and allitization, kaolinite-rich clay minerals and strong sesquioxide illuviation in the B<sub>s</sub> horizon. These pedogenic characteristics are associated with the laterization process and the development of a deeply kaolinized palaeosurface evolved under humid tropical and subtropical climates. The S<sub>a</sub> and S<sub>af</sub> ratios of the red palaeosols range from 1.4 to 2.3, and from 0.8 to 1.4, respectively. These values are similar to those found in the highly weathered Oxisols and Ultisols, which are in a range of 1.31–2.19 for S<sub>a</sub>. Therefore, the only possibility is that these red palaeosols were uplifted by neotectonics after formation. The presence of highly weathered soils at an altitude of 2200–2400 m indicated the influence of tectonic uplift on the soil vertical distribution of the plateau. It is deduced that the red palaeosols formed at high temperature and under abundant rainfall conditions in the Early Pleistocene were uplifted to their current height by the tectonic uplift of the plateau. According to the difference in elevation between the red palaeosols and modern red soil base, it was estimated that the red palaeosols had been uplifted about 1600–2000 m since their formation.

P-3878

## The different climatic response of pedogenic hematite and ferrimagnetic minerals: Evidence from particle-sized modern soils over the Chinese Loess Plateau

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### Abstract

The direct interaction between soils and climatic conditions makes paleosols a potentially powerful resource for quantitative paleoclimatic reconstruction. On the Chinese Loess Plateau, the loess/paleosol sequences contain hundreds of paleosol horizons, which are regarded as one of the most important archives of past warm periods. Over the past two decades, reference has increasingly been made to the aspects of linking magnetic minerals within soils quantitatively to paleoclimatic reconstructions. Earlier studies have long focused on ferrimagnetic minerals. Recently, increasing studies have shifted their attention to quantitative relationships between hematite-related proxies and modern climatic factors. However, the linkage between the hematite formation and climatic variables remains controversial. Here we present the results of a comprehensive investigation of the magnetic properties and statistical analysis of a suite of clay and silt fractions of modern soil samples from 179 sites across the Chinese Loess Plateau (CLP) and adjacent regions. Our objective was to clarify the relationships between modern climatic variables and pedogenic hematite, as well as pedogenic ferrimagnetic minerals. Our results show that pipette extraction separates the fine-grained superparamagnetic (SP) and most of the single-domain (SD) magnetic grains into the clay fraction, and that the remaining silt fraction displays the magnetic properties of coarse pseudo-single domain (PSD) or a mixture of multidomain (MD)/PSD and a few SD particles. Only the pedogenic clay fraction shows a strong correlation with climatic variables. The application of redundancy analysis helps to distinguish the climate variables controlling the formation of ferrimagnetic minerals and hematite during pedogenesis. On the CLP, pedogenic ferrimagnetic minerals are sensitive to mean annual precipitation, while pedogenic hematite formation is preferentially dependent on mean annual temperature. The confirmation of the temperature-dependent nature of hematite on the CLP provides a new possibility for quantitatively reconstructing the paleotemperature history of Chinese loess/paleosol sequences.

**P-3879**

## **Lithium isotopes in lake sediments as a proxy for past soil development at the catchment scale**

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### **Abstract**

Soil development regulates landscape evolution, as well as the delivery of sediments and nutrients to rivers. One key question is how this process responds to climate variability, tectonic and human activity. To tackle this issue, one approach is to investigate how soil development has varied during the Quaternary.

Lithium (Li) isotopes (<sup>7</sup>Li and <sup>6</sup>Li) fractionate during clay formation and thus can be used as a proxy for the extent of soil formation. For instance, in river sediments, it has been shown that their Li isotopic composition directly correlates with weathering regimes at the catchment scale [1]. Applied to sedimentary deposits, this tool can be used to assess how soil development has varied over the Quaternary.

The Li isotope composition of Lake Dojran sediments (FYROM/Greece) shows that soil development continuously increased during the early and mid Holocene, in response to the end of the Younger Dryas (Fig.1; [2]). Unlike erosion, soil development was insensitive to short-lived (less than 1,000 yr) climatic fluctuations at 8.2 and 4.2 ka. At 3.5 ka, Li isotopes suggest that sediments deposited were poorly weathered, evidencing a deep erosion event associated with the emergence of agriculture in the region.

In Germany, Li isotope results from maar lakes show that for most of the late Pleistocene there was little soil development, as a consequence of an overall cold climate, and contrasting with extensive soil development during the Holocene. Although less intense than during the Holocene, some soil development occurred at about 50-55 ka, associated with the only period when *Picea* and *Carpinus* coexisted. These observations illustrate the role of ecosystems on soil development, and allow us to identify which vegetation taxa have a more important role compared to others.

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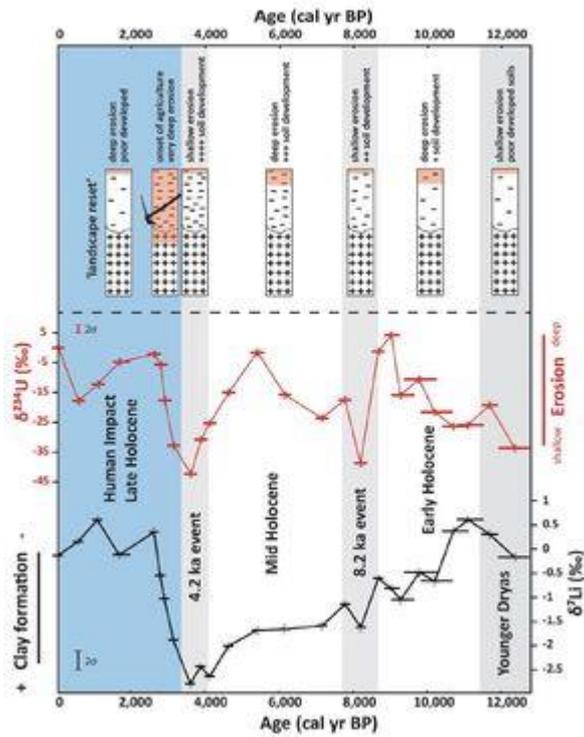


Figure 1. Lithium and uranium isotope compositions of Lake Dojran sediments, proxies of soil development and erosion, respectively [2]. Between 12,000 and 4,000 cal yr BP, soil development continuously increases while erosion responds to short-lived climatic events at 8,200 and 4,200 cal yr BP. At 3,500 cal yr BP, both proxies suggest a deep erosion event associated with the development of agriculture in the region.

P-3880

## Modelling of interglacial paleosol development in the Chinese Loess Plateau

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### Abstract

#### Modelling of interglacial paleosol development in the Chinese Loess Plateau

#### Introduction and Rationale of Research

The loess deposits in the Chinese Loess Plateau (CLP) are a huge continuous record of paleoclimates. Paleosoils and intercalated loess layers have long been studied and correlated with modelled paleoclimates.

Interglacials are the major periods of soil formation and greatly differ from other interglacials by duration and strength. It has been identified that paleosol formation does not strongly concur with globally established paleoclimate signals especially for interglacial Marine Isotope Stages MIS 5e, MIS9 and MIS13. Analysis of just soil data would not be straightforward to identify relations between modelled past climate intensity and soil development. Not only the past climate (precipitation, temperature) has an effect on soil formation but also vegetation and interglacial duration plays a vital role. Additionally, pedogenetic overwriting during later periods of soil formation may affect the observed soils. The intention of this research study is to identify the relative importance, magnitude of favorable conditions of soil forming factors on soil formation during six interglacials in the past 500 000 years in the CLP in China.

#### Research methodology

Combination of the soil formation model SoilGen and the earth system model LOVECLIM is a promising tool to compare simulated paleosol properties to paleoclimate.

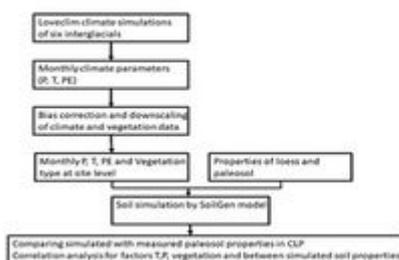


Figure1. Graphical illustration of ongoing research work

### Results

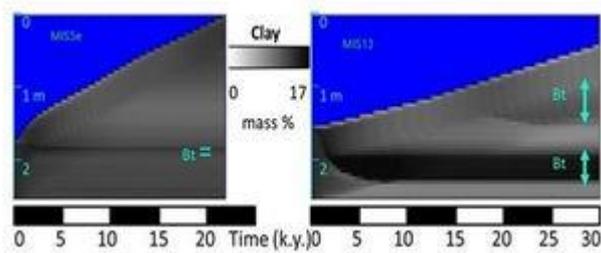


Figure 2. Example results of LOVECLIM-SoilGen climate-soil evolution model: distinct Bt horizon is visible in the MIS13 soil (right) than MIS5e

Table 1. Example result of paired t-test on difference of means representing an aridity gradient:  $H_0$ : no difference between mean values of soil properties in the simulated soil. Clay content difference calculated by (MIS13-MIS5e).

Sites of CLP	Aridity percentile over CLP	Clay content
mean difference (kg clay m <sup>-2</sup> )	P( $H_0$ )	t
	Wet	
	to	
Wugong		0.127 -2.139 0.002
	Dry	
Chang'an	0.185	-1.249 0.080
Weinan	0.241	-1.417 0.013
Luochuan	0.349	-1.226 <0.001
Changwu	0.430	-0.691 0.001
Xifeng	0.676	-1.132 0.001
Pengyang	0.761	-0.035 0.039
Jingyuan	0.869	-0.413 0.000

## Conclusion

Clay content was significantly higher in MIS 5e than MIS13 paleosols for all plots, indicating strong weathering and leaching in MIS13.



The clay differences between MIS 5e and MIS 13 soils become less with increasing aridity.

Precipitation surplus is the leading soil forming factor for soil horizonation during MIS13 than MIS5e.

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## **Acknowledgement**

This work was supported by Professor Peter Finke for the SoilGen modelling and Professor Qiuzhen Yin for the construction of climate data.

**P-3881**

## **Soil erosion process and human activities recorded by check dam deposit in the gully region of Chinese Loess Plateau**

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Check dams are important engineering measures to prevent soil erosion and to settle sediments and pollutants. The dam sediments are also good archive for past climatic change and human activities of small watershed. We choose a check dam (HSC) section from the Chinese Loess Plateau as a case to discuss their relationships. Firstly, based on AMS 14C and 137Cs dating, we established the chronological frame of this section. Secondly, we employed magnetic susceptibility, particle size, mineralogy to reconstruct the soil erosion process. Finally, we compared these records with the local rainfall and historical archives, and explore the relationship between the process of soil erosion and human activities since 1950s. The results show that the check dam deposition has recorded the process of soil erosion, which can be subdivided into 5 phases. The erosion process is not only related to precipitation changes, but also closely related to human activities. The reform and opening up, croplands creation and afforestation activities have great influence on soil erosion. This work can provide important clues to the study of regional man-land relationship.

P-3882

## Soils and environmental conditions in the Bronze and Early Iron Ages in the dry-steppe area of Russia

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### Abstract

Modern soils in the steppe area perfectly reflect climatic fluctuations in the Holocene. The main goal of our research is to reveal the landscape parameters of various time slices based on the features of paleosols buried under kurgans, which are widely spread in the study region. The relevance of the study is based on a complex set of methods, including morphogenetic studies of soils at various hierarchical levels and physical and chemical properties. The age of buried soils was determined by radiocarbon dating of various carbonaceous substances.

The kurgan cemeteries named *Krasikovo 1* (Pit-grave archaeological culture, The Bronze Age) and *Vysokaya Mogila* (Sarmatian culture, The Early Iron Age) are located in the dry-steppe area of Orenburg region, Russia. Set of burials belonging to the same archaeological cultures allows providing a short-term paleoclimate reconstruction for a long period of the time: The Bronze Age (~4600 BP) – The Early Iron Age (~2000 BP) – nowadays. Based on the study of buried and surface soils it can be concluded, that the Bronze Age environment conditions were similar to modern and characterized by a dry climate. In the Early Iron Age soils were formed in more humid period, which is evidenced by a relatively high content of organic carbon, less carbonate accumulation and lower carbonate table.

In the *Krasikovo 1* cemetery five kurgans were constructed with time intervals in 50-100 years and were divided into early and later constructed groups based on radiocarbon data. Paleosols buried under earlier constructed group of kurgans showed more humid soil properties: thick humus horizon and deep carbonate table; the soils buried under the second group are characterized by more arid properties: shallow humus horizon with a lower TOC content, high carbonate table, the presence of gypsum and lower values of magnetic susceptibility. These data allow us to assume that during the construction of kurgans the mean annual of precipitation decreased.

The radiocarbon data showed that the time interval between the constructions of two kurgans in the *Vysokaya Mogila* site is ~ 200 years (2191±35 and 2022±25 BP). The soil buried under the older kurgan has thicker humus horizon and higher humus content; the pedogenic carbonates are absent, and the gypsum formations located deeper than those in the younger paleosol. This comparison showed, that the environment within a short time interval became more arid.

The study of buried soils confirms rhythmic climatic fluctuations within the time span from the Bronze Age till nowadays. In the wide scale, environment conditions in the Bronze Age was similar to modern, while in the Early Iron Age the era of humidization occurred. Soil properties prove to be very reflective to quick environmental changes.

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P-3883

## Understanding geomorphic and pedogenic forcing on the organic matter distribution from vegetation to soil and its use in paleovegetation reconstruction

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### Abstract

The  $d^{13}\text{C}$  values of organic matter (OM) have been used to reconstruct abundance of  $\text{C}_3$  and  $\text{C}_4$  plants. However, the intimate connection of distribution of vegetation with geomorphic processes and landforms may impart variation in  $d^{13}\text{C}$  of  $\text{C}_3$  and  $\text{C}_4$  plants. Such variation can impart change in  $d^{13}\text{C}_{\text{SOM}}$  value without change in abundance of  $\text{C}_3$  and  $\text{C}_4$  plants. Therefore, it is important to understand the effect of lateral variation in riverine geomorphic architecture and its impact on the  $d^{13}\text{C}$  value of vegetation and soil. In this study, a lateral transect (~6 km) of an undulatory geomorphic surface of north-south trending lateritic alluvium of South Bengal (India) was considered to unveil the effect of topography, and active channel distance on the contemporaneous vegetation and soil. A variation of ca. 50‰ is observed in the n-alkane H-isotopic composition ( $d\text{D}_{\text{C}_{31}}$ ) of the dominating tropical deciduous species (*Sal-Shorearo busta*). The  $d^{18}\text{O}$  value of the groundwater and the river water was analysed to understand the source of water for the trees. The D/H ratio suggests that the vegetation near the active channel was mostly influenced by the river water (enriched) and in distal areas by the groundwater (depleted). Preliminary study on the  $d^{13}\text{C}_{\text{Bulk}}$  values of the deciduous species suggests an enrichment of 7‰ away from the active river channel. The difference can be attributed to the change in water-availability, canopy, topography, and vegetation density that varied along transect. The variation in the efficiency of water use was also observed in the average chain length (ACL) and carbon preference index (CPI) distribution. The higher ACL (>29) and CPI (>2) values are mostly associated with the badlands or upland soil environment with very low moisture availability. Preservation of the contemporaneous vegetation signals in the litter layer was regulated by the geomorphology, vegetation density, and soil texture. The upland, and the distal area, with sparse vegetation, tend to preserve more positive  $^{13}\text{C}/^{12}\text{C}$  ratio (-24‰) compared to the lowland with well-developed soils (-28‰). The upland and distal soils, with coarser texture, suggests faster decomposition of OM (TOC% <0.2) due to higher percolation and soil aeration; whereas in fine-textured lowland soils depleted (-4‰) and high TOC % (>0.5) is observed. Further, due to continuous abrasion by the riverine process, the TOC is also low in the soils adjacent to the active river. The nitrogen isotopic composition ( $d^{15}\text{N}_{\text{Bulk}}$ ) of OM increases as alteration/decay or leaching of organic matter proceeds. The faster decomposition and microbial processing of OM in upland and distal area soils registered higher  $d^{15}\text{N}_{\text{Bulk}}$  (+4‰) value. This variation in the vegetation and soil will result in ambiguous interpretation about the past vegetation and thus requires detail vegetation, geomorphic and physical or chemical characterisation before employing it as paleo-record archives.

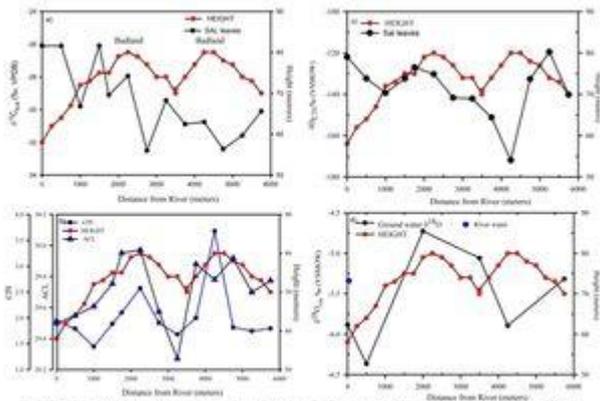


Fig. 1. Variation in the soil  $\delta^{13}\text{C}_{\text{Bulk}}$ ,  $\delta^{15}\text{N}_{\text{Bulk}}$ , C/N and  $\delta^{15}\text{N}_{\text{top}}$  value, and Groundwater  $\delta^{15}\text{N}_{\text{top}}$  value along the lateral transect of the river.

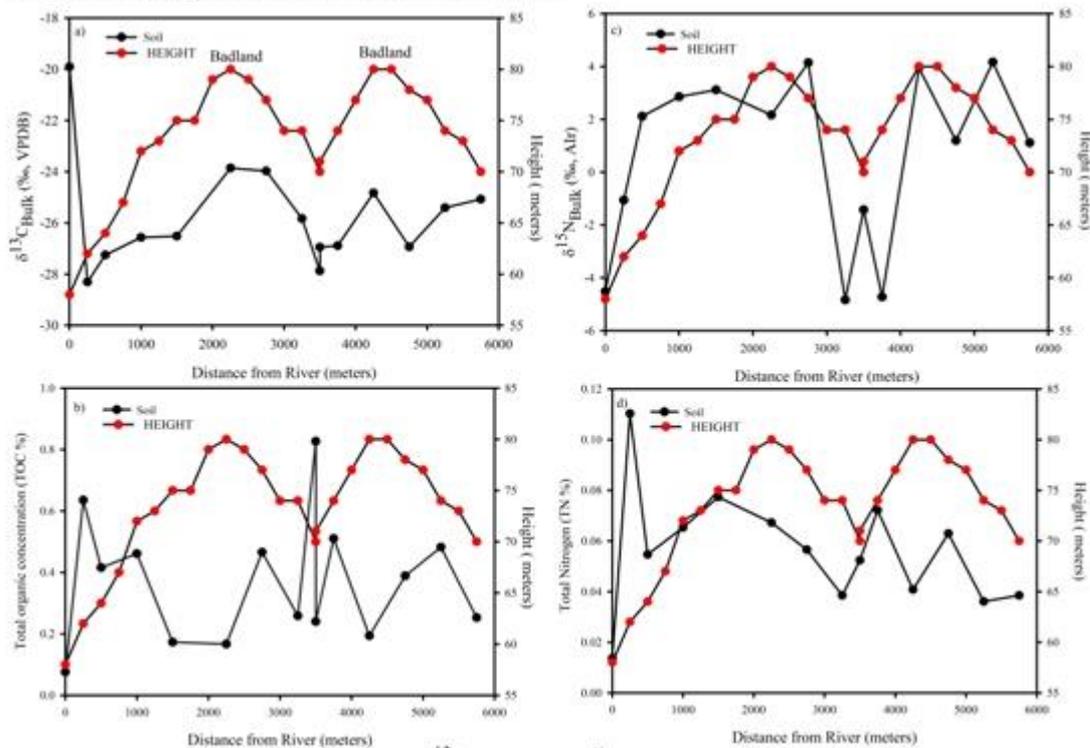


Fig. 2. Variation in the: Soil a)  $\delta^{13}\text{C}_{\text{Bulk}}$ , b) TOC, c)  $\delta^{15}\text{N}$  value; and TN % along the lateral transect of the river.

**P-3884**

## **Paleosols in Cover Sediments on Pleistocene Terraces of the Mosel River**

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### **Abstract**

Previous studies of Pleistocene archives at the Mosel River focused mainly on the evolution and characterization of terrace levels (e.g. Rixhon et al. 2016; Cordier et al. 2006, Negendank 1978), on fluvial dynamics and soil development in general (Weidenfeller, 1990), and on the youngest terrace stage in more detail concerning dating purposes and fluvial erosion (Cordier et al. 2014). Cover sediments with intercalated paleosols on the Mosel terraces are valuable paleoenvironmental archives but were not studied in detail until now.

We present pedological data from two sediment-paleosol sequences (SPS) on Pleistocene fluvial terraces in the lower Mosel valley, including soil physical, micromorphological, geochemical and biochemical data. The chronology is based on 13 optically stimulated luminescence (OSL) model ages (Bandemer SPS: 7, Hetzerath SPS: 6) to support the proposed pedostratigraphy and yield the first minimum ages for fluvial terraces of the Mosel River older than Würmian. According to the terrace-grouping of Müller (1976) the Bandemer SPS is located on a high terrace (145 m above the present Mosel) and the Hetzerath SPS is located on an upper middle terrace (70 m above the present Mosel).

The surface soil at both SPSs is a Stagnic Luvisol supposed to have developed during the Holocene. The buried paleosols are generally Btg horizons of Stagnic Luvisols with different redoximorphic features formed in loess derivatives. Both archives cover the last three glacial-interglacial cycles as indicated by distinct paleosols and OSL based chronology. The Bandemer SPS comprises a fourth glacial-interglacial cycle indicated by soil formation in fluvial sands and gravels, however, within the saturation limit of OSL dating techniques.

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P-3885

## Loess-palaeosol sections along the Rhône Graben: records of Late Quaternary changes of a climatic gradient from central to southern Europe

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### Abstract

The Rhône Graben in south-eastern France stretches from 45°5'N at the confluence of the Saône River southward to 43°2'N at the Rhône delta on the Mediterranean coast. At present, the climatic conditions along this north-to-south transect represent a gradient from a humid-temperate to a Mediterranean climate. The aims of our study are (i) to reconstruct, how this climatic and environmental gradient changed over the Late Quaternary, based on a series of loess-palaeosol sections along that transect, and (ii) to correlate these sections with loess-palaeosol sections in central Europe.

At the current stage of the work, we have studied several loess-palaeosol sections along the Rhône Graben and developed a preliminary stratigraphy, based on three sampled key sections. The chronological framework will be established by optically stimulated luminescence (OSL) dating (in progress). Samples are currently analysed for colour, particle-size distribution, carbonate content, total contents of C, N, Fe, Al, Ca, Mg, K, Na, and contents of dithionite-extractable Fe and Al. Besides, plant biomarker analyses and thin section analyses will be carried out. The results will be used for reconstructing the changing palaeoenvironmental conditions through time at each site. Along the Rhône-Graben transect, mean annual temperature (MAT) increases from 12.2°C to 13.7°C, and the ratio of mean monthly maximum to mean monthly minimum precipitation  $MMP_{max}/MMP_{min}$  increases from 1.89 to 4.04, thus reflecting a progressive shift towards a typical Mediterranean precipitation pattern. The northernmost key section is located at 45°5'N: (1) Profile Les Chaux, NE of Tournon-sur-Rhône (MAT = 12.2°C, MAP = 810 mm,  $MMP_{max}/MMP_{min}$  = 1.89). The second key section is at 44°4'N: (2) Profile Garenne, NNW of Montélimar (MAT = 12.9°C, MAP = 840 mm,  $MMP_{max}/MMP_{min}$  = 2.81), representing the present-day transition zone between temperate and Mediterranean climate. The southernmost key section is located near Collias, West of Avignon (MAP = 698 mm, MAT = 13.7°C,  $MMP_{max}/MMP_{min}$  = 4.04), including (3a) Profile Collias-North (43°6'N), (3b) Profile Collias D112-South (43°6'N), and (3c) Profile Collias-Wood (43°6'N). The transect will be extended northwards over the next years to link central European sections.

Comparing the profiles studied so far, the most conspicuous stratigraphic unit is a brown palaeosol horizon, marked by vertically oriented calcium carbonate rhizoliths in most of the sections. Based on the position of this horizon, we assume that it formed during MIS 3. It appears to be a suitable marker horizon for correlating the loess-palaeosol sections along the Rhône-Graben transect. Furthermore, a red palaeosol horizon above a thick petrocalcic horizon in profiles (3b) Collias D112-South and (3c) Collias-Wood suggest Last Interglacial soil formation. However, the exact chronostratigraphic positions still need to be determined by OSL dating.

P-3886

## Late Holocene environmental dynamics in Zackenberg area (NE Greenland) through the study of earth hummocks

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### Abstract

Although the most commonly used records to study past environmental and climatic conditions are marine and lake sediments and ice cores, there are many other records can provide valuable information for this purpose. This is the case of earth hummocks (*thúfur* or *pounus*), which have been scarcely used until now as paleoenvironmental record. Earth hummocks are dome-shaped periglacial features typical of poorly-drained permafrost environments. Their internal composition is made mostly of organic-rich layers that can be used to trace past environmental and climatic conditions.

In August 2018, three fields with hundreds of earth hummocks were studied in Zackenberg, an ice-free area located in the Northeast Greenland National Park (74°28' N, 20°34' W). We examined the morphometric, geochronological and sedimentological characteristics of these periglacial features. The three sites were located at altitudes ranging between 50 and 75 m asl distributed between different moraine systems from different glacial stages. Several sedimentological analyses of the internal structure of earth hummock were conducted (textural characterization through the quantification of sand, silt and clay fractions, organic matter content as the sum of both % labile and % refractory fractions, Rp index, and percentage of total organic carbon and total nitrogen), as well as six <sup>14</sup>C datings in the Radiochronology Lab of the Laval University (Canada).

Results show that the average length of earth hummocks ranges between 67 and 85 cm, the width between 51 and 62 cm, the maximum height between 38 and 39 cm, the minimum height between 23 and 30 cm, and the depth of permafrost varies between 20 and 24 cm inside and between 1 to 13 cm outside of these features. These parameters are related to topography, as well as to water and sediment availability. Geochronological data show that earth hummocks have ages between 1.8 and 0.4 ka BP, while sedimentological analyses show a general increase in organic matter content from the bottom to the top. Therefore, geomorphological processes (transport and sedimentation of particles) predominate in the initial stages of earth hummocks formation, whereas in the stages of greater evolution of these features soil formation prevails. However, in detail there is a succession of mineral and organic layers. This succession reveals the occurrence of at least five contrasted stages in the environmental evolution of this area of NE Greenland during the last two millennia. Sedimentation rates vary between 0.15 to 0.26 mm/year in organic layers, while in mineral layers generated in dynamic geomorphological environments, sedimentation rates of 0.69 mm/year can be achieved.

**P-3887**

## **Assessing loess proportions in Pleistocene periglacial slope deposits (PPSD) and their spatial variation**

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### **Abstract**

Admixture of loess plays an important role in the formation of Pleistocene periglacial slope deposits (PPSD) in the central European subdued mountains, and it is also a key criterion in their classification. Typical patterns of loess admixture in different types of PPSD have been extensively reported for numerous regions of central Europe. However, the quantification of loess proportions in PPSD still remains a challenge. The lack of quantification methods hampers (1) the establishment of relationships between the loess proportion and its effect on ecologically relevant soil properties (e.g., water-holding capacity, base saturation, etc.), and (2) the assessment of variations in the loess proportion of an individual PPSD in different relief positions across a landscape.

In this study, we tested the potential of laser-diffraction particle size analysis for quantifying loess proportions in PPSD, and used color determination by spectrophotometry for independent cross-check.

We examined the particle size distribution of twenty pedons developed in PPSD and Holocene colluvial deposits in different topographic positions along a little valley carved into Lower Triassic sandstone (Buntsandstein) near Göttingen, central Germany. The particle size distribution of the Holocene colluvial deposits, upper layers (ULs) and intermediate layers (ILs) mostly showed a bimodal pattern. It included (1) a silty mode, corresponding perfectly to that of nearby primary loess that served as a reference, and (2) a sandy mode, matching with that of the basal layers (BLs), which consist entirely of local weathering materials. The consistency of the silty mode between the UP and the IL, irrespective small variations among different sites reflected that the loess component in the ULs was incorporated from underlying loess that previously existed. Very similar loess contents at different depths within individual ULs (and colluvial deposits) indicated a rather complete homogenization due to a variety of processes, including solifluction, bioturbation and anthropogenic influence. Further, the only slightly overlapping particle size distribution curves of loess and sandstone allowed for the calculation of loess proportions in loess-containing layers. Proportions of loess in loess-containing layers varied from less than 10% to more than 90%, and showed maximum loess proportions in the ILs. The loess proportions calculated based on laser-diffraction data showed a high correlation ( $r^2=0.88$ ,  $n=79$ ; A horizons excluded) with the  $b^*$  value (yellowness) obtained by spectrophotometry. This close relationship suggests that (1) a detailed assesment of grain size distributions may provide reliable estimates of loess proportions in the studied soils and (2) the  $b^*$  value may serve as another sensitive proxy that can be used to calculate loess proportions in soils. This new approach enabled us to assess spatial variations of loess admixture in PPSD at a landscape scale and thus to obtain a deeper understanding of the erosional-depositional history of each site.

P-3888

## Buried late Pleistocene paleosols in the context of the Quaternary landscape evolution of North-Western Siberia

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### Abstract

Recent development of non-glacial scenario for the Quaternary landscape evolution of North-Western Siberia (Sheinkman 2016, 2017) stimulated search for the paleopedological archives in this region. During the 2013-2018 field surveys we identified and studied 3 major Late Pleistocene pedomorphological levels in the sedimentary sequences of the high terraces of the rivers, which run to the north and south from the Siberian Uval. The lowest level identified in the Middle Ob' terrace sections Kiryas and Belaya Gora yielded U/Th dates 100-120 kyr BP and thus is attributed to the MIS5 – Kazantsevo thermochrone. It is represented by a pedocomplex in which the lower paleosol unit has micromorphological signs of clay illuviation (indicative of taiga pedogenesis) whereas the upper one consists of the peat and gleyic horizons. We correlate this level with Mezin pedocomplex of the East European loess sequences and suppose that the differences of pedogenesis between the lower and upper unit mark the paleoclimate deterioration after MIS5e. MIS3(Karginsky interstadial) paleosols (with C14 dates from the soil organic materials in the range 25-35 ka BP) lie above the MIS5 level being separated by the alluvial sediments containing dropstones. These paleosols show macro- and micromorphological features redoximorphic processes (ferruginous mottles, nodules and coatings) and frost action (cryogenic aggregation, mixing of organic and mineral materials, grain size sorting). Pedogenetic properties of these paleosols are indicative of soil development under tundra or tundra-steppe ecosystems. The paleosol level corresponding to Late Glacial – end of MIS2 (C14 dates 10-12 ka BP) was identified in the uppermost parts of the high terrace sections of the basins of the rivers Taz and Nadym. This strongly gleyed paleosol is associated with a cryogenic horizon and partly is presented by pedosediments filling large ice wedge casts. We suppose that this paleosol level is associated with the warming events at the end of the last cryochrone. Paleoenvironmental interpretation of the paleosols agrees with the palinological and paleontological records.

P-4001

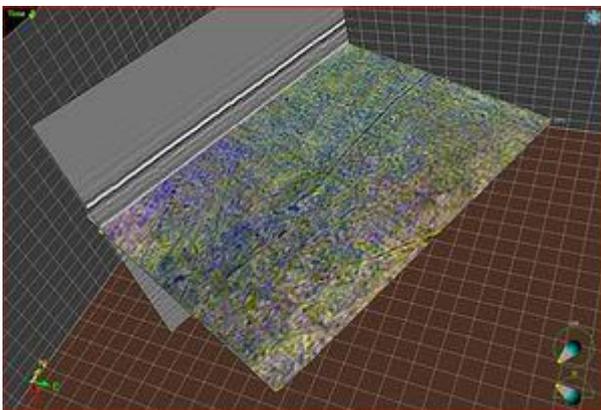
## Quaternary ice sheet limits on the continental shelf west of Ireland.

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### Abstract

Recent investigations have shown that the continental shelf west of Ireland contains sedimentary landforms recording occupation by grounded, lobate ice sheet margins that extended from Ireland during at least the last glacial cycle. This paper reviews some of the offshore evidence of past glacial events available from high-resolution bathymetry, 2D/3D seismic datasets (Fig. 1), and shallow sediment cores providing information on the sedimentology, rheology and age of glacial units. The available data suggest that the continental shelf has been repeatedly occupied by tidewater ice margins characterised by ice streaming, possibly since the mid-Pleistocene transition. The offshore record provides as yet incomplete information on the extent and timing of glaciation from multiple centres of dispersal in Ireland. The dynamics of former ice sheets in Ireland, downwind of the climatically important central North Atlantic region, makes them of wider interest in the study of partially marine based ice sheet-ocean interactions in rapidly changing environments.

Fig 1. The first appearance of ice berg plough marks within a Plio-Pleistocene sediment wedge on the inner shelf west of Ireland.



P-4002

## Submarine evidence of ice-streaming and ice-sheet re-advance of the British Ice Sheet, offshore eastern Scotland and north-eastern England

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### Abstract

An improved understanding past cycles of glaciation, timing and extent, has far-reaching implications for better understanding global climate change and ice-sheet behaviour. The study of palaeo-ice sheets and their drainage systems, both within the ice dome and their outlet glaciers and ice streams, are recognised as crucial for improved understanding of contemporary ice sheets such as the West Antarctic, East Antarctic and Greenland ice sheets (e.g. Stokes *et al.*, 2015). The 1000+ metre-thick Quaternary sediment sequence of the North Sea Basin provides an excellent opportunity to investigate evidence for numerous glaciations, including geomorphological features as discussed here.

The Quaternary strata of the North Sea basin are also important in terms of their role as overburden for hydrocarbon systems and CO<sub>2</sub> storage potential; multiple cycles of glaciation affect subsidence rates and migration pathways. Quaternary strata also form the foundations for offshore renewable installations and infrastructure for hydrocarbon exploration and extraction. The impact on geotechnical properties of glacial loading and unloading and lateral variation in these deposits is an important consideration for offshore development. Cycles of loading and unloading of ice also impact fluid release from the sub-surface and therefore geohazard assessment. Glacial geomorphology shapes the current seabed topography and glacial deposits determine seabed composition, which influences the benthic community composition and distribution as well as forming commercially valuable aggregate resources.

A number of major ice streams have been identified within the Pleistocene British–Irish Ice Sheet (BIIS), primarily based on onshore mapping and single beam bathymetric datasets offshore (e.g. Bradwell *et al.*, 2008). The identification of these ice streams is crucial to better understand the flow pattern and demise of the last BIIS.

This work combines multibeam echosounder datasets with high-resolution topographic digital surface models (NEXTMap), 2D seismic reflection profiles, and shallow borehole data, to reveal strong evidence for onshore-offshore palaeo-ice streaming in eastern Scotland and northeastern England, UK, which extends out into the western North Sea Basin. The study area includes the catchments of the North Sea Lobe, Strathmore, Forth–Tay, and Tweed palaeo-ice streams. Long suspected to terminate offshore, the full flow path and dimensions of these palaeo-ice stream systems are reconstructed with some certainty using these new data. Drumlin fields, large arcuate moraine ridges, smaller-scale moraine ridges, grounding zone wedges and incised channels are mapped in detail to provide new information about the offshore behaviour of the last BIIS.

Bradwell *et al.*, 2008. DOI: 10.1016/j.earscirev.2008.01.008

Stokes *et al.*, 2015. DOI: 10.1016/j.quascirev.2015.07.01

P-4004

## Submarine geomorphology of the Celtic Sea continental shelf and the southern extent of glaciation on the Atlantic margin of Europe

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### Abstract

Ice sheets have occupied the Atlantic continental margin of Europe as far south as the Celtic Sea, where the maximum extent of glaciation remains in question. The Celtic Sea contains no obvious glacial landforms, but is dominated by a system of shelf-crossing seafloor megaridges, up to 60 m high and 10 km wide, that extend seaward up to 300 km in water depths of 100-200 m. The last British-Irish Ice Sheet (BIIS) was thought to have reached a limit on the mid-shelf, based on glacial sediments sampled on and between megaridges in the Irish-UK sectors, but recent work in this area has shown that the BIIS extended at least 150 km farther, at minimum to the UK shelf edge at 48°20'N. Stratigraphic analysis of newly acquired core and seismic data has indicated the megaridges to be eroded sand bodies, which can be interpreted as a) glaciofluvial ridges modified by post-glacial megatides, or b) tidal banks truncated by wave energy. Here we examine megaridge morphology using a regional bathymetric grid and multibeam data across a 25x100 km area of the mid-shelf. At regional scale, the megaridges fan seaward to meet the shelf edge near-transversely along 600 km of its length, their axes rotating by 80° from W-E (Irish shelf) to almost N-S (French shelf). The fan-shaped network points to an apex in the north Celtic Sea, yet axial convergences are more common to seaward than landward. Individual megaridges consist of segments tens of kms long, of differing orientation, that form bathymetric highs. On the Irish-UK mid-shelf, multibeam imagery show that *en echelon* megaridge segments (up to 40 km long, 7 km wide, 55 m high) give way both axially and laterally to transverse 'ribs' (up to 10 km long, 10 m high). The ribs vary in form and spacing, distinct from asymmetric regularly-spaced sand waves within the multibeam data. Glacial sediments have been reported near seabed on and between both the megaridges and ribs, but subglacial lineations are not observed at seafloor. We hypothesise that the rectilinear network of megaridges and ribs are the eroded remnants of giant eskerine ridges flanked by glaciofluvial De Geer moraines, formed time-transgressively along an ice sheet margin during its retreat from the shelf edge. If correct, this interpretation would have broad implications for the dynamics of the last BIIS, and for the supply of meltwater and sediment across the shelf and slope to the North Atlantic at the LGM. Glaciofluvial vs tidal models for the formation of Celtic Sea bedforms invite testing through the targeted acquisition of core data, notably from areas of existing multibeam data in both the Irish-UK and French sectors.

**P-4005**

## **Late Holocene increases in the rate of sea-level fall across the Antarctic Peninsula point to a weak Earth rheology**

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### **Abstract**

Most Holocene relative sea-level reconstructions from across Antarctica are thought to reflect a steady, exponential fall in response to the decay of the last glacial maximum ice sheets. However, many of these reconstructions are obscured by large scatter in the sea-level index points and difficulties associated with dating geomorphic and sedimentary materials in Antarctica. We present new relative sea-level data from locations across the Antarctic Peninsula based on the dating of raised beaches. Our new data record episodic periods of increased rates of relative sea-level fall (isostatic uplift) as high as 5.3 mm/yr on both sides of the Antarctic Peninsula during the late Holocene. These periods of increased rates of relative sea-level fall support recent notions that the Earth beneath parts of Antarctica is much weaker than initially thought with upper mantle viscosities as low as  $10^{18}$  Pa s, more than three orders of magnitude less than the Earth model (VM2) commonly used with ICE-5G. Furthermore, these periods of increased uplift are likely in response to late Holocene oscillations of the Antarctic Peninsula Ice Sheet and/or the ice caps of the surrounding islands. These relative sea-level histories also provide support for recent assertions that the retreat of the Antarctic Ice Sheet from the Last Glacial Maximum was not a steady decline but punctuated by both ice retreat and readvance.

**P-4006**

## **Deglaciation of Spitsbergenbanken, W-Barents Sea: improved reconstruction based on new acoustic data**

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### **Abstract**

Spitsbergenbanken is a large bank (about 77000 km<sup>2</sup>) in W-Barents Sea. The bank is bordered by the northern Norwegian Sea to the west and by two large troughs; Storfjordrenna to the north and Bjørnøyrenna to the south and east. The bank consists of sedimentary bedrock and is locally influenced by fault zones/complexes. Although a large part of the bank is less than 50 m deep, the islands of Bjørnøya and Hopen are the only subaerially exposed parts of the bank. The glacial dynamics and retreat pattern of the Barents Sea Ice Sheet are fairly well known for the parts filling Storfjordrenna and Bjørnøyrenna as glacial landforms and stratigraphy in these troughs have been extensively documented in a number of studies. Spitsbergenbanken, has received comparatively little attention and despite many assumptions having been made on the general ice flow pattern and glacial dynamics of this bank, the general lack of field observations and empirical datasets from the area have so far made it hard to confirm or reject these ideas.

Increased acquisition of both crowd-sourced data such as Olex, as well as more high resolution multibeam data acquired by MAREANO from the area in the past years has added much to our understanding of the glacial history of Spitsbergenbanken. This includes new results from geomorphic mapping based on these bathymetry datasets and acoustic stratigraphy based on new sub-bottom profiler data from Spitsbergenbanken. Combined with findings from existing studies, these new results are used to reconstruct the main elements of the glacial history of Spitsbergenbanken, as well as comparing them with existing ice sheet modelling results from the area. Here we present the main conclusions of the new mapping and reconstruction, and their fit with modelling results, as well as a brief discussion on the most important controls on glacial dynamics and the wider importance of these new results.

P-4007

## Late Holocene subtropical mangrove dynamics in response to the climate change

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### Abstract

This work aims to study the impacts of climate change in the subtropical mangroves during the late Holocene on a southern Brazilian coastal plain and discuss the environmental conditions to the mangrove establishment near the austral limit of South America mangroves. Three sediment cores were collected to study palynological groups, sedimentary features, and geochemical data, synchronized by radiocarbon ages. The main result of this research was the mangrove genus succession, divided in three palynological zones composing two facies association: 1) herbaceous tidal flat and 2) mangrove tidal flat. The first zone between at least ~1815 and ~1629 cal yr BP was marked by the mangrove absence with marine particulate organic carbon, C3 terrestrial plants and macrophytes influence with  $\delta^{13}\text{C}$  values between -26.7 and -20‰,  $\delta^{15}\text{N}$  values  $\bar{x} = 3.5$  and C:N around 21.8, while the second zone between ~1629 and ~853 cal yr BP is marked by the mangrove establishment represented only by *Laguncularia* pollen under influence of estuarine organic matter ( $\delta^{13}\text{C} \bar{x} = -26.5$ ;  $\delta^{15}\text{N} \bar{x} = 3.2\text{‰}$  and C:N around 16.4). The third zone reveals an increase of *Laguncularia* and presence of *Avicennia* pollen since ~853 cal yr BP. Near the surface (< 10 cm) occurs *Rhizophora* pollen, indicating the establishment of this genus during the last decades, under the modern environmental condition ( $\delta^{13}\text{C} \bar{x} = -27.02$ ;  $\delta^{15}\text{N} \bar{x} = 3.12\text{‰}$  and C:N around 17.42). This mangrove vertical succession may be associated with the low-temperature tolerance of mangrove, where the sequence *Rhizophora*, *Avicennia*, and *Laguncularia* mangrove occurs from northern to the southern limit of Santa Catarina coast, respectively, reflecting the temperature gradient. Then, probably, the establishment of the mangrove assemblage identified along the studied pollen profiles was influenced by a temperature increase of air and water during the late Holocene and, mainly last decades.

**P-4008**

## **Basement Fault Propagation Through Quaternary Sediments Along The Indian East Coast: A Remote Sensing And GPR Based Study**

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### **Abstract**

Two surface faults (Jajpur fault and Gop fault) have been identified along the coastal plains of Odisha in the Indian east coast; using tectono-geomorphological signatures and Ground Penetrating Radar (GPR). As direct expression of fault scarps is not available due to geomorphic and anthropogenic modifications, negligible relief and sedimentation; these faults are marked as wide zones showing various fluvial anomalies. Tectonic geomorphological parameters such as sinuosity index of channels, longitudinal river profiles, channel offset, drainage convergence, new streams generation etc.; validate the surface position and continuation of the Jajpur fault and the Gop fault about 48 km and 21 km, respectively. Though valley width to height ratio is an important parameter for fault identification across the stream path, but it is not implemented in plain area for alluvial rivers; as in the present study. Because in alluvial plains; valley width is more as compared to its depth due to loose sediments. The Jajpur fault offsets the Bramhani, Kharsuan and Baitarani rivers about 4 km, 2.7 km and 3 km, respectively. Anomalous sinuosity of Reb, Kapali and Salandi rivers, and linear arrangement of stream converging points marks this fault zone. The Gop fault is marked by offset of the Kushabhadra, Kadua and Prachi rivers about 3.6, 0.5 and 1.2 km, respectively. Abandonment of the paleo-course of the Kushabhadra River is marked by this fault. Optical stimulated luminescence (OSL) chronology of these paleochannels suggests 6 Ka of channel abandonment, which in turn suggests the last major activity along this fault. Both of these faults could be well detected from the longitudinal river profiles. GPR study across these fault zones shows a series of faults with more than a meter vertical displacement in subsurface strata. Geographical position and alignment of these coast-parallel faults fairly coincide with the underlying basement faults. Therefore, these surface faults are believed to have been developed due to surface ward propagation of the basement faults or nucleation of new faults at surface level by reactivation of those basement faults. These faults are responsible for recent infrastructure damage, coastal subsidence and loss of land to sea in the area.

P-4009

## Palaeoenvironmental Evolution at Lake Belevi, Surroundings of ancient Ephesus, Turkey

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### Abstract

Since the deceleration of the Holocene sea-level rise, delta progradation and siltation of marine embayments are accounted as some of the most significant landscape changes in coastal areas. This holds especially true for many sites in western Turkey where within the linear graben structures dramatic progradations of the coastline have occurred. In case of the Küçük Menderes, the direct environs of the ancient Ephesus have been subject to several studies while the areas further land inwards have been neglected so far. This study deals with the lake of Belevi that is located in the Küçük Menderes graben ca. 15 km east of ancient Ephesus and forms an excellent geo-bio-archive. On the basis of two sediment cores with a max. length of 15.60 m geochemical, sedimentological, microfaunal, palynological and tephrochronological analyses were performed in order to decipher the palaeoenvironmental change. The pollen and microfaunal assemblages reveal the development of a freshwater lake at about 8.3-8.1 ka. Due to the rising sea level and the transgression into the graben valley the lake was connected to the sea from late 6<sup>th</sup> millennium BC. The delta progradation of the Küçük Menderes provoked a westward shift of the shoreline which resulted in the development of a lagoon at the site of Belevi and a gradual shift from marine-brackish to lagoonal conditions. This is further reflected by peat growth with intercalated greyish lake layers from mid-5<sup>th</sup> millennium BC on. For the first time, the tephra of the Santorini eruption has been detected in the environs of Ephesus. An in-situ ash layer of 3 cm is overlain by several decimetres of allochthonous material. The palynological investigations clearly show that the vegetation was covered by an ash layer and low-growing plants were strongly affected. In the further course the occurrence of the *cerealia*-type pollen may hint agricultural activity within the closer surroundings at least since the 7<sup>th</sup> century BC. The human influence is further reflected in the speed of the delta progradation, respectively in the increased sedimentation rates since that time, that are mainly governed by the riverine sediment load, which, in turn, are very much dependent on the human impact on the vegetation cover of the drainage basins.

**P-4010**

## **High-resolution geochemical record of three marshes from the San Francisco Bay area**

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### **Abstract**

The San Francisco Bay has the largest concentration of salt marshes in the state of California, representing a diversity of marsh habit. Protecting these environments is critical, as salt marshes provide refuge to endangered species, absorb carbon from the atmosphere, and preserve detailed evidence of past climatic, hydrologic, geomorphic, and ecologic conditions. In the last 170 years, 95% of the historic tidal wetlands in the bay have been destroyed due to diking and filling. Additionally, many of the remaining marshes have been impacted by pollutants such as heavy metals over this period, making ecological trajectories and resilience to disturbance uncertain. In this study, we collected data from three different marshes in the Bay Area to document the geochemical changes including heavy metal concentrations, and shifts in productivity as a response to climatic and anthropogenic changes since the mid-Holocene. Preliminary results confirm anthropogenic impacts on the geochemistry of marshes in the San Francisco Bay over the last 150-200 years following European arrival. However, based on statistical time-series analysis of long-core elemental concentrations, results show that modern conditions are not so far removed compared to prehistoric conditions, as often suggested by century-scale analyses. Modern levels of Pb and Mn are unprecedented throughout the cores, likely due to increased erosion due to European land clearance, logging, and increased production and emissions of Pb (lead). Our results show the effects of anthropogenic changes on these ancient and ecologically important marshes in the San Francisco Bay area that can help better inform restoration ecologists and policy makers, specifically with regards to heavy-metal pollutants.

P-4011

## Holocene coastal dune evolution in Western France: reconstruction from archaeological data

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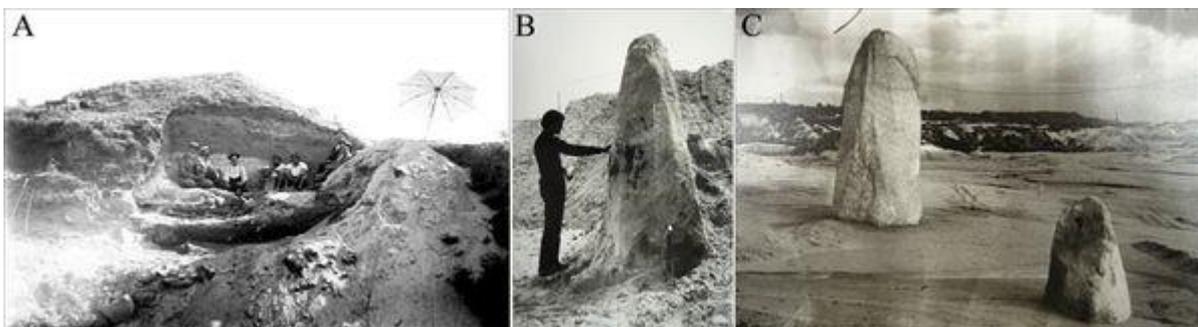
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### Abstract

The long-term evolution of coastal dune barriers is controlled by variations in sediment supply, relative sea-level (RSL), wind energy, vegetation cover, anthropogenic forcing. Based on stratigraphical, geomorphological and chronological investigation of sand drift, numerous works highlighted the link between episodic sand invasion and changes in climate conditions (enhanced storminess) along the Atlantic coasts of Europe. While well-constrained chronologies of Holocene dune accretion were reconstructed in Portugal, Spain and Ireland, the data available for the French Atlantic coast are limited to the Aquitaine dune complex (SW France). This lack of data is mainly due to the absence of well-developed palaeosoils interbedded into the aeolian sand deposits, especially in Brittany where only thin humic layers are preserved into the coastal dune sediment records.

In this paper, we propose an alternative approach based on the use of archaeological information available in the coastal dunes of Brittany. Located in the most western part of the Atlantic coast of France, the Brittany peninsula is characterized by a limited sand supply from rivers and from soft cliff retreat. Consequently, the offshore sedimentary cover is thin and the shallow waters are dominated by rock outcrops. The coastal sediment accumulations usually form single-ridge sandy barriers, topped with a thin dune, isolating brackish lagoons, salt-marshes or small-size infilled valleys. However, some coastal dune complexes extend more than 2 km inland, consisting of foredunes and artificially stabilized dune fields where a high density of well-conserved archaeological sites were excavated from the end of the 19<sup>th</sup> century. These widely available archaeological data were used as chronological indicators to reconstruct the coastal dunes evolution during the last 7000 years at a regional scale (figure).



**Figure.** Examples of archaeological sites discovered in dune contexts. A. Excavations of the necropolis of Saint-Urnel (Plomeur, Finistère) in 1923-1924; B. and C. Megaliths discovered in the dune field of the Bay of Audierne (Kerharo, Plomeur, Finistère) 1978-1978.

From a re-evaluation of the archaeological documentation, 236 archaeological sites distributed along the Brittany coastline were selected to provide accurate information in terms of dune stratigraphy and chronology. Three main phases of aeolian activity were identified at a regional scale: Phase 1 dated from 1600 to 500 cal. BC, Phase 2 dated



from 800 to 1400 cal. AD, Phase 3 dated from 1650 to 1850 cal. AD. A synchronicity is found between the North, West and South coasts of the Brittany peninsula and suggests that periods of sand dune invasion were triggered by a series of regional forcings, involving a decreasing RSL rise, significant changes in the coastal sediment budget and palaeogeography.

P-4012

## Morphological diversity of *Quercus* fossil pollen indicates evergreen forest in the northern South China Sea during the last glacial maximum

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### Abstract

We aimed to obtain high resolution vegetation data and climate information about the LGM in the inland of the northern SCS based on key pollen types. Dominant *Quercus* fossil pollen grains in the terrestrial (core LX02) and marine sediments (core MD05-2906) of the northern SCS have been identified at the infrageneric level by using scanning electron microscopy. Based on tectum ornamentation, we recognized five sculpture types of *Quercus* pollen, namely, rodlike, rodlike masked, rodlike vertical, verrucate and micro-verrucate. According to comparison with pollen sculptures of modern *Quercus* species collected by us, such a high diversity of *Quercus* fossil pollen types indicated that broadleaved forests were widely distributed in the inland along the northern SCS and included the sect. *Ilex* and sect. *Cyclobalanopsis* in subg. *Cerris* and sect. *Quercus* of subg. *Quercus*, of which evergreen sect. *Cyclobalanopsis* populations were highly dominant. Low abundance of deciduous *Quercus* pollen probably derived from temperate-subtropical forests, while abundant evergreen pollen types of *Quercus* and sect. *Cyclobalanopsis*, as well as other pollen of broadleaved taxa in the pollen assemblages, strongly suggest that the inland has been covered by dense subtropical forests. Consequently, the warm and humid subtropical climate prevailed during the LGM in the inland along the northern SCS. Our results shed new light on regional climatic conditions during the LGM in eastern Asia based on high diversity of *Quercus* fossil pollen in terrestrial and marine deposits from northern SCS.

**P-4013**

## **A multiproxy approach in the study of the Holocene evolution of a densely inhabited coastal area: the Apuo-Versilian plain.**

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### **Abstract**

The Apuo-Versilian plain, a key area for the study of Quaternary (Blanc, 1936), is nowadays densely inhabited, and the geomorphological features related to fluvial and marine processes that contributed to its formation have been destroyed by human activities.

Our approach based on the analyses of historical cartography, geomorphological, remote sensing, stratigraphic, and archaeological data together with the study of new cores, have allowed us to reconstruct the main steps of the evolution of the Apuo-Versilian plain. This study was complemented by analyses of speleothems data from nearby caves for reconstruction of the general frame of the hydrological and climatic changes occurred during the Holocene. Our study suggests that over the last 7000 years the plain has undergone an important progradation. However, this general progradation has not been continuous, showing phases of stability and even phases of retrogradation.

A new core, performed near the Porta Lake in the central part of the plain, intensively radiocarbon-dated, shows an increase in the alluvial plain aggradation at ca. 6600 cal yr BP and ca. 2700 cal yr BP.

The first event (6600 yrs BP) is likely to be related to the general trend documented in several Mediterranean coastal plains after the deceleration of sea-level rise and increase in fluvial sediment supply (Anthony et al. 2014). The second event (2700 yrs BP) might be related to a paleoclimatic deterioration documented between 2800 yrs BP and 2600 yrs BP in a speleothem in the Apuan Alps (Isola et al. 2018).

Since ca. 1200 AD the Apuo-Versilia plain has experienced a progressive shift seaward of the coastline. The settlements and the coastal towers have followed this shift, adapting to the environmental changes. An increase in the rate of progradation up to 2.5 m/yr is documented between 1600 AD and 1850 AD. This change could be related to the effects of the climate condition during the Little Ice Age, which seems to correspond locally to an increase in flood events documented after 1500 AD (Giannecchini & D'Amato, 2012). Despite the frequent occurrence of flooding events also in present times, a general phase of coastal erosion has replaced the long phase of progradation.

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**P-4014**

## **The environs of Elaia's ancient harbour – a reconstruction based on microfaunal evidence**

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### **Abstract**

During Hellenistic and Roman times Elaia, the maritime satellite city of ancient Pergamum, was an important place of trading and traffic in the eastern Mediterranean. Intense mercantile and military activities are documented by literary sources and archaeological evidence. Our study aims at reconstructing the history of Elaia's harbour within the context of migrating shorelines. For that purpose, a sediment core was drilled in the centre of the basin of the ancient closed harbour, one of Elaia's three harbours. As indicated by a diverse marine microfauna (ostracods, foraminifers), the site's evolution starts after a short transgression phase in fully-marine conditions and with many phytal taxa, followed by a lagoonal soft bottom assemblage mirroring the construction of the breakwaters in early Hellenistic times. Ongoing siltation caused the abandonment of the harbour in late Roman times.

While foraminifers are more abundant during the marine period and can be used together with ostracods, the latter are more valuable proxies recording the siltation of ancient coastal harbours. Furthermore, our study demonstrates that Elaia holds a unique position as a harbour city during ancient times in the eastern Aegean region, because it was not completely influenced by the high sediment load associated with river deltas. Consequently, no dredging of the harbour basins is documented – neither by sedimentological means nor by literary accounts or archaeological evidence. In addition, due to the short settlement period of Elaia (maximum 1000 years) – bracketed by natural conditions – the closed harbour basin constitutes a valuable geo-bio-archive.

**P-4015**

## **Recognizing sedimentary environments on Amazon by mult-sensors data**

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### **Abstract**

The use of Synthetic Aperture Radar (SAR) images operating in the microwave range, as well as optical images that operate on Visible-Near Infrared (VNIR) to recognize and map the different fluvial environments of the Lower Amazon has facilitated the recognition of difficult areas especially in cloud-covered regions throughout the year. The area of interest (central sector of the Lower Amazon River) was chosen because it is the closest region of the city of Santarém, whose validation and verification of the technique, in order to increase the accuracy and quality of control points, more accessible. The recognition and mapping of the sedimentary features was based on automatic classifications and visual interpretation of the optical images, SAR and the SPC-SAR image, product of the synergism between the optical multi-sensors and SAR. The results allowed the identification of guiding classes: tree vegetation, aquatic grass, water, sand, mud, exposed soil and urban area, resulting in the association of environments: lakes, river dikes, fluvial channels, river deltas, riverbanks, fluvial ", river beach and river. The indexes generated for the general and kappa accuracy of the guide classes were: 89% and 0.90 for the optical sensor image; 88% and 0.67 for the SAR image; and 84% and 0.77 for the SPC-SAR product. These data corroborate works such as de Souza & Rodrigues (2017) in which they obtained good results with the technique in an island called "Ilha Grande do Tapará", in the Amazon river, whose optical and fused product offered a better product in relation to the SAR image. In this way, it is concluded that the use of remote sensor images provides important results for the recognition of sedimentary and geomorphological environments in a short time, making these products material for environmental management programs, as it will facilitate the decision making of difficult to access areas.

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**P-4016**

## **Stratigraphic hiatus of coastal deposits from 6-3 ka BP along the macrotidal west coast of Korea**

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### **Abstract**

Extensive tidal flats is a typical coastal landform found both in embayments and along the open macrotidal west coast of Korea (eastern Yellow Sea). Typically, beach-dune systems along the shore overlie the tidal flats from places to places. An about 20-50 km-wide and approximately 50 m-thick coastal deposit thus extends from the shore across the broad continental shelf, the region receiving abundant sediment supply from large rivers. Here, a variety of transgressive sedimentary facies formed in the course of the Holocene in association with the postglacial rise in sea level. An interesting feature is the general lack of sedimentary deposits in the period from roughly 6–3 ka BP, not only on the shelf itself, but also along the tidal shore. Geochemical and sedimentary facies analyses of numerous long cores, supplemented by <sup>14</sup>C-AMS and OSL age dates, reveal that, stratigraphically, the beach-dune deposits along the shore are underlain by muddy tidal flat deposits, which results in a clear upward coarsening grain-size trend and thus intimates transgressive deposition associated with sea-level rise over the past 7–8 ka. However, within the sequence, a time gap of about 3 ka has been documented to exist between about 6–7 ka BP, marking the age of the uppermost underlying tidal flat deposits, and about 3 ka BP, marking the age of the basal beach-dune sands. Non-deposition commencing around 6-7 ka BP may have been caused either by a sudden decrease in sediment supply or by local sea-level fall. After about 3 ka BP, high sediment supply may once again have resumed, amongst others forming the sandy beach deposits along the coast. This means that the regime shift occurs from tide-domination to wave-domination in that period of time. Further study requires to validate this fact particularly along the Chinese part of the Yellow Sea.

**P-4017**

## **Application of a geoarchaeological approach for paleoenvironmental reconstruction and contextualization of the paleontological GNLQ1 site, coast of Central Chile.**

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### **Abstract**

The GNL Quintero 1 (GNLQ1) site is a paleontological deposit characterized by a wide dispersion of faunal assemblages of terrestrial origin. This site of Late Pleistocene age (21-27,000 cal BP) is currently submerged at a depth of 13 m and 650 m offshore from the present-day coastline of Quintero bay (~32°S), coast of central Chile. One of the most outstanding features of this site is the high concentration of extinct megafauna bone remains, characterized by a large number of individuals of diverse taxa in high resolution and high integrity contexts. GNLQ1 site also present no conclusive evidence of early human occupations, represented by two bone cut-marks. However, further research is required. For all these reasons, the GNLQ1 site represents the only documented Late Pleistocene drowned terrestrial site along the Pacific Coast of South America, offering primary information about submerged paleolandscapes. Considering the geological context of the study area, there are numerous natural variables that have influenced the formation and preservation of the GNLQ1 site, including eustatic variations, tectonic activity, climate changes, among others. In this work, we show the integration of results from geological analyses (geomorphology, sedimentology, stratigraphy, mineralogy, geochemistry and geochronology), together with geophysical studies through the application of remote sensing (side scan sonar, subbottom profiler), and archaeological methods (survey, excavations, documentation, photogrammetry and 3D modeling, and bone recovery) and taxonomic analyses, carried out on the surface as well as underwater. These results have allowed us to assess the variables that have conditioned the formation of this site, its depositional environment, and the physical-chemical processes that have affected it, helping to understand and contextualize this remarkable finding, contributing to establish the basis to systematize future searches for early - potentially submerged - sites in South America.

**P-4018**

## **Getting to the core of climate change: using marine sediment cores to reconstruct past climatic conditions in the high Arctic**

Amy Gray

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### **Abstract**

Climate change is arguably one of humanity's greatest threats, with human activity widely recognised to be driving the current discrepancies between anticipated change and current planetary warming. As such, one of science's greatest challenges is trying to determine how climate change is going to impact upon Earth's biome and the ecological systems upon which we depend, with a view to ensuring that humanity doesn't irreparably damage our planet's biological functionality.

When looking at patterns of climate change globally, over the last century, the High Arctic has experienced rapid warming at a higher rate than the global average. This makes the Arctic a prime location to study in order to better understand the immediate environmental impacts of climate change. However, unlike more populated parts of the world, the Arctic is relatively sparsely monitored, and as such, documenting environmental changes and their impacts remains challenging. Consequently, more effort needs to be made to study this remote and challenging environment in order to refine our understanding of the science behind climate change and its planetary and humanitarian consequences.

This project aims to overcome the challenges associated with the lack of high-resolution, long-term environmental monitoring in the Arctic by developing a state-of-the-art multi-proxy approach to analysing ocean sediment cores. In particular, this project will focus on detailing records of sedimentological, chemical and ecological changes in marine sediment cores from the waters around Svalbard to decipher past and present environmental changes in response to climate fluctuations.

Suspended ocean sediments sequentially accumulate on the ocean floor to form chronological layers that encapsulate details of past environments. Once dated, environmental conditions can be deduced by analysing various properties of the core's sediments. In the case of this project, this will be achieved using advanced multivariate statistical approaches (e.g. structural equation modelling, generalised additive models), which will focus on factors such as grain consistency, chemical composition, presence/diversity of fossilised lifeforms (Diatoms) and the concentrations of pollutants.

By understanding past climate-driven environmental changes, it is then possible to develop more accurate impact-assessment models to anticipate future environmental responses to climate change. This improved understanding will help influence policies on global carbon reduction targets and encourage sustainability and innovation in carbon neutral industries.

Sediment core collection has already been undertaken at previously unstudied locations to the north and north-west of Svalbard (Figure 1). Analysis is underway.



Figure 1

This poster will detail the advantages and pitfalls of using sediment cores to infer past climate-induced environmental changes in data-poor areas, such as the Arctic, and the likelihood that this type of methodology can be reliably used to expand and improve the models that decision-makers use to gauge policy responses to the current climate crisis.

**P-4019**

## **Dancing to the water table's beat! Multi-millennial dynamics of hidro-hygrophilous vegetation in Doñana (SW Iberia), the largest European wetland**

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### **Abstract**

The Doñana wetlands, in the estuary of the Guadalquivir River, constitutes a vast seasonal freshwater area of enormous international ecological importance including a long dune ecosystem, salt and freshwater marshes, temporary ponds, peat bogs and lagoons, probably the largest wetland and one of the most emblematic protected areas in Europe for its rich biotic diversity. They were declared National Park in 1969, Biosphere Reserve in 1981, Important Wetland site under the Ramsar Convention in 1982 and UNESCO Natural World Heritage site in 1984, and they are also integrated into the Natura 2000 network. Furthermore, Doñana marshes constitute one of the largest and best preserved Mediterranean marsh areas in Western Europe, being considered today a hotspot of biodiversity.

As a result of man-made habitat changes, a complex mosaic of diverse aquatic habitat types of different size and water depth are found: from natural to artificial wetlands, from fresh to hypersaline and from ephemeral to permanent water. Although their aquatic ecosystems are well known in terms of their ecology and biodiversity, the most important knowledge gap is the lack of information on historical inundation patterns, and their relationships with natural climatic variability and/or anthropogenic disturbances. Understanding how marshland ecosystem has been influenced by both climate variability and human transformations for millennia, is crucial to anticipate short and long-term trends of annual flood patterns and hydroperiod, and to better understand the response of hygrophilous and hydrophilic vegetation to flood cycles of future climate scenarios. Despite some studies on the vegetation history of the Doñana wetlands, there is a shortage of detailed studies on the temporal and multi-millennial dynamics of aquatic and hygrophilous vegetation. In fact, none of them relates such dynamics to climate variability, human impact and the geomorphological changes that occurred in Doñana during the mid-late Holocene. Understanding the behavior of this complex marsh environment would require high-resolution palaeoenvironmental long-time series. Here, we present the first detailed high-resolution palynological analysis of the Doñana marshland. This is the first attempt to understand the complex relationships established between aquatic and hygrophilous vegetation, climatic variability and human activities in the Doñana marshes during the last five thousand years (mid to late-Holocene).

**P-4020**

## **Environmental change in a backbarrier wetland over the last millennium**

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### **Abstract**

Lowland, coastal wetlands often comprise a complex array of habitats that reflect the interface between marine and terrestrial forcing. They are often highly responsive to changes in climate and human impacts that typically alter sediment dynamics, water quality and hydrology, and the sedimentary archive they preserve is key to exploring changes in forcing and system response. Sheskinmore Lough, located on the west coast of Donegal, northwest Ireland comprises a shallow (<1.5m) freshwater sedimentary lake surrounded by a diverse array of coastal and freshwater wetland habitats within a backbarrier context. In particular the environmental history of the site and its complicated hydrogeology has resulted in a complex ecosystem structure that supports 23 nationally and internationally significant and protected (SAC and SPA) habitats, including lowland oligotrophic lake, orchid-rich calcareous grassland, machair, mire, and fen.

Stratigraphic evidence of a shift from estuarine to freshwater conditions constrains lake formation to c. 1000 years ago when it is thought that dune dynamics blocked a secondary valley of the neighbouring Loughros More estuary. Shallow and deep cores across the lake and wider wetland reveal a sedimentary drape of calcareous dune sand over acidic granitic bedrock, within which wetland peats have accumulated. A multiproxy evaluation of stratigraphies at the centre of the lake reveals distinct climatic and geomorphological shifts that define the three key phases in the recent (multi-century scale) environmental and ecohydrological history of the system. Supported by radiocarbon dating, evidence of shifts between drier and wetter conditions are linked to aeolian forcing (supply of wind blown sand) and transitions between open-water, vs. riverine and floodplain conditions are determined through sediment analyses, macrofossil and diatom analysis. Long-term historical variability in ecosystem structure and function is clearly driven by climate variability over the century time-scale, with the added driver of human intervention at the recent decadal scale. Contemporary management of the site is focused on maintaining a suite of habitats to support key species, but significant questions remain regarding the sustainability of this, and in particular how far removed the site is from its' historical envelope of variability. Here, we explore environmental change and forcing at the transition between late Holocene and the Anthropocene in the context of the contemporary conservation management.

**P-4021**

## **Grain-size and sedimentary records of the XYZ Core in the downstream of the Cao'e River, northern Zhejiang province, China**

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### **Abstract**

Based on the analysis of grain-size constitution and distribution curves of the XYZ core in the downstream of the Cao'e River—the central section of the Ningshao plain, we arrived at the following conclusions: (1) According to the grain-size constitution, the sediments of the XYZ Core can be divided into four lithologies: silty sand, sandy silt, silt, and clayey silt. They distribute along the core alternately. The core is divided into 9 layers and they compose multiple grain-size combinations. The 9 layers are marked as layer 1 to layer 9 from the bottom to the top. Among them, layer 1 and layer 4 are silty sand, and the percentage of clay is 10%~15%, which is poorly sorted and the dynamics is complicated. Layer 3 and layer 5 are sandy silt, the percentage of silt is no more than 70%, and clay is more than 20%. The percentage of clay is low. Layer 2, layer 7, and layer 9 are silt, the percentage of silt is more than 70%, and clay and sand are less than 20%. Layer 6 and layer 8 are clayey silt, the percentage of silt is more than 70%, and clay is more than 20%. The percentage of sand is very low. (2) According to the C-M graph of the max and the mean values and the analysis of its variation, there were four types of deposits from the bottom to the top: fluvial, tidal flat, shallow marine, and lakes and marshes. For layer 1 and layer 2, the hydrology was high energy and unstable, which indicates a fluvial environment; for layer 3 to layer 7, the max hydrology weakened, but the mean hydrology was strong and the range was still wide, and the hydrology was similar to the SYTT tidal flat samples. It referred to a tidal flat environment; for layer 8 and layer 9, the hydrology was weak and stable, which indicates still water environment. Based on the grain-size and biology information, it can be concluded that the under part of layer 8 belonged to shallow marine environment, but the upper part and layer 9 belonged to lakes and marshes environment. (3) Vertical variation of grain-size indicates that clay increased from the bottom to the top with fluctuation, while sand declined. The average grain diameter is decreasing and the sorting coefficient is higher. The sediments change from the bottom to the top reveals that the XYZ Core and its adjacent area experienced sea level rise, and then water level decreased during 9690~5131 cal.a BP. The results of the study are helpful for identifying the paleoenvironmental evolution characteristics of the Qiantang River Basin.

P-4022

## Evolution of Lisbon riverine area (Portugal) using multi-proxy analysis on sediments collected on the northern margin of the Tagus estuary

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### Abstract

The Tagus estuary is one of the larger estuaries of Europe (area of c.325km<sup>2</sup>). Lisbon is located in the northern margin of the estuary and despite the long diachrony of its occupation since the Palaeolithic, the city was founded during the Iron Age and grown continuously since then. The riverine front, containing archaeological evidences of occupation since the Iron Age, and clearly modified during the Roman Period, was successively enlarged at the end of the Middle Age by the construction of landfills, conquering area to the river that was used since then for the development of maritime-related activities and others.

In 2014 a 7.5m-long core was collected from sediment below the landfill (-1m MSL) during the re-arrangement works of Ribeira das Naus (a Lisbon downtown riverine street built-up on a landfill constructed in the 1940's) in an area used as a dock - Doca da Caldeirinha - between the 18<sup>th</sup> and the 20<sup>th</sup> centuries. According to bibliography, the area was strongly affected by the 1755 earthquake and related tsunamis.

Several environmental proxies, combined with <sup>14</sup>C dating, were analyzed at vertical high resolution. The sediment is essentially composed by mud (>90% of fine particles) with ca. 9% of organic matter and ca. 4% of CaCO<sub>3</sub>. δ<sup>13</sup>C values are around -25‰, reflecting estuarine conditions. Sediments have accumulated between 2000 cal BP and 1362 cal BP, evidencing high sedimentation rates (SR) in this area during the Roman Period. SR were extrapolated using Clam 2.2 software and values of 0.9 cm yr<sup>-1</sup> (-8.5m to -5.7m MSL; 2000 cal BP to 1600 cal BP) and 1.9-2cm yr<sup>-1</sup> (-5.7m to -1m MSL; 1600 cal BP to 1362 cal BP) were determined. The high SR can result from both natural and anthropic causes; however, changes on the sedimentary pattern of the Tagus estuary over the last 2000 years are mainly due to human impact. The pollen record preserved in the core attests the existence of open landscape vegetation between 2000 cal BP and 1362 cal BP with the occurrence of heath and widespread of anthropogenic taxa. The inexistence of sediments younger than 1300 cal BP above -1m MSL could be related with anthropogenic activities (e.g. dredging of the area for maintenance of the maritime activities) or due to natural causes (e.g. lack of accommodation space in this low intertidal area, erosion by extreme events).

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P-4023

## Past environmental changes during the mid-Holocene sea-level rise (7-5.5 Ka) at the NE coastal plain of Buenos Aires, Argentina.

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### Abstract

Coastal plains contain important archives of the environmental changes, in particular, salt marsh sediments has been an important tool for the understanding of sea level fluctuations during the Holocene. The NE coastal plains located adjacent to Río de la Plata estuary, specifically from Bahía Samborombón area, developed over several sea-level transgressive periods during the Quaternary. The sedimentary sequences along this plain have a stratigraphic continuity and abundant fossil record characterizing different depositional environments. In this regard, these sedimentary sequences are considered as key archives for reconstructing the geomorphological history as well as past environmental conditions related to the Holocene sea-level changes. This study integrates geomorphological and paleontological (pollen, non-pollen palynomorphs, shells) proxy data from the central zone of Bahía Samborombón (~35.6°S), to reconstruct the salt marsh vegetation history and environmental changes at millennial to centennial time scale, and to develop a geomorphological evolution model during the mid-Holocene sea-level transgressive phase corresponding to MIS 1. The dominance of Chenopodiaceae and Poaceae suggest that between ~7000-6670 cal yr BP halophytic salt marsh vegetation predominates over an extensive tidal flat environment under significant marine influence. It is consistent with geomorphological evidences like relict tidal channels. Pollen assemblages registered during this period present similarity with the middle-high salt marsh zone developed in the current coastal strip of Bahía Samborombón. This environment developed at ~10 km from the present shoreline. During this period relative sea-level rose, reaching ~+3 meters at 6800 cal yr BP. Between 6670-6535 cal yr BP the replacement of a middle-high salt marsh vegetation by another of low salt marsh zone occurred as a result of continuous sea level rise. The gradual increase of dinocysts *Operculodinium* spp. and *Spiniferites* spp. indicates the greatest tidal influence in response to sea-level rise that continues in this period. Between 6535-6453 cal yr BP continues the predominance of marsh vegetation under significant and increasing marine influence. This halophyte vegetation coexists with freshwater communities. After ~6450 cal yr BP, the palynological record is limited to dinocysts and scarce pollen content. However, the record of autochthonous mollusk assemblages of *Tagelus plebeius* with articulated valves and in life position could be indicating environmental stabilization. This is coherent with the maximum transgressive of the sea-level registered for the zone, which is followed by a period of stability of the relative sea-level at +4 m during ~6000-5500 cal yr BP. After 5500 cal yr BP the formation of sand bars and beach ridges towards the east (seaward) occurs, isolating the environments that developed behind, and protected from the action of the marine tidal influence. Eolian and pedogenetic processes took place on the ancient tidal plain at ~10 km from the current coast.

P-4024

## Long-term assessment of climate induced regime shifts in coastal areas

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### Abstract

Resilience has become an important theoretical context for interpreting the sustainability of socio-ecological systems because of its applicability to socioeconomic and environmental systems under changing conditions, regardless if changes are slow and less perceptible. Estuarine and coastal ecosystems around the world are constantly changing in response to combined effects of climate drivers and human activities, and many of them may be approaching critical thresholds threatening their healthy functioning and services they provide. However, shifts from one ecological stable state to another can last for long periods, making long-term studies necessary to understand the real nature of these transitions.

Estuaries contain sediments that preserve the signature of multiple processes acting upon the coastal system. These records can therefore provide valuable palaeoecological data covering decadal to millennial time-scales and overcome the lack of long-term monitoring data required to investigate these processes. We have collected sediment cores from shallow, near-coast sites in the Sado estuary that provides a natural archive of environmental change since the early Holocene. The Sado Estuary is the second largest estuary in Portugal, with an area of approximately 24,000 ha. It is a mesotidal system, well mixed and generally well oxygenated, with a salinity variation depending on the annual precipitation and river flow. Most of the estuary is classified as a natural reserve but it also plays an important role in the local and national economy. Tidal marsh habitats cover about 30% of the total area. The Sado estuary is a good example of a site where human pressures and natural values coexist each other.

Using a combined spatial and temporal approach, this work aims to study ecological resilience and regime shifts in this part of the SW Portuguese coast. Thus, we study the sedimentary infill of a number of tidal marshes located in the Sado estuary to assess variability in both sensitivity and exposure to sea level rise (SLR) at a local scale. Site-specific accretion and wetland elevation change are quantified, and temporal trends understood to produce reliable projections of the effect of SLR. Empirical time-series of tidal data and coeval sedimentological records obtained from the study sites regarding wetland response and sea level changes are used to assess past trends that can inform future scenarios of wetland changes and responses. Contemporary data and multiannual to millennial reconstructions provide insights on patterns and drivers of abrupt environmental change in response to SLR and yield important information on the average state and natural variability of the coastal system. We expect that our results will provide information on the long-term development and patterns of variability of the Sado estuary in relation to socio-cultural activities, which is vital to understand and mitigate the effects of global change on coastal ecosystems.

P-4025

## Enrichment of hazardous trace elements in Kochi Backwaters sediments, India

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### Abstract

The most complex mixture of biogeochemical interactions on earth taking place at the land-ocean interaction in the coastal zone. This is due to the different types of inputs and processes taking place, including materials from atmosphere, terrestrial and marine environments including anthropogenic inputs as well as generation of new particles during the mixing of river with the seawater. About 90% of terrestrial material transported through rivers to the oceans are trapped in the coastal marine systems due to the rapid removal of both dissolved and particulate matter as a result of drastic changes in physico-chemical and biogeochemical processes. However, deposited sediments, their re-suspension and re-mobilization of red-ox sensitive toxic elements in sedimentary column make the narrow coastal zone as a sink and source for contaminants to the nearshore ocean water. India has long coastline (7517 km), dense population (250 million) with fisheries resource (3.5 - 4.7 million tons) that alone contributes to 10% of the GDP. The coastal systems in India includes brackish water, estuarine, deltaic and coastal waters, wetlands; coastal mudflats; tidal flats, rocky shores; mangrove forests; and nearshore marine areas and coral reefs that are under the threat from effluents, untreated sewage and solid waste discharge ( $50 \times 10^6 \text{ m}^3\text{yr}^{-1}$ ,  $0.41 \times 10^9 \text{ m}^3\text{yr}^{-1}$  and  $34 \times 10^6 \text{ tonnes yr}^{-1}$  respectively). The south west coast of India, Kocki backwaters in particular, is under the impact of anthropogenic activities since little more than a century. In this study, a sediment core was collected from the vicinity of anthropocentric region. The nuclear fission product nuclide - Cs-137 was used as a stratigraphic marker to determine the pre- and post-bomb produced nuclides sections to determine the age of the sediment core. Sediment texture determined by conventional technique, whereas major and toxic trace elements - Cr, Pb, Ni, Cu, Zn and Cd, in the sedimentary sub-sections measured by ICP-MS. On an average, these elements are enriched by factors of 2.75 (Pb), 3.83 (Cr), 7.06 (Zn) and 39.41 (Cd) as compared to their background levels. Most of these elements tend to increase from the early part of the 20th century till recently, suggesting anthropogenic inputs. Since, these are non-degradable elements, they cycle in the coastal zone thereby not only cause hazards to the coastal living resource, but also to human health. The most red-ox sensitive element- Mn is strongly depleted in the sediment by an average of 70% as compared to background level suggesting the impact of deoxygenation in the estuarine/coastal waters. This has implication to the reduction of marine bio-diversity as well as the decrease of biotic resources.

P-4026

## Impacts of the 2017-2018 winter freeze and sea-level rise on the boreal limit of an American mangrove

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### Abstract

The global mangrove distribution has been significantly influenced by the winter air temperature extremes and sea-level rise. The combined effects of these driving forces in the septentrional limits of the American mangroves still need to be investigated. We analyzed the black mangroves dynamics from Louisiana coast-United States of America in response to air temperature changes and Relative Sea-Level (RSL) rise based on a spatial temporal analysis of Quickbird (spatial resolution of 60 cm) and drone (3 cm) images between 2004 and 2018. These data were combined with digital elevation models based on topographical data obtained by photogrammetry and Global Navigation Satellite System. During this time, the black mangrove area from Port Fourchon increased from 30.4 ha to 124.3 ha as the monthly average of minimum temperatures during the winters in the study site have increased from 4.7°C to 6.6°C between 1970 and 2018. However, the 2017/2018 winter freeze, with 14 days of minimum temperature less than or equal 0°C and January with an average minimum temperature of 4.1°C, degraded ~90% (110.8 ha) of black mangroves, where the youngest *Avicennia* (<1 m tall) were most impacted. The 2017/2018 winter freeze caused significant impacts on the studied mangroves equivalent to 1980s winter freezes. In addition, losses of about 27 ha of mangrove and marsh areas, located behind the beach ridges, along 4.5 km of coastline, have been caused by landward sand migration on muddy tidal flats occupied by wetlands. This migration led to a coastal retrogradation of ~200 m during the last 17 years due to overwash events, contributing to a continuous degradation of these wetlands. The combined action of these climatic and oceanographic processes is leading to the loss of mangrove areas along the coastline, while mangroves are migrating to more continental and norther sectors as the RSL and monthly average of minimum temperatures rise. Therefore, the poleward expansion of mangroves caused by the global warming are not occurring linearly. The response of this ecosystem to the extreme winters (warmer and colder) should cause events of expansion and contraction of mangrove areas, but with a migration trend to more temperate latitudes. However, the expansion and degradation of mangrove areas caused by the global warming and winter freezes, respectively, probably are not directly proportional to increase and decrease in temperatures. Local coastal characteristics related mainly to the rates of RSL changes, sediment supplies to coastal system, longshore currents, and the interaction topographic gradients of muddy tidal flats and tidal ranges may accentuate or mitigate the effects of climatic extremes.

P-4027

## Holocene evolution of Kuttanad Kole (Ramsar) Wetland in SW India - A multi-proxy approach

Padmalal D

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### Abstract

The Kuttanad Kole Wetland (KKW) in the Southern Vembanad basin, SW India is a unique wetland system, where paddy cultivation is being carried out 1-2 m below mean sea level. The fertile soil in KKW is formed essentially from deposition of fluvial sediments from the hinterland rivers. Although many studies have been carried out on different aspects this wetland system not much information exists on the geological evolution of the KKW, which is acting as the prime carbon sink in the region. Therefore, a study has been undertaken to unravel the Holocene evolution of this wetland system using multi-proxy data of 21 drilled borehole cores retrieved from the wetlands. Except the top 2-3m of riverine sediments, the rest of the core sediments are of lagoonal nature with occasional presence of marine and brackish water shells. The entire sequence is deposited over lateralized Neogene sediments. The top riverine sediments are yellowish brown with heavy minerals derived from charnockite provenance which is characteristic of the hinterland rivers. On the contrary, the heavy mineral suite in the lagoonal sediments of Early-Middle Holocene age is dominated by the mineral sillimanite derived from the Khondalite group of rocks that occur in areas south of Achankovil Shear Zone (ASZ). This points to the fact that, during Early-Middle Holocene, the KKW part of the Vemband basin was not influenced by the hinterland rivers that drain the Charnockite provenance, instead influenced by the longshore drift of sediments from the Khondalite terrain south of the ASZ. This together with the occurrence of subfossil shells of *Villoritta* sp. (and indicator species showing the fresh water end of an estuary) in the lagoonal sediments with radiocarbon dates of 3-4 k yrs of BP reiterate that the hinterland rivers that drain the Charnockite provenance joined the KKW only during Late Holocene. Based on the study, a 3-fold evolutionary model has been proposed and is discussed in the paper.

**P-4028**

## **The paleolimnological approach in the environmental and sea-level reconstructions in the Eastern coast of the Baltic Sea.**

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### **Abstract**

In the conditions of modern climate change, special attention is paid to paleogeographic reconstructions, because the prediction of climate scenarios in the future is modeled on the basis of data from past eras. One of the most reliable methods for the reconstruction of natural conditions of the Late Pleistocene and Holocene is a complex study of bottom sediments of lakes. Climate changes cause the nature and intensity of sedimentation processes, which is reflected in the formed sedimentary sequence of bottom sediments of lakes. Of particular interest is the study of the relationship between changes in climatic conditions and the paleo level of the Baltic Sea. It is established that one of the reasons of Littoral transgressions is eustatic ocean level rise, associated with the degradation of glaciers and climate changes (Bjork et al., 2008). The study of the bottom sediments of the lakes flooded by the Baltic transgressions and isolated from them will allow reconstructing in detail the climatic conditions under which such an increase in sea level could occur. After the reconstruction of the dynamics of natural and climatic conditions, it will be possible to assess the relationship between the intensity of transgressions and the average temperatures of July.

With the aim of reconstruction, the dynamics of the transgression-regressive cycles of the Baltic Sea and comparing this changing with the natural conditions in the northern part of the Karelian Isthmus, the lakes were chosen at different hypsometric levels: Goluboye (11 m ASL), Mozhevelnoye (14 m ASL) and Trigoriskoye (16 m ASL).

The strong salinity influence was identified in the sediments of Goluboye lake by Br/Ti ratio. For this core sediment analysis of the loss on ignition, diatom, geochemical, palynological, Chironomidae and radiocarbon analysis will be applying. The obtained data will show the relation between organic and inorganic material, physicochemical features and bio-productivity of lakes, the duration of sediment formation, vegetation change, average temperatures in July.

The first results of lab analysis will be presented at the conference.

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P-4029

## A resilient deep-water rhodolith bed off the Egadi Archipelago (Mediterranean Sea) and its actuopaleontological significance

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### Abstract

Rhodolith beds (Rb) are priority marine benthic habitats because of their relevance as biodiversity hotspots and their role in the carbonate budget. Mediterranean Sea hosts rhodolith-dominated habitats, targeted over the years for ecological research and management actions, but also. an important fossil legacy of Rb, formed under contrasting climatic scenarios since Neogene. Most of Mediterranean Rb refer to relatively shallow-water situations (30-75 m), far less is known about deeper water occurrences.

An outstanding Rb has been recently identified between 70-100 m off Egadi Archipelago (Central Mediterranean Sea) in the frame of the Marine Strategy Framework Directive. The seabed has been mapped by remote sensing and ground-truthed with by Remote Operated Vehicle (ROV) visual observation and sampling with Van Veen grab (70 l).

The resulting cartographic outcome provides a precise information on the Rb distribution and its main features, including algal morphotypes, dominant algae species and associated biodiversity. The ecological study has been complemented by the radiocarbon dating of the inner structure of some rhodoliths to investigate the tempo of their origin and subsequent growth to unravel the evolution of this carbonate facies during the Holocene.

The Rb carpets an area > 7 km<sup>2</sup> between Marettimo and Favignana Islands (Egadi Archipelago), with a coverage of live rhodoliths up to 95%. The dominant morphotype is *pralines*, ellipsoidal to discoidal in shape, with an average size of 12 mm and maximum size of 31 mm. Old algal nodules, other bioclasts, or, less frequently, terrigenous particles serve as nucleus of individual rhodoliths. Living calcareous algae are *Lithothamnion valens*, *Lithothamnion* cf. *minervae*, *Phymatolithon lenormandii*, and *Lithothamnion* spp. *Lithothamnion* spp. characterize the algal association close to the nucleus, with scatter presence of *Lithophyllum* sp. The dominant sediment type is mostly biogenic gravelly-sand. Seafloor bedforms (megaripples and ripples) and frequent bioturbations by epifaunal and semi-infaunal sea-urchins have been observed on ROV videos. Benthic fauna (e.g., mollusks) corresponds to the circalittoral environment, with exclusive species of the Coastal Detritic biocoenosis or related to coarse sediments. Moreover, the textural aspects associated sediments is in line with moderate water energy at bottom. Radiocarbon ages reveal that the cores of rhodoliths date back to 2734±24, 2559±23 and 2397±23 yr cal BP, which correspond to the Roman Little Climate Optimum. Calculated growth rate provides a very low figure (0.004 mm/yr). The inception of such Rb occurred under warmer climate conditions, but its development is continuing at present because of the persistence of adequate light conditions and bottom hydrological regime, with a very slow growth-rate reflecting the demanding conditions for their development. Therefore, the Egadi case certifies a rare example of a deep-water resilient Rb, which should be taken into consideration for the potential recognition of fossil analogs in the Mediterranean Basin.

**P-4201**

## **A research program to understand human behavioural adaptations to the MPR**

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### **Abstract**

The Mid-Pleistocene Revolution (MPR) was a period of profound ecosystem reconfiguration. It is generally accepted that those environmental changes affected the survival opportunities and the distribution patterns of humans in Europe. The human responses to those environmental perturbations were likely complex and, in many respects, they are still not well understood. One way or the other, human adaptive responses imply changes in behaviour and Human Behavioural Ecology (HBE) provides a theoretical framework to approach the study of the behavioural responses of hominins. The basic premise of HBE is that human behaviour is shaped by natural selection, and its aim is to understand the patterns in behaviour by identifying the constraints that affect differences in reproductive success (O'Connell, 1995). HBE focuses on how a particular behaviour contributes to the fitness and reproductive success of the individual. The methodological approach consist in the definition of Formal Optimality Models, i.e. mathematical models which incorporate the cost and benefits of a particular behaviour in a certain environment and determine the net return of that behaviour. Although the framework of HBE may be applied to any aspect of human behaviour, in archaeology it has been mainly used to understand trophic behaviour by using Optimal Foraging Models (Winterhalder, 1981).

In this framework, Formal Optimality models may be developed to evaluate the responses of hominins to the changing environments during the MPR. These models should incorporate the availability of plant and animal resources, their characteristics, the cost of exploitation of those resources in the different environmental conditions and the requirements of hominins. Moreover, the models may also incorporate the availability of other resources (e.g. shelter or raw materials) the costs associated to their use, and the cognitive or technical capabilities of the hominin species. Resource availability may be reconstructed from the palaeontological record, but the requirements of hominins should be extrapolated from human physiology. Estimating the cost of harvesting different resources, however, requires combining information provided by the archaeological record with palaeophysiological data obtained from the extrapolation of experimental studies with *in vivo* subjects (Mateos et al. 2018; Prado-Nóvoa et al, 2017).

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**P-4202**

## **The METHOD IFG**

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### **Abstract**

The Mid-Pleistocene Revolution (MPR), or Early-Middle Pleistocene Transition (EMPT) was a period of profound ecosystem reconfiguration, caused by climatic changes driven by variations in orbital forcing that took place at around 1 Ma. Changes in climate drastically affected vegetation in complex ways and led to a significant renewal of mammalian faunal complexes in Europe and elsewhere. In particular, it is generally accepted that those environmental changes affected the survival opportunities and the distribution patterns of humans in Europe. However, it is not well established how, where, when and at which extent the environment affected human population dynamics.

The study of complex phenomena, as the ones described above, requires the contribution and cooperation of researchers from several fields. During the last decades, palaeontologists, palaeoanthropologists and archaeologists have produced organized datasets describing hominin distribution and databases containing quantitative palaeoenvironmental and palaeoecological. In parallel, several conceptual models have been proposed to explain the dynamics of the human colonisation of Europe in this period, but too often they reflect the actual data only loosely or were based selectively on data provided from a specific research field. Complex questions like understanding the dynamics of the early dispersal and, at least, temporary settlement of the continent require multidisciplinary synergic approaches.

Mathematical modelling has revealed itself as an extremely helpful tool to describe complex systems dynamics in other disciplines, but it has been rarely used in terrestrial Quaternary palaeoecology or Palaeolithic archaeology. The METHOD International Focus Group (“Modelling Environmental Dynamics and Hominin Dispersals Around the Mid-Pleistocene Revolution”), funded by INQUA HabCom (1604F), promotes an active collaboration among researchers interested in understanding the dynamics of the first European humans, the specialists with knowledge on the ecological and environmental scenarios and the people with the skill to set up mathematical models, including mathematicians, physicists or engineers with experience in the study of complex systems through mathematical modelling and computer simulations.

Since the MPR was a planetary event, the IFG has a worldwide scope, though it is initially focused on Europe because the quality and quantity of available data are significantly higher for this than for other regions. Europe constitutes an excellent case study to explore the application of quantitative approaches and mathematical modelling in the study of the early human settlement and dispersals.

METHOD organised a number of activities during the 2016-2019 inter-congress period to promote collaboration among researchers and to provide training in specific topics. Main workshops were held in Burgos (2017, 2018), Mauer (2017) and Rome (2019), and Training Labs on the uses of databases and different modeling techniques were organised in Sassari (2016), Frankfurt (2017, 2018) and Burgos (2018). Up to 45 researchers from 10 different countries participated in the activities organised by METHOD during this period.

P-4203

## Early Pleistocene paleo-vegetation maps of the Guadix-Baza Basin (Spain) and plant resource availability for early humans

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### Abstract

The Guadix-Baza Basin is situated in the province of Granada, in South-Eastern Spain. The Early Pleistocene deposits of the Basin contain some of the oldest (around 1.4 Ma) evidences of hominin presence in Western Europe. Taxonomic composition of the Early Pleistocene vegetation is known thanks to pollen analysis of the lacustrine deposits of the Baza sub-basin. The Coexistence Approach (CA) has provided paleoclimatic measurements for different precipitation parameters. The analysis reveals a cyclic climate with phases of different humidity which in turn create cyclical vegetation changes. A humid phase ('interglacial'), with precipitations higher than the modern ones and a dry phase ('glacial'), with precipitations more similar to the ones currently registered in the Basin. During the humid phase, the main vegetation unit of the Basin would be similar to the modern meso- and supra-Mediterranean *Quercus* forests. During the dry phase, the more widespread vegetation unit would be the *Artemisia* steppe. Paleo-vegetation maps for both humid and dry phases are created by extrapolating modern precipitation maps with paleo-precipitation measurements given by the CA method. In these maps the vegetation is divided in different vegetation units which are constrained by precipitation values, much like the modern vegetation units in the modern Guadix-Baza Basin. The potential plant resources for each vegetation unit are extracted from ethnobotanical data. Plant resources are measured as the quantity of edible plant parts from taxa found in the pollen record and the usual taxonomic composition of the modern vegetation units that are considered analogues of the Early Pleistocene ones. The forested vegetation units provide higher amount of plant resources and are more widespread during the humid phases. The steppic vegetation unit occupies the majority of the area during the dry phases. The access of early hominins to edible plant parts was heavily limited during dry phases, although the more productive vegetation units would still be present in areas next to freshwater environments (riparian vegetation unit) and higher altitudes. Early inhabitants of the Basin could have found enough edible plant parts in these units even during the dry phases. These map reconstructions have the potential to be used in simulation approaches, such as agent-based modelling.

**P-4204**

## **A Cognitive Agent Architecture for Simulating Early Human Decision-Making and Knowledge Transfer**

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### **Abstract**

There is a variety of questions concerning human evolution and culture that are difficult to answer based on the archeological record alone, such as: How do energy consumption and energy gain, availability of stone tools and fire for food preparation and preservation, group size and composition impact early human mobility? Additionally, vice versa, how does mobility affect knowledge and cultural transfer between groups? Moreover, which individual and group decisions drive these processes and lead to an evolutionary advantage?

Agent-based modeling and simulation methods can complement classical archeological research by opening up experimentation as a research method to answer the aforementioned questions. However, existing agent-based approaches in archaeology and paleoanthropology fall short of representing the cognitive abilities needed by the modeled humans to use technology for gaining strategic evolutionary advantages. This necessitates agents that use knowledge for individual decision-making and to adopt particular roles for coordinated action in groups. Utilizing knowledge representation, reasoning, and learning techniques from artificial intelligence, it is possible to represent these sophisticated behaviors in simulation models. To this end, we present an extendable agent architecture based on artificial intelligence and cognitive science which allows for simulating knowledge-based processes like planned action for tool manufacturing and hunting as well as cultural exchange.

Our agent architecture is based on the Beliefs-Desires-Intentions (BDI) approach to practical reasoning. It uses mental states to implement goal-directed behavior for representing strategic usage of technology as well as preconditions and effects of activities. An agent has a local state, available actions, perception, and activity selection methods. In its local state, an agent maintains its situational state knowledge (Beliefs), abstract goals (Desires), intended courses of action (Intentions), capabilities (Plans), and goal relevance in the current situation. Such an agent's state knowledge covers the perceived situation of its environment (e.g., food resources, predators, shelter, group members), its goals represent its immediate or long-term needs (e.g., food acquisition, reproduction, protection, knowledge acquisition), and its capabilities model the available strategies to achieve these goals by means of intended activities given its state knowledge (e.g., manufacture a handaxe to increase utilization of food resources).

Moreover, technology usage requires complex interrelations between capabilities which only become available if specific technology or tools are present. Those tools in turn can be acquired using other capabilities. Additionally, activities like hunting are group capabilities which are based on cooperation of several group members fulfilling different roles. These capabilities can also be passed on within a group to enable agents to learn from each other. To achieve this in a simulation, we present strategic agent decision-making mechanisms which evaluate possible worlds in order to anticipate potential future gains from actions without an immediate physical benefit.

P-4205

## Paleoenvironment of the central north Anatolia during the MPT: A possible refuge for large & small mammals?

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### Abstract

Basins formed on the Central North Anatolian Shear Zone (NASZ) preserve well exposed sedimentary successions of various depositional environments providing insights on the paleoenvironment of Anatolia since the late Pliocene throughout the Quaternary.

These records provide evidence for tectonic evolution of this distinct transform fault zone but also provide insights on the paleoenvironment of Anatolia. Bounded by the pontide mountain range to the North, each basin is connected with river network and also the corridor morphology of the NASZ.

Based on the fossil remains of small and large mammals as well as invertebrates collected from the Suluova Basin, the climatic and environmental changes can be inferred throughout the Pleistocene, especially including the formation of a vast paleolake during the MPT (1.7-0.8 Ma). For instance, the giant giraffid *Sivatherium* from the early Pleistocene indicates such palaeoenvironment with grasslands and well-watered humid landscape under control of warmer temperature which is more or less sustained up to late early Biharian (~MNQ20) following the habitat preferences of voles (*Mimomys* cf. *pliocaenicus*) and wood mouse (*Apodemus* cf. *dominans*), in addition to unidentified fish teeth, some freshwater invertebrates (e.g. *Unio* sp., *Pisidium* sp., *Valvata* sp.) as well as some terrestrial molluscs (e.g. *Vallonia* sp?, *Daudebardia* sp. and *Carpathica* sp.; Pupilloidea). Molar remains of *Mammuthus trogontherii* allow us to infer that Suluova has been on the route of the Pleistocene dispersion of mammoths where the paleolake might acted as refugia by providing favourable conditions during the increased aridity of MPT prior to MIS 22.

Following the MPT, the basin and the Suluova Lake was captured from SE part by the Yeşilirmak River. Remains of hamsters (*Mesocricetus brandti*) from the early Toringian, indicates again that Suluova, as the rest of Anatolia in general, plays an important role for the evolution of hamsters during Middle Pleistocene, which is favoured by alternating dry periods and spreading lakes causing steppe-corridors for hamster's dispersals and adaptations.

In conclusion, Suluova Basin can be considered as local, yet one of the most significant regions where faunal and climatic changes can be observed around the evolving paleolake of which shorelines may have played a refugial role during the MPT.

P-4206

## Corridor-barrier function of Palaeo-Dniester Valley facilitated the dispersal of steppe rodent species: the example of Early Pleistocene ground squirrels

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### Abstract

During the Early Pleistocene, two ground squirrel species, *Spermophilus nogaici* (Northern Black and Azov Sea areas) and *S. polonicus* (Central Europe) coexisted in geographically well separated ranges. Studied samples from Tiligul (Ukraine) and Kamyk (Poland) represent early evolutionary stages of these species and have approximately the same biostratigraphical age: early Odessa faunal complex (Tiligul) and Villanyian-Biharian transition (Kamyk).

*S. nogaici* and *S. polonicus* have been analysed and compared by means of occlusal morphology, modular wear facets and mesowear. A significant difference in trophic niches of these species and a high similarity of phylogenetically significant characters has been established. We suggest that *S. polonicus* branched off from *S. nogaici*; the speciation was fast and triggered by the expansion to the northwest.

Here we discuss a palaeogeographic scenario, which could have driven populations of early *S. nogaici* on the edge of the ground squirrel adaptive zone (which always implies open habitats) to give rise to *S. polonicus*. This expansion must have occurred between the FADs of *S. nogaici* and of *S. polonicus*, i.e. within the Tiglian (Beregove) time.

River valleys are broadly known as highways of long-distant expansion of species. Climatic changes amplify the corridor effect of valleys because wet epochs reduced the area of open habitats on watersheds and steppe species became more or less restricted to the valleys, with their floodplains and woodless slopes.

In this way the Middle and Upper Dniester area could provide a steppe corridor between ranges of *S. nogaici* and *S. polonicus*. The Pliocene-Quaternary history of the Dniester includes two stages. The first one is the period of the lateral wandering of the river under the condition of tectonic stability, with large yearly flooded areas, low broad terraces and relatively frequent catastrophic floods. Such conditions facilitated the dispersal of ground squirrels over the Dniester via cutting incised meanders, but were not conducive for an expansion along the valley. In the second stage, the Dniester valley underwent incisions and a transformation into a deep canyon-like valley with well-developed internally-canyon terraces on the inner banks of meanders. Within this stage, barrier functions of the river enhanced. Changes in the corridor function of the Dniester valley for open-habitat species included the appearance of new non-flooded surfaces (positive effect on the expansion of xerophilous species to the northwest) and development of numerous tributaries (negative effect).



The Beregove time, which, for the Middle and Upper Dniester, was a turning point between the meandering and canyon stage, might create a beneficial combination of the landscape characteristics to pave *S. nogaici* the way northwest. Starting uplift and revitalization of karst within Prae-Beregove terraces and the Prut-Dniester watershed created open habitats with necessary for this species xerophilous vegetation.

**P-4207**

## **Spatio-temporal interpolation of paleoclimate data based on $\delta^{18}\text{O}$ climate variability observations**

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### **Abstract**

In this study we present a method that allows to compute paleoclimate datasets for the last 1.2 mio. years in 1ky temporal resolution. The computational model is based on a spatio-temporal interpolation along  $\delta^{18}\text{O}$  measures, to provide a high resolution record of paleoclimate variability, between modeled paleoclimate and current observed climate data. In particular we interpolate temperature and precipitation monthly values between time steps. The interpolated results are evaluated, using different techniques and approaches, against modeled and observed published paleoclimate data sets, based on qualitative and quantitative evaluation methods.

The interpolated climate data, that are 36 layers per interpolated time step of monthly precipitation, minimum temperature and maximum temperature, will be published as open data, to enable and foster reuse of the data for example in the context of paleoenvironmental modeling applications.

The presentation will detail mostly on the development of the interpolation technique and the evaluation of the datasets. It will also give advice for what kind of applications, in terms of scale and scope, this data is suitable and for what kind of applications this data is unsuitable.

P-4208

## Concepts and design of a Multi-Scale Agent-Based Model Simulation on Pleistocene Hominin Migration in Java

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### Abstract

Considered as relatively isolated island, Java has yielded a remarkable record of early hominin fossils, extending back to the Early Pleistocene. Java holds an important role of *Homo erectus* migration as it records the furthest point of an early dispersal out of Africa. The question why and how hominins migrated further to Southeast Asia has been in the centre of the debate of early human expansions beyond the African continent. The migration and dispersal of early humans in Java have been long-studied. Despite of that, the interpretation of early hominin migration in stratigraphic context is not straightforward and has always been challenged by multiple factors. A number of relevant issues promoting the migration are still being questioned. For example: changes in paleogeography, paleoenvironment, vegetation types and their succession, climate parameters, and finally the interpretation of human and animal biology, ecology and behavior. Notably, due to the use of different proxies and divergent interpretation of the stratigraphic records, the reconstruction of migration varies. Thus, the situation cannot simply be resolved or improved by additional empirical data. Instead, an experimental approach is necessary, which allows studying the preconditions, circumstances and effects of the relationships between human behavior, environmental dynamics and glacial / interglacial shifts as well as climate change.

In this study, we use ABM (Agent-Based Modeling) as an approach to reconstruct mobility patterns, migration and dispersal of early hominins into and within Southeast Asia, including the island of Java, by analysing and testing the interaction among human groups and between humans and their respective environments. ABM offers a perfect opportunity to examine the advantages and disadvantages of a variety of scenarios of human migration into and in Java and compare their respective performance through simulation. This study deals with both *Homo erectus* and earliest *Homo sapiens* inhabiting Java during the Pleistocene. We try to formalize agents' attributes of both hominin species, environment patches of Java during the Pleistocene and rules controlling the migration. As a first step, we discuss concepts of migration and respective transfers into an agent-based modelling approach.

**P-4209**

## **A first look at non-pollen palynomorphs from the Llanos de Moxos, Bolivia**

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### **Abstract**

The application of non-pollen palynomorphs (NPPs) in enhancing pollen based landscape reconstructions in the Neotropics is still in its infancy. Here we present the first examination of fungal NPPs from the seasonally inundated forest-savanna of south-western Amazonia. A 1000-year NPP record from Laguna El Cerrito is integrated into an existing pollen and charcoal record providing new insights into past land-use, agriculture and vegetation change within the pre-Columbian raised-field region of the Llanos de Moxos (northern Bolivia). Palynological analysis has shown that fire was used as a common management practice until AD 1300 in a landscape dominated by herbaceous taxa, however, savanna trees and gallery forest did not recolonise the region until after AD 1500. Here we use additional modern NPP analysis of surface lake sediments from across the mosaic landscape of the Llanos de Moxos to refining the interpretation of vegetation structure and composition in the palaeoecological record. Autecological characteristics for NPP morphotypes are speculated upon for types identified from Bolivia. Integrating previously published work from Ecuador and Venezuela we suggest that despite regional differences in environmental and climatic conditions, key morphotypes are frequently encountered across ecological gradients.

**P-4210**

## **Pollen dispersal in traditional processing of buckwheat and its application in agricultural archaeology**

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### **Abstract**

Pollen, as an important index of the paleoenvironment and ancient human agricultural activities, is also one of the significant indicators for research on buckwheat agriculture. In order to test buckwheat pollen dispersal during each crop processing stage, we applied traditional processing simulation experiments of buckwheat crops in a modern village, to collect aerial pollen and perform statistical analysis. The result has shown that the distribution of buckwheat pollen in residential areas is closely related to human processing behaviour. Among all the processing procedures, pollen release rate is highest in the threshing and the sieving stages. The redistribution and burial of pollen during crop processing is an important reason for the prominent increase of crop pollen concentration in the cultural layer. Not only can it indicate the cultivation and processing behaviour of humans but also provide a basis for identifying the crop processing remains in archaeological sites and assessing the intensity of agricultural activities.

**P-4211**

## **Local vegetation patterns in a human-modified environment in the Tianluoshan site, indicated by coprolite analysis**

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### **Abstract**

The Tianluoshan site is located in the Lower Yangtze Region, China and dated back to 7000-5500 cal B.P. in the Late Neolithic Phase. 103 coprolites from the Tianluoshan site were analyzed to explore the palynological and biomarker information.

In biomarker analysis, n-alkanes are dominated by n-C16, n-C17 and n-C18 homologues from microbial input, indicating fecal bacteria existing in the scats of carnivorous or omnivorous animals. n-Alkanols display a strong even-over-odd predominance, with higher abundances of n-C24 and n-C26 alkanols, pointing to grass vegetation. The relatively high abundances of cholesterol, cholestanol and 5 $\alpha$ -stigmasterol in sterols provide strong evidence that most excrements originated from domestic dogs and possible pigs and humans. Higher proportions of plant-derived sterols over animal-derived sterols further imply that the diets of these domestic dogs highly depended on human-derived food.

Compared to traditional pollen analysis of natural sediments, dung pollen spectra have been demonstrated to be the best analogue of local vegetation in previous studies. Thus, pollen and non-pollen palynomorphs analysis of these coprolite samples may present an opportunity to examine the possible human subsistence and microenvironments modified by human activities in the Tianluoshan site.

Two types of vegetation, represented by typical subtropical forest arboreal and herbaceous pollen, as well as shrub and liana pollen, can be distinguished from detrended correspondence analysis of pollen data. The first type of vegetation, together with cereal pollen in the DCA plot, may indicate the large areas of rice cultivation in a wooded zone. Large amounts of entomophilous shrub and liana pollen were first observed in ancient pollen record in the Lower Yangtze Region. This vegetation pattern may indicate either natural plant succession at forest edge after human disturbances or intentional cultivation and maintenance of useful plants in a house garden. Previous macrofossil researches also gave clues of bottle gourd and peach cultivation on the same site, suggesting the presence of garden areas. Under the term "human niche construction", our pollen data supports more diversified human-environment interactions besides rice cultivation, which has been widely discussed before.

In non-pollen palynomorphs analysis, 31 previously undescribed morphotypes were recorded and compared to possible existing types. An inverse relationship of *Cercophora*-type and *Sporormiella*-type in DCA, covarying with tree and shrub pollen respectively, consists with a preference of *Cercophora*-type fungi growing in forest environment in previous research. *Sporormiella*-type, as the most reliable dung indicator in previous studies, shows a correlation with shrub and liana pollen, which may further suggest possible human diets or compost system. Other taxa include aquatic fungi *Savoryella* sp., and pathogen species *Curvularia* sp., *Urocystis* sp., etc.

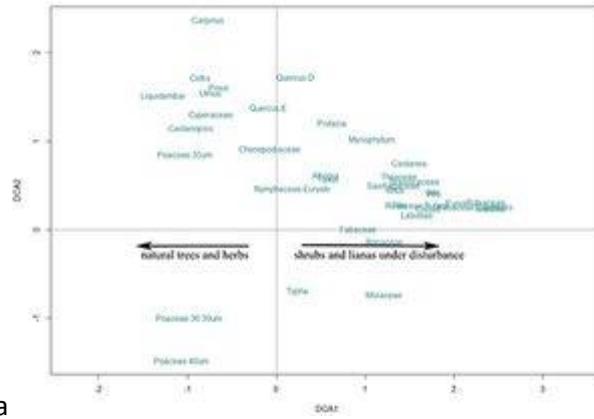
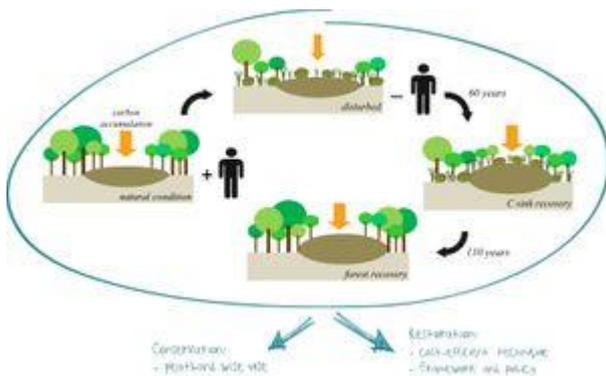


Figure1. DCA plot of pollen data

P-4212

## Resilience of a peatland in Central Sumatra, Indonesia to past anthropogenic disturbance

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Tropical peatlands are important for biodiversity provisioning and carbon (C) storage that are currently threatened mainly by landuse conversions. Conservation and restoration efforts thus are needed to maintain their functions. Nowadays, conservation concepts aiming to segregate human from ecosystems are no longer conceivable. Therefore, understanding peatland response (resistance, recovery or transformation) to human disturbance, can help to integrate human needs in conservation strategies and improve the restoration design. Located close to the archaeological remains of Malayu Empire, Sungai Buluh peatland in Sumatra, Indonesia provides an opportunity to study the resilience of a tropical peatland to human disturbance in the past. We analyzed a 250 cm long peat core for pollen and spores, charcoal and carbon (C) content to delineate the anthropogenic impact to the peatland and the ecosystem's response. The results revealed that extensive human activities in Sungai Buluh that changed the vegetation composition and decreased the peatland's capacity to store carbon started soon after humans occupied the vicinity of the peatland ca. 1000 cal yr BP. Following the site abandonment after the demise of the empire in ca. 600 cal yr BP, the result suggests that the Sungai Buluh peatland recovered in terms of both floristic composition and C sink function with the latter recovered faster (ca. 60 years) than the former (ca. 170 years). The "resilience-friendly" human activities as identified in this study can be used as a blueprint for peatland sustainable use. Additionally, the recovery time of Sungai Buluh hints at the appropriate period allocation for tropical peatland restoration projects.

**P-4213**

## **Sedimentary processes in lake nearshore areas and their interaction with human activity of Palaeolithic and Mesolithic communities in young-glacial landscape**

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### **Abstract**

Geomorphological, pedological and ecological investigations are a necessary component of archaeological studies. These investigations enable the reconstruction of the local palaeoenvironmental conditions of ancient human populations. The analysed archaeological sites of late Palaeolithic and Mesolithic communities (Ludowice, Trzciano and Paliwodzizna) are located in an area of young-glacial landscape in northern-central Poland (Chełmno-Dobrzyń Lakeland and Drwęca River Valley), in the marginal part of large kettle holes, on the surface of sandurs and in tunnel valleys. These landscape features changed dynamically due to climate fluctuations and hydrological network transformations in the Late Glacial and early Holocene.

Geomorphological research made it possible to identify the glacial landforms favourable to late Palaeolithic and Mesolithic settlements. Recognition of the geological structure and reconstruction of sedimentary processes made it possible to identify the type and dynamics of landform transformation in the nearshore zone of former lakes where the archaeological sites of late Palaeolithic and Mesolithic communities were documented. The research involves grain-size distribution analysis of sediments and recognition of their sedimentary environments on the basis of lithofacial analysis. The Ludowice site lies in the marginal part of a large depression where the former lake developed. At this site, three cycles of sediment deposition were distinguished in the lake nearshore zone. Two cycles of sedimentation were associated with the domination of cross-shore littoral transport, and the third with the activation of shoreline erosion and slope denudation. The Trzciano site is located on a sandur surface and in the vicinity of the Wieczno Lake. The results of sedimentological research indicate redeposition of sand and gravel deposits as a result of human activity, and surface sediment wash-off processes. The Paliwodzizna site lies in the northern part of the Grodno Lake tunnel valley, in the littoral zone of a former lake. Investigations of grain-size distributions and the results of lithofacial analysis enabled the reconstruction of littoral zone morphology and lake-level fluctuations that affected the location of late Palaeolithic and Mesolithic settlements.

The geomorphological, pedological, archaeological and ecological analysis performed at the sites located in a young-glacial landscape have demonstrated that sediments layers are mixed as a result of denudation processes, sediment wash-off, wave action and human activity in the area where land, streams, mires and lake all meet. This transitional environment was influenced by the movement and processing of material flowing into the lake from terrestrial runoff and stream connections, which affected the physical and biological processes in the lake onshore zone. The local palaeoenvironment was characterized by changing hydrological conditions due to climate fluctuations during the Late-Glacial/early-Holocene transition, when geological processes developed intensively.

This study was carried out as part of a scientific project financed by the National Science Centre (NCN) in Cracow (Poland), project no. 2016/23/B/HS3/00689.

**P-4214**

## **The dIANA baseline database for the Baltic Sea region**

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### **Abstract**

The north European (paleo)dietary isotopic research has significantly expanded during the last twenty years. As a result, the data are scattered into dozens of publications written in multiple languages, making them laborious to find and use. Here we present the first publicly available compilation of this data, the open access dIANA database (Dietary Isotopic baseline for the Ancient North; <https://www.oasisnorth.org/diana.html>). The dIANA database contains currently mainly animal bone collagen  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  analyses (>1300 samples) and radiocarbon dates but also has a growing number of other types of ancient and modern ecological data, such as fish and plant values. The data have been extracted from over 50 studies published between 2003 and 2019. Temporal range covers the last 57 ka.

Our data examples show existing spatiotemporal isotope patterns related to diet and differences in the environmental carbon sources, and the current status of baseline research and the need for further analyses in the circum-Baltic area. Likely due to demanding soil conditions and the required sample size, archaeological or paleoecological bird and freshwater fish analyses are still underrepresented in the data. In order to significantly improve the situation regarding wild faunal baseline for Fennoscandia and northwest Russia, we analysed a collagen dataset ( $n=81$ ;  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ ) from the Finnish modern zoological collections. These results significantly increase the number of data for North European birds and the amount of Finnish faunal analyses in general.

Our work adds to the body of knowledge of North European spatiotemporal isotopic patterns, which are visible especially in the Baltic seals but also reveals that the selection of animal species and sample numbers in the dIANA data are temporally and geographically skewed. Our results also reveal the areas that are still scarce in data and show the overall need for further scientific datings, invaluable for the understanding of the complexity of dietary patterns. Moreover, accompanied with dietary modellings, the data helps to understand the origin of carbon, relevant in estimating chronological reservoir offsets.

The dIANA database is aimed to support various types of (paleo)ecological, dietary and chronological research in northern Europe. Further development plans include listing the used pretreatment method and expanding the database to contain more isotope systems, and in the future also human data.

Etu-Sihvola, H., Bocherens, H., Drucker, D., Junno, A., Mannermaa, K., Oinonen, M., Uusitalo, J., Arppe, L. The dIANA database – resource for isotopic paleodietary research in the Baltic Sea area. *Journal of Archaeological Science:Reports* (under review)

**P-4215**

## **Investigating the impact of faunal biodiversity on late Neanderthal and early modern human behaviour in Britain**

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Palaeolithic Britain had a highly variable landscape into which Neanderthal and early modern human groups ventured. Climate during the late middle Palaeolithic was characterised by repeated warm and cold events while the upper Palaeolithic was dominated by the rise and fall of the last glacial maximum. As the north western peninsula of Europe, Britain was at the limit of the hunter-gatherer geographical range and the ultimate test for biological and cultural adaptations. Neanderthal and modern human groups came and went during this time, with long episodes of apparent absence. The archaeological record for this period in Britain is sparse and challenged further by the methods of early excavators and difficulties associated with cave stratigraphy.

Through combining biomolecular (ZooMs, stable isotope and radiocarbon) analyses with traditional zooarchaeological studies at Palaeolithic sites in south and west Britain we aim to provide further insight into the ecological plasticity of hominin groups ranging so far from the heartland of their home range. This approach will significantly increase the available data for faunal presence/absence and further understanding of how faunal ecology and migratory behaviour responded to changing environments. Integration of these various streams of archaeological and scientific evidence will test how changes or continuity of faunal biodiversity influenced hunter-gatherer settlement patterns, landscape use, versatility in the landscape and responses to a variable climate. This poster outlines the project rationale, sites under study, methodologies and initial results.

P-4216

## Dynamics of prehistoric settlement regional patterns governed by cultural and environmental factors in the south east Baltic territory (Lithuania)

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### Abstract

Predictive modeling is a very effective tool for disentangling human distributional attributes, whether it is used for cultural heritage management, prediction of new archeological sites or research of human-environment. Thus, we applied this approach to study regional distribution patterns of prehistoric settlements in Lithuania. The goal of the study was to estimate how environmental-confinement and regional niche of settlement locations changed throughout prehistory and correlate it with archeological and environmental data. For this purpose we used time-series study design that divided Lithuanian prehistory into 6 periods. Coordinates of prehistoric settlements were extracted from the digital archeological-site dataset PROLIGIS. A set of 21 GIS and PCA environmental variables was used as an input for the random forest and Generalized Additive Model (GAM) analyses. The problematic nature of archeological and spatial data was approached by using dummy variables (simulated as random fields on the basis of original variables) for null hypothesis tests of variables' importance, as well as by validating results with repeated stratified cross-validation and repeating analysis with only precisely dated settlements. Results revealed that there is a marked difference in settlement distribution patterns and "ecological niches" between Neolithic and Bronze Age, while Stone Age and Metal Age periods display intra-group similarity with some small scale trends. Stone Age settlements are environmentally well-confined and characterized by high spatial clusterization. Whereas, location of Metal Age settlements are hard to predict by variables used and their distribution is close to spatial randomness. Nevertheless, Metal Age models have more reliable null hypothesis test scores. Location of Stone Age settlements is mostly confined by amount of water in a region, distance to flint mines and to the sea, ruggedness of region's landscape, ratio of sand to moraine loam area and region's mean slope length and steepness factor. Whereas, location of Metal Age settlements is mostly confined by amount of water in a region, ruggedness of region's landscape, distance to the sea, average slope steepness and average elevation above channel network in a region. We suggest that the observed large-scale settlement reorganization event that happened in Lithuania between Neolithic and Bronze Age is related to the three major events that happened about that time: 1) massive immigration of steppe people into territory of Lithuania, 2) major spread of agriculture and Neolithic 'package', 3) long-lasting drought climatic event. This research was funded by a grant (No. S-LL-18-2) from the Research Council of Lithuania.

P-4217

## Effects of climate and land use on Holocene vegetation in the Italian Lepontine Alps

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### Abstract

Mountain ecosystems are extremely vulnerable to climate change, and specifically the tree line ecotone is very sensitive to temperature changes. However, besides climate change, land use is an important factor as well in shaping ecosystem properties, vegetation composition and species distribution. Sediment series from high-elevation lakes provide valuable records of the interactions among climate, humans and vegetation. We present a pollen, spore and macrofossil-inferred reconstruction of the Holocene vegetation from Lago Inferiore del Sangiatto (1990 m a.s.l.), a small lake located close to the treeline ecotone of the Ossola region in the Italian Alps (timberline at ca. 2050 m, treeline ca. 2250 m a.s.l. in the Sangiatto area). Archaeological evidence for human presence in the area surrounding Sangiatto goes back as far as the Mesolithic; the important nearby mountain pass Albrun, connecting the Ossola valley (Italy) with the Valais (Switzerland), was intensively used during Roman times.

The sediment record starts at the end of the Late Glacial and spans the entire Holocene. Analyses of pollen and plant macrofossils show that Swiss-stone pine forests (*Pinus cembra*) established at the onset of the Holocene. The composition of the forest slowly changed to a mixed conifer forest, including *Larix decidua* and *Picea abies*. Increasing human impact and land use (e.g. anthropogenic indicators *Plantago lanceolata* and *Cerealia* pollen) around the lake allowed the mass expansion of *Alnus viridis* during the Neolithic.

To reconstruct the natural fire regimes and the impact of anthropogenic fires we analysed micro- and macroscopic charcoal. Anthropogenic fires, used to create pastures for cattle grazing, may have played an important role in the mass expansion of *Alnus viridis* and the change in vegetation composition around the lake, which resulted in today's pure larch forests.

This study is the first to describe the afforestation processes at the start of the Holocene and the impact of land use on the vegetation of this region. Our results provide important information for nature conservation, for instance for the Alpe Devero Natural Park, in which our lake is located. In particular, the long-term ecological record of Sangiatto may help identifying threats to alpine biodiversity under future climate change.

P-4218

## Anthropogenic and natural drivers of vegetation and fire history along the forest-steppe border of the eastern Andes (38-50°S)

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### Abstract

Disentangling anthropogenic and natural drivers of vegetation and fire history at different spatiotemporal scales is a fundamental challenge in Earth Systems science. In the forest-steppe ecotone of southern South America, fire and climate have shaped the position of lower treeline, but the influence of pre-European peoples at the ecotone is less clear. A new 10,800-year history of climate, vegetation, fire, and land use from Laguna Portezuelo (38°S, 71°W, 1730 m elev.), east of the Andes, provides information on pre-European anthropogenic fires in *Araucaria* forest. *Araucaria* was an important resource for pre-Europeans and is ingrained into Mapuche-Pehuenche cultural identity. The pollen record shows that *Araucaria* expanded in the late Holocene with rising human populations and strengthened ENSO. Prior to that, the forest-steppe region supported scattered *Nothofagus* (mostly *N. dombeyi*-type pollen) and moderate-to-high fire activity. Beginning at 6800 cal yr BP, changes in ecotone composition and fire are attributed to increased climate variability and human presence. Increased *Nothofagus* and *Araucaria* pollen and null-to-low fire activity occurred at 1800, 1200, and 800 cal yr BP, in association with increased strength and frequency of wet El Niño events. After 500 cal yr BP, increased abundance of *Plantago*, *Rumex*, and other disturbance taxa (e.g., Apiaceae and Caryophyllaceae) and high fire activity mark Euro-American land use. Non-native *Pinus* pollen in the 20th century indicate the establishment of *Pinus* plantations near Laguna Portezuelo.

Although archaeological investigations suggest that people lived in southern South America east of the Andes since ca. 12,000 cal yr BP, the vegetation and fire history for most of the postglacial period was governed by the strength and position of the SWW storm tracks. From the late-glacial to early Holocene, region-wide increases in fire were associated with aridity while the SWW were weakened and south of their present position. Between 7000-4000 cal yr BP, increased arboreal taxa and decreased fire throughout Patagonia suggest effectively wet conditions, as the SWW moved northward to their present position. After 4000 cal yr BP, a combination of rising human population and greater climate variability, led to spatially heterogeneous but generally rising fire activity along the forest-steppe ecotone. Throughout Patagonia, wet El Niño and/or negative Southern Annual Mode (SAM) events increased biomass, but made the landscape less flammable and reduced anthropogenic burning. Transitions from wet El Niño and/or negative SAM to dry La Niña and/or positive SAM events increased burnable biomass, amplifying anthropogenic burning. During the last 100 years, increased Euro-American settlement and land clearance led to forest loss, more disturbance, and the spread of introduced taxa along the eastern flanks of the Andes. The ecological changes in recent decades far outweigh thousands of years of pre-European human influence on fire and vegetation history.

**P-4219**

## **The change of $\delta^{13}\text{C}$ values in Belizean soil and its implications on Maya agriculture**

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### **Abstract**

The size and extent of the Classic Maya civilization was dependent on the ability to produce sustainable agriculture. The dependence on “rainfall-dependent maize agriculture” would make the Classic Maya people susceptible to drought and other climate variabilities (Hoggarth et al., 2016). In the semitropical Belize Valley, the Maya experienced wet and dry seasons and had to account for each season in their agricultural cultivation (Lucero, 2011). The Maya used diverse cultivation systems including house gardens, terraces, and wetland agriculture systems (raised fields/ditch fields) (Dunning et al. 1998; Fedick 1996). Most of the tropical plants native to the Maya lowlands in Belize use the  $\text{C}_3$  photosynthetic pathway (Webb et al., 2004). Maize is the only known cultivated plant using the  $\text{C}_4$  photosynthetic pathway in this area, indicating that unless the area was previously a grassland, high  $\delta^{13}\text{C}$  values denote the presence of cultivated maize (Lentz, 1999; Tieszen et al., 1993; Webb et al., 2004). Therefore, an identifiable transition in carbon isotope ratios can be used to identify the transition from grassland/forest cover in a region, to agricultural practices focused on growing maize. A preliminary pilot project was undertaken between 2017 and 2018 in which excavations were conducted in the agricultural ditch field system southwest of Baking Pot, Belize. The goal of this project is to determine the climatic conditions and the agricultural use of the ditched field system during Maya occupation at Baking Pot, Belize. Preliminary results from samples collected in 2017 demonstrate an increase in  $\delta^{13}\text{C}$  values between 40-60 cm in Ditch 1 suggesting the introduction of maize. Ditch 1 returns to more negative isotopic values below 60 cm indicating a return to native vegetation. Ditch 2 shows similar results with an increase in  $\delta^{13}\text{C}$  values between 60-100 cm in and a return to native vegetation below 1 meter.

P-4220

## Testing the effectiveness of high-resolution palynological records for investigating human-environment interactions in the Irish Mesolithic.

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### Abstract

Until recently, Mesolithic people were viewed as opportunistic hunter-gatherers who had little control over or impact on their environment whereas Neolithic people were sophisticated agriculturalists, capable of domesticating plants and modifying landscapes through large-scale forest clearance. However, recent interdisciplinary studies from Britain have challenged environmentally deterministic views of Mesolithic people by showing that they were managing and systematically exploiting economically important plants<sup>1</sup>, and creating small-scale woodland clearances<sup>2</sup>.

Ireland's Mesolithic settlers also exploited plants for food, fuel and timber but evidence for woodland management is limited. Also, palynological evidence for anthropogenic clearance is negligible because: (a) research into Mesolithic disturbances has been lacking since the 1980's, (b) clearances were potentially overlooked due to a dearth of high-resolution analyses, and (c) few multi-proxy investigations have targeted Mesolithic sites. Consequently, the human-environment interactions of Ireland's Mesolithic occupants are poorly understood.

This paper presents the results of two new, high-resolution palaeoenvironmental studies of key Irish Mesolithic occupation areas<sup>3</sup>. The first study examines whether the human-environment interactions of the Mesolithic occupants of three sites in County Antrim, Drumakeely, Drumnaglea and Lisnasoo<sup>4</sup>, could be detected in a stand-alone palynological sequence taken from Frosses Bog, within 1 km. of each site. The second study investigates the nature of anthropogenic disturbance at different spatial scales at Derragh Island, County Longford, using published anthracological and archaeobotanical evidence for woodland exploitation<sup>5,6</sup>, and palynological data derived from two on-site sequences and one off-site sequence obtained from 30m away.

When compared, the results: (1) show that proximal multi-pollen and multi-proxy records provide greater insights into the complexities of Mesolithic human-environment relationships than distal, stand-alone pollen records, and (2) highlight the possibilities and limitations of these approaches. This paper emphasises the urgent need for further multi-proxy/interdisciplinary research into the palaeoenvironmental impacts of Mesolithic people on Ireland's post-glacial woodlands. Only when these impacts are understood can the dynamics of Late Quaternary environmental change in Ireland be fully acknowledged.

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P-4221

## A millennium history of river connectivity and anthropogenic disturbances in central China

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### Abstract

Anthropogenic pressure derived from heavy metal pollution, eutrophication and hydrological regulation are known to threaten ecosystem health in many lakes. In the context of millennium-scale climate fluctuation and catchment development, however, little is known about the long-term response of lake biota to the independent impact of multiple stressors. Daye Lake, located in the middle reaches of the Yangtze River, is selected for sediment analyses due to its longest documented history of smelting in central China, as well as its change in connectivity with Yantze River.

Multiple-proxy analyses (e.g.  $^{137}\text{Cs}$  and AMS  $^{14}\text{C}$  dating, lithogenic metals, heavy metals grain size,  $X_{\text{if}}$  and cladocerans) provided a millennium history of metal pollution, hydrological fluctuation and ecosystem changes from a 110-cm long sediment core. The grain size results also showed a gradual increase in water level up to ~60cm, and more recently displayed stronger hydrological fluctuation after ~20cm. Particularly, lithogenic metal and  $X_{\text{if}}$  records show that the catchment development and soil erosion was more intensive prior to ~60 cm and after ~20 cm. While heavy metal input was elevated prior to ~60 cm as observed in previous studies, their concentrations showed a rapid spike after ~20 cm which corresponded well to the severe pollution level of Daye Lake as shown in modern surveys. While TOC and TN results showed a gradual trend of nutrient enrichment before 1950, the process of lake eutrophication has accelerated after 1990s. Accordingly, the cladoceran flux showed a gradual decrease up to ~60 cm, and a clear increase after ~20 cm. Cladoceran assemblages showed a clear replacement of oligotrophic *Bosmina longispina* by *Bosmina longirostris*, prior to ~65cm. After ~1990, *Bosmina longirostris* decreased obviously with a concurrent increase in littoral cladocerans in the context of heavy metal pollution and eutrophication.

**P-4222**

## **Human and environmental dynamics in the crater lakes region of western Uganda during the late Holocene**

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### **Abstract**

A sedimentary record obtained from the marginal sites of a crater lake within an archaeological site provides evidence of human and vegetation dynamics in the crater lakes region of western Uganda during the late Holocene, ca. 4,000 years BP. The last ca. 4,000 - 3000 yr. BP is characterized by a period of forest vegetation cover, indicating a phase of wet and moist environmental conditions in the region mainly dominated by swamp forest vegetation (Palmae) taxa. This phase is also characterized by high levels of diatom taxa, suggesting a period of moist conditions. This period was followed by a phase of reduced forest environment, ca. 3,000 - 2500 yr. BP, mainly contributed by less moist C<sub>4</sub> grasses (Poaceae morphotypes) at the expense of C<sub>3</sub> taxa. This period is also characterized by significant increase in proportions of charcoal records, suggesting a period of increased anthropogenic activities reflected by forest clearance and anthropogenic fires. Diatom records also declined to significantly low levels possibly reflecting a reduction in moist environmental conditions. The last ca. 2,000 yr. BP is characterized by episodes of forest and fire fluctuations indicating evidence of anthropogenic activities in the crater lakes region. Generally, this period is characterized by variable anthropogenic activities reported in archaeological records that suggest a period of increased anthropogenic activities in western Uganda, more specifically the last ca. 1000 yr. BP. Significant increase in charcoal records with reduced forest habitat is evident during this period from the last ca. 1000 yr. BP, suggesting increased anthropogenic fires and forest clearance. The last ca. 200 yr. BP is characterized by significant reduction in forest cover at the expense of grass cover (Poaceae morphotypes) mainly contributed by short C<sub>4</sub> Poaceae morphotypes that indicate less moist environmental condition. Charcoal records are relatively high during this period, indicating episodes of increased anthropogenic forest clearance and fire regimes. Generally the last ca. 1000 yr. BP is a period of transition in western Uganda that began approximately around the 10th century AD with significant social, political and economic changes in the region. This period included the emergence of large sedentary settlements with increased population density and the rise of strong political hierarchies centered at major archaeological sites such as Bigo, Ntusi and Munsa.

P-4223

## Vegetation change and human activities during late Pleistocene-mid Holocene in Chahai region, Liaoning Province, NE China

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### Abstract

Chahai-1 Section, which contains multiple culture layers, provides us the information of human activities and vegetation history from late Pleistocene to middle Holocene in Chahai region, Liaoning Province, northeastern China. Culture layers and AMS14C dating results show that Chahai region had been occupied by humans at 12700~12570 cal BP, 10200~9300 cal a BP and 7200~6300 cal a BP. Fossil pollen results of Chahai-1 Section show a process of increased humidity and the vegetation was converted from shrub grassland to forest grassland before 12700 cal a BP. Then an arid steppe landscape was presented at about 12700~12570 cal a BP, and forest disappeared in this region. The vegetation was dominated by meadow grassland with few trees between 10200 and 6300 cal a BP. A dramatic increase in tree revealed the temperate deciduous broad-leaved forest recovered in this region and then which was converted into sparse-wood grassland or shrub grassland after 6300 cal a BP.

The relation between vegetation and human could be divided into three stages: (1) Rational utilization period: the period between 12600 and 9300 cal a BP, lifestyle was dominated by hunting and gathering, local vegetation was little influenced by human activities. (2) Excessive utilization period: population expansion intensify conflict between resource and human during 7200~6300 cal a BP, lots of trees were felled, which caused an abnormal phenomenon that grassland landscape exhibited in Holocene optimum. (3) Ecological recovery period: accompanied with weakened human activity intensity after 6300 cal a BP, forest recovered in Chahai region rapidly.

P-4224

## Environmental conditions of Neolithic settlement development on the northern edge of Sandomierz Upland (Poland)

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### Abstract

The area of geoarchaeological studies is located on the border between the loess Sandomierz Upland and the sandy-loamy areas of the Iłża Foothills (central Poland). Numerous traces of human activity from the Middle Palaeolithic to modern times have been documented in this area. Detailed research was carried out in the mouth of the Przepaść River to the Kamienna River near Ćmielów. The main objective of the research was to comprehensively reconstruct human settlement and economic activity in the study area in the last ~10,000 years, along with identifying its conditions, both at the chronological-cultural and the environmental level. The greatest emphasis has been placed on the identification of settlement processes during the Neolithic period (6th-3rd millennium BC) as well as their any environmental conditions and consequences in areas beyond the reach of compact loess formations, i.e. within the ecological and landscape regions significantly deviating from the typical settlement preferences of early agricultural communities.

Environmental fieldwork was conducted within and around early Neolithic archaeological sites associated mainly with the settlement of early agricultural communities cultivating the Danubian cultural traditions developed between the 2<sup>nd</sup> half of the 6<sup>th</sup> and the end of the 5<sup>th</sup> millennium BC. In selected archaeological sites, non-invasive geophysical (magnetic) surveys were carried out in the preliminary phase, which revealed the existence of remnants of extensive settlements with permanent residential buildings. This was confirmed by the conducted excavation research, which led to the discovery of the relics of so-called long houses – typical residential constructions of the communities of both mentioned archaeological cultures. GIS analyses and a series of laboratory works, including: lithology, geochemistry and paleobotanical studies complemented the field studies. The spectrum of research has been extended to include radiocarbon dating.

The obtained results of the analysis were used to reconstruct the natural environment for two geomorphologically different and neighbouring regions. A different geomorphological link between the two areas is the valley of the aforementioned rivers dissecting them with a system of different-age terraces, which are rich in geo-archives of human activity in the past. Based on the obtained data, important palaeoenvironmental and cultural periods were determined, referring to the time interval from the Upper Plenivechelian (the Late Palaeolithic), through the complex Holocene (especially the Neolithic), to modern times associated with particularly anthropopressure (including erosion) of the entire study area. The most comprehensive correlation of geoarchaeological results was obtained for the Middle Holocene, and especially the Atlantic period, for which the largest amount of diverse data was collected. These results document the permanent and intensive settlement and economic activity in this period and the associated strong anthropopressure resulting in clear transformations of the local natural environment.

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P-4225

## Radiocarbon of phytolith reveals rice domestication began at about 10,000 years ago

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### Abstract

Rice is one of the world's most important staple foods, sustaining more than half of the global population. Research into when, where, and in what kind of environmental background the rice was domesticated have led to a considerable amount of attention in the last decade.

Rice remains found at the Shangshan site in the Lower Yangtze may represent the first instance of rice cultivation. However, organic materials were poor-preserved at the site because of the acidic soil conditions. So, debate exists as to whether the rice is domesticated, wild, or transitional. The chronology of the Shangshan site was also unclear. Accordingly, further dating initiatives are needed to constrain the absolute-calendar time of the rice remains.

Phytoliths can occlude some organic carbon during their deposition, which is captured through photosynthesis from atmospheric CO<sub>2</sub> during plant growth. Carbon occluded in phytoliths thus can directly reflect the age of the organic sources exploited by humans. We carried out phytolith carbon-14 studies on three archaeological sites from Shangshan culture. The results showed that phytolith dates were consistent with their paired charcoal or seeds dates. Two phytolith dates from the early (upper layer of the eighth cultural stratum) and late stages (upper layer of the fifth cultural stratum) of the site range in age from 9,417-9,134 calibrated years before the present (abbreviated as cal yr BP) to 8,175-8,012 cal yr BP. This suggests that the initial occupation of Shangshan may have occurred at about 9,400 cal yr BP or perhaps somewhat earlier around 10,000 cal yr BP, because phytolith sample SH-8 was retrieved between the seventh and eighth cultural strata of the site.

The detailed studies on rice bulliform phytolith morphological characteristic showed that approximately 36% had more than nine fish-scales in the early occupation stages of Shangshan and Hehuashan (ca. 10000 to 9000 cal yr BP), less than the approximately 60% counted from the late stages of Hehuashan and Huxi (ca. 9000-8500 cal yr BP). However, there was a significantly larger amount of rice bulliforms with more than nine fish-scales in the early stages compared to modern wild rice ( $17.5 \pm 8.3\%$ ), suggesting that the process of rice domestication have begun at Shangshan in the Lower Yangtze of China during the beginning of the Holocene.

Such an age for the beginnings of rice cultivation and domestication would agree with the parallel beginnings of agriculture in other regions of the world during a period of profound environmental change when the Pleistocene was transitioning into the Holocene. Climatic amelioration during these transitional periods may thus serve as key factors in the early process of rice domestication.

P-4226

## A chronological study of wooden columns excavated at the Mawaki archeological site of the Noto Peninsula, central Japan

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### Abstract

The Mawaki site is located on the eastern coast of the Noto Peninsula, central Japan. It consists of alluvial coastal plain with area of about 11 ha. The site was discovered beneath cultivated fields and is located between a hilly terrain and the present day coastal residential area. In 1982 and 1983, an archeologically important discovery occurred owing to farmland consolidation, and many dolphin bones were discovered along with remains of Jomon pottery. Some dolphin bones were radiocarbon dated around 5600 cal BP. This was a very important discovery as regards evidence of past human subsistence strategies. The site represents a village with evidence of habitation from around 6000 to 2400 cal BP. The early part of this period was marked by a Holocene high sea level in Japan. The period corresponds to the Early through Final Jomon periods of the Japanese archaeological timescale. The archeological excavations suggested three important stages of this site: (a) a dolphin bone layer including Jomon pottery fragments as thick as 1 m (6000-5000 cal BP); (b) several tombs of human laid on the wooden plates (5200-4500 cal BP); (c) wooden pillar remains forming a structure of wooden houses and the circular array of wooden columns considered as a special monument (3500-2400 cal BP). In the study of the 3<sup>rd</sup> stage, we have excavated more than 60 pillar remains, in the area of 20 m x 20 m. We have analyzed the species of each tree and found out that the pillars were consisted of two tree species. The 2/3 was Japanese chestnut tree and the remaining 1/3 was hiba arborvitae. Radiocarbon dating all of them suggested that the calibrated ages were from 3500 to 2400 cal BP. The pillars with older ages were mainly hiba arborvitae and younger ones were Japanese chestnuts tree. This trend suggests that ancient people did a selection of tree species for building their houses. Otherwise, hiba arborvitae was growing early period and then chestnut trees became abundant later time, maybe depending on the local environmental change. A unique monument, the circular array of wooden columns made of chestnut trees, located about 30 m north from this area were dated to be about 2800 - 2500 cal BP. The monument was constructed by ancient people lived the place. In addition, as a second example in Japan, a wooden plate (39.1 cm long, 5.5 cm wide, 1.8 cm thick) used as a tool to make fire by friction rotating wooden stick on it was detected in the same area of wooden pillars. The species of the plate was Japanese cedar. It was dated to be 3300 cal BP, consistent with the ages of wooden pillars.

P-4227

## Weichselian Lateglacial environmental and vegetation development in the Moervaart palaeolake area (NW Belgium); implications for former human occupation patterns

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### Abstract

A detailed vegetation and environmental reconstruction for the Weichselian Lateglacial interstadial in the Moervaart area (NW Belgium) is discussed in relation to former human occupation patterns. The reconstruction is based on a multi-disciplinary research carried out on calcareous deposits of one of the largest palaeolakes (~25 km<sup>2</sup>) that existed during the Lateglacial interstadial in NW Europe. The combination of geophysical (magnetic susceptibility, micromorphology, organic matter, calcium carbonate), botanical (pollen, macrofossils, diatoms), zoological (chironomids, molluscs, ostracods) and geochemical analyses (stable carbon and oxygen isotopes) allowed for a highly detailed reconstruction of the lake ecosystem and vegetation surrounding the lake. The chronology of the lake record was provided by radiocarbon dating and comparison with the nearby Rieme sites and regional biostratigraphy.

During the Weichselian Lateglacial (GI-1), as result of climate amelioration, the vegetation and geomorphology of the Moervaart coversand landscape changed from a tundra landscape to boreal forest with initially birch but later also pine. In the Bølling period (GI-1e), the Moervaart palaeolake started to form caused by a major rise of the groundwater table in the area. Waterlevel rise continued during the early Allerød phase (GI-1c) and a rich waterflora and fauna developed in the lake, while in the lake environment birch woodlands expanded. From this period onwards, the area provided a suitable landscape for the *Federmesser* Culture hunter-gatherers with fresh drinking water, extensive and fertile woodlands and lake edges for wild game hunting, plant gathering and fowling. Waterlevels rose to a maximum at the end of the early Allerød. Thereafter, an outlet for the lake was formed in the east. As a result, water levels gradually decreased during the middle to late Allerød and eventually the Moervaart lake turned into a swamp and ceased to exist. In combination with the prevailing colder conditions, this led to a marked population decrease with probably temporary abandonment of the region.

P-4228

## Archaeopedological Investigation of Colluvial Sediments in SW-Germany: Using Multi-Proxy Analyses for the Reconstruction of Bronze Age Land Use Practices

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### Abstract

The project comprises an interdisciplinary approach combining archaeopedological and archaeological methods for the reconstruction of Bronze Age settlement patterns and land use practices in three landscapes in SW-Germany (Hegau, Western Allgäu, Baar), which are different in physical-geographical conditions and archaeological records. Hegau is assessed as favourable and both Western Allgäu and Baar as unfavourable for prehistoric subsistence. However, since favourability is not exclusively a function of natural deterministic conditions, we assume that material and immaterial requirements such as agricultural practices, knowledge, religious and cultural beliefs may have changed through time and space. The presentation focuses on first archaeopedological and archaeological results at the study site Anselfingen (Hegau).

Bronze Age archaeological structures like post holes or fire places and findings like pottery, bones and metals within the settlement and its vicinity are discussed. Hence, based on first <sup>14</sup>C-datings of settlement features and typological analysis, initial conclusions can be drawn about settlement chronology, duration and activity areas.

Archaeopedological data acquisition is based on the analysis of multi-layered colluvial deposits (Zádorová et al., 2018, Henkner et al., 2018, Pietsch and Kühn, 2017). They can be interpreted as the correlative sediments of human-induced soil erosion and as archives to reconstruct land use practices and landscape evolution (Henkner et al., 2017, Leopeold and Völkel, 2007). First chronostratigraphies comprising luminescence dating techniques (OSL), AMS-<sup>14</sup>C radiocarbon datings and typological classification of archaeological findings are presented for the study site. The results from field work provide us with archaeological and archaeopedological assumptions for all three landscape units. Supplemented by pedological data (SOC, pH, CaCO<sub>3</sub>, grain size distribution, pedogenic oxides), phases of geomorphological stability (pedogenesis) and activity (soil erosion) of colluvial deposits will be discussed. Data sets of heavy metals, phosphorus, enzymatic activity (e.g. urease), black carbon and steroids (sterols, stanoles, stanones) are used to decipher human-environment interactions like ore processing, intensified anthropogenic input (waste, dung), fire management and domestication practices in the settlement complex.

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P-4229

## Management and dynamics of vegetation landscapes in the Mayan lowlands: The case of Naachtun's Maya city

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Guatemala's tropical lowlands yield many of the most famous Maya archaeological sites. Today covered by the tropical forest of Petén, the adaptation of Mayan societies to such a closed environment raises many questions for paleoenvironmentalists. The study of vegetation dynamics, in response to climatic and anthropogenic forcing, is particularly complicated due to the absence of bio-proxies such as pollen or charcoal, poorly preserved in this tropical region. Phytoliths offer an important alternative fossil records for landscapes reconstruction in the Maya zone for many reasons: i. They are formed in plant tissues and therefore have a taxonomic signature, ii. Their siliceous nature allows a better preservation in terrestrial sediments. iii. The deposition processes, by in-situ decomposition of the plant, make them excellent local vegetal indicators. Although little studied, they have a great potential for the vegetation dynamics reconstruction, as evidenced by their richness on the Naachtun sediments.

The classic Mayan site of Naachtun (150 BC - 950 BC) is located in the middle of the central lowlands of Petén. It is bordered to the north by a large karstic polje (bajo) recording deposits covering the Mayan settlement period of the city. Using a general approach, this study was conducted on 150 phytolith samples. The preliminary work linking current botanical ecosystems to the phytolith assemblages from current soils was necessary to test the potential of phytoliths in such closed environment. Thus, 40 samples from current forest environments of the Naachtun site and 30 samples from current agricultural fields in the village of Uaxactun were studied to build a modern phytolith reference. Finally, that allowed us to study a hundred fossil samples from the bajo and intra-site deposits of Naachtun territory.

Results indicate than opening of the bajo forests to the preclassic period as supported by the dominance of herbaceous morphotypes (GSCP - Grass Short Cell Phytoliths) and the presence of Cyperaceae and Commelinaceae. This opening of the environment is also found in intra-site soundings where the herbaceous signal is present. The phytoliths in Naachtun deposits also allow us to study the dynamics of the wetland (sival) in the centre of the bajo. The high proportions of Cyperaceae and aquatic bioindicators (molluscs, sponges spicules, diatoms) in the more carbonate layers of the boreholes are witnesses to it. While many hypotheses remain to be tested, particularly concerning agriculture, our study demonstrates the potential of phytoliths in the Maya zone. These observations applied to both in-situ and offsite scale, help to understand the socio-environmental dynamics on a territorial scale.

**P-4230**

## **Size Distribution of Neolithic Sites in the Middle Reaches of the Yangtze River**

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Cultural sites are relics of human activity and they are also the product of the interactions between human and nature. The size of cultural sites could reflect the population size and grade of the ancient settlements. The study of cultural sites could help us to deepen the understanding of the relationships between human and nature. This paper established the spatial database of the Neolithic cultural sites in the middle reaches of Yangtze River from 9000 a BP to 4000 a BP by using ArcGIS software. Overlay analysis and statistical method were employed to examine the spatial relationships between the size of archaeological sites and elevation, slope, the distance to the river in different periods. The results showed that, from the early Neolithic period to the late Neolithic period, the number of sites, the size of sites and the spatial distribution range of the sites showed an increasing or expanding trend, and the proportion of overlapping sites increased; Sites with different sizes generally had low altitude, gentle terrain and near river selection tendency. For sites of the late Neolithic Age, while there existed the above-mentioned selection tendency, the selection of altitude, slope and the distance to river tended to show the characteristics of diversification. There were some differences in location selection of Neolithic cultural sites with different sizes in the late Neolithic period. Small sites were mostly located on the gentle slope of 6-15 degrees. The large or medium-sized sites tended to be distributed on the flat land with a slope of 2-6 degrees; From small to large sites, Neolithic sites was dominated by an elevation of 30-50 m. The elevation of super sites was mainly in a range from 50 m to 100 m. The super sites were located in the area less than 1 km far from the river; The Neolithic culture was greatly influenced by the natural factors such as climate, water resources and topography in the early and middle Neolithic Age, and the adaptation ability of culture in the late Neolithic period was gradually enhanced.

**P-4231**

## **Human-environmental interactions during the Early Holocene in the central region of Eastern Iberia: settlement dynamics and foraging adaptations**

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Understanding the variable impacts of Early Holocene climatic and environmental shifts on prehistoric hunter-gatherers is often challenged by the paucity of integrated research programs analyzing human and climatic systems.

In this paper we present a synthesis of an interdisciplinary research program to study human-environmental interactions along the Early Holocene in the central region of Eastern Iberia. This sub-regional unit provides a unique opportunity to examine the effects of the postglacial sea level rise, expansion of forests and aridity events on human subsistence and mobility strategies.

Within this region, two different local units -located in the coastal and inland extremes of a regional settlement network- have been investigated producing primary paleoecological and archaeological data from Mesolithic human settlement areas: the Pego-Oliva marsh, in the south of the Valencian Gulf, and the Upper Vinalopó Valley, 90 km away inland. The analyzed palaeoecological records provide robust evidence of significant environmental transformations, in both coastal and inland locations, along the Early and Late Mesolithic periods.

In the Pego-Oliva marsh, the inland migration of the coastline was associated to the progressive disappearance of coastal plains and the dramatic contraction of lagoon biotopes. Zooarchaeological and bioarchaeological records show a decrease on shellfish productivity, species diversity of game and shifts in human paleodiets, particularly with a decreasing contribution of marine-origin proteins. These transformations on subsistence patterns seem to be driven by a dramatic drop in environmental carrying capacity, prompting a change in the occupation strategies of this area during the Late Mesolithic.

In the Upper Vinalopó Valley, the multi-proxy analysis of two lake records show the progressive expansion of evergreen and deciduous *Quercus* woodlands during the Preboreal, as well as recurrent events of aridity affecting the palaeo-hydrological budget. This pattern of recursive aridity events is interrupted during the Boreal chrono-zone when the archaeological radiocarbon records clearly reflect an increase of human activity in Early Mesolithic residential camps. Finally, the 8.2 kya event is clearly identified in both lake records and archaeological stratigraphic sequences signaling a short period of increasing aridity and hypersaline lake conditions.

The observed transformations are consistent with the settlement and population dynamics at regional scale, reflecting a dramatic drop in the number open-air residential sites and the radiocarbon activity signals during the 8.2 kya climatic event.

P-4232

## Use of GIS technology for the analysis of Prehispanic settlement patterns in the Holocene Paraná Delta (Argentina)

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The research of Prehispanic cultures in the Paraná Delta (PD), a system that evolved after the mid-Holocene sea-level high stand (17.400 km<sup>2</sup>), has received a recent increase. More than 90 archaeological sites were registered, being in different study stages. Their economy was predominantly hunter-gather-fisher type, with high territorial mobility. The study scale used in archaeological investigations is spatially restricted and doesn't allow a good overview of the relationship established between those settlements and the landscape all over the PD. The analysis of the areal distribution of settlements indicates a significant geomorphological control. Archaeological and geological data were used to elaborate a geo-archaeological map for understanding the complex relationships between the population dynamic along the Holocene PD and the paleoenvironmental conditions. The methodology employed was the use of free GIS software (QGIS, GRASS) and satellite images, with field control, also chronological data obtained by others authors in some landforms of the Holocene PD were considered. Most of human settlements are found on fluvial levees, over which mounds of complex stratigraphy were in general anthropically built, and partially modified by river flooding. Those settlements tend to concentrate at the upper and lower parts of the Holocene PD. This pattern could be related to the geomorphological characteristics of the delta and the associated dynamic, or/and to the present-day anthropic activity that had not allowed the recognition of archaeological sites at the middle part of it (wave-dominated growth stage of the PD). At the lower part, most of the sites concentrate where the anthropic activity has recently increased, few of them are found on the Tidal plain and the Distal zone with cheniers geomorphological units (middle-lower part of the PD). In the upper part of the Holocene PD (fluvial-dominated growth stage with inter-distributary bays), sites distributed on fluvial landforms. Few sites are found at the mid-Holocene Beach ridges geomorphological unit (wave-dominated part of the PD), even though local people refer some archaeological findings. The first populations settled between 2.0 and 1.7 ka. BP, after that the settlements diversified along the PD. The oldest found settlements are on the Tidal plain geomorphological unit, at the middle part of the PD. Moderate wind to windy environmental conditions were deduced from geomorphological indicators for that period. After 1.7 ka. BP, the PD developed its lower part (fluvial-dominated). Warmer and less windy conditions allowed human occupation of the lower delta plain, and its dispersion through the entire delta system. The study scale of geoarchaeology allows to collect valuable data for the archaeological record, especially when there are many human settlements in a very dynamic landscape such as the PD. This work can contribute to a better understanding of groups organization and their relationships with the landscape.

P-4233

## Human-environment interactions in northeast Iceland: the impact of baseline environmental conditions on post-settlement system responses

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The impact of a forcing mechanism on a system may be affected by the system's baseline conditions, and in pristine and unsettled environments these baseline conditions will in large part be controlled by long-term climatic conditions. Perturbations can be caused by natural processes such as climatic deterioration and tephra fall, and human activity such as deforestation, burning, and grazing by domesticated animals. Increasing elevation and decreasing temperature may increase the vulnerability of a system to change, and this is particularly important in marginal areas where organisms exist close to their ecological limits. Settlement in such marginal environments can be risky and unsustainable, and understanding the responses of these environments to interacting natural drivers and human activities presents a challenge in palaeoenvironmental reconstructions. Comparative studies with sites at varying distances from a margin can provide insights into these issues, but such comparisons are often hindered by chronostratigraphic uncertainties.

Iceland presents a well-controlled environment in which to develop understanding of human impacts on environments over large spatial scales. Precisely dated tephra layers allow the construction of robust chronologies with smaller uncertainties than other dating techniques and provide isochrons that permit chronostratigraphic correlation of sequences across large areas. This allows inter-site comparisons to be made with enhanced confidence. The late settlement in the late AD 9th Century provides a long-term, human-free baseline against which to compare subsequent changes. The relatively simple subarctic flora, with only *Betula pubescens* forming significant woodlands, permits past vegetation and land-use to be inferred relatively straight-forwardly. Finally, the Norse settlers imposed a system of land-use developed in other regions, introducing grazing herbivores to Iceland for the first time. This marked a significant change in the pressures on local ecosystems. Overall, Iceland presents a case study for the rapid introduction of human pressures on an environment that to that point had developed in isolation from human activity. It should preserve significant anthropogenic signals in both terrestrial and lacustrine systems that may be relevant to understanding human activity in regions with more complex settlement histories and more diverse ecosystem responses.

This paper presents palaeoenvironmental reconstructions from five lakes distributed along a 30 km transect spanning a 350 m elevation range in Mývatnssveit, northeast Iceland. Multiproxy data, including pollen, non-pollen palynomorph and carbon:nitrogen ratio data, are used to develop understanding of baseline pre-settlement vegetation and lake systems and changes to these upon settlement. These reconstructions are then compared on a regional scale to test the hypothesis that more marginal upland sites were more susceptible to human-induced change. This study develops one of the densest networks of palaeoenvironmental reconstructions in the North Atlantic region and significantly enhances knowledge of the complexity of regional landscape responses to the onset of human activity.

P-4234

## Environmental evolution of the Murgab delta as an important factor of Bronze age population dynamics (Margiana civilization)

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A huge necropolis, dating back to the III Millennium BC, was found in the Mary oasis (Turkmenistan) during the Margian archaeological expedition under the leadership of V. I. Sarianidi in 1972. The monumental cult complex, excavated at Gonur Depe settlement, was a large regional Zoroastrian center in Margiana. The complex was located on a low hill on the right Bank of the Murgab riverbed. It was a capital city, with the Palace and several temples, able to compete with the buildings of Assyria and Babylon. It is the largest settlement in Margiana. The area of the ancient settlement ranges from 20 to 50 hectares. The Temple city existed until the end of the XVI century BC. Its Central part is the Kremlin with a Palace in the center, which is surrounded by walls with rectangular towers. The earliest of the famous Temples of Fire was built outside these walls on the East-side. The system of two basins, the main of which has a size of 100 to 60 m was adjoined from the South to the walls of the settlement. Almost all the authors agree that the important factors determining the historical processes in the III-II thousand. B.C., are natural and demographic: intense aridization in the middle of the III Millennium B.C. (including that caused by believed intensive farming), and high population density in the "Crescent of fertility", formed as a result of the Neolithic revolution (Bar-Matthews et al, 1997; Gibbons, 1993; et al). This situation definitely influenced the increase in mobility of the population, called it a significant move. These processes have not been fully studied in Turkmenistan. A special place in understanding, in particular, the possibilities of extensive migrations from the Eurasian steppes to the southern agricultural areas, takes information about the hydrological regime of large rivers in the region. We have analyzed the space images of the Murghab Delta, performed a field geomorphological study of ancient channels. Highlighted the main pagliarulo, located to the West of the settlement from which in ancient times there was a canal to a large receiving pool. Apparently, the desolation of Gonur-Depe is associated with the development and movement of this channel to the West by 15 km. New data on the morphology and age of development of the Gonur-Depe paleorusel system will give a new look at the history of the Margiana civilization.

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P-4235

## Reconstructing human-induced fire from archaeological sites of Belan valley, north-central India

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Fire disturbance appears to be one of the vital processes in shaping vegetation composition and landscape dynamics of an area. It is an important driver of ecosystem structure, in close association with environmental conditions. Environmental factors, as well as human, can equally induce the fire at the stand. Untying the natural and anthropogenic factors is important to comprehend the paleoclimatic conditions at a regional and global scale. Therefore, identifying the fire events from archaeological sites would provide an opportunity to decode its cause and impact on the terrestrial environment. Hence, the present study is conducted on middle Paleolithic to Neolithic archaeological sites preserved in alluvial soils of Belan valley, north-central India.

In this study, 48 paleosols sampled from six archaeological sites of Belan River. Paleosols were analyzed for *n*-alkane distribution pattern and micro-charcoal as a paleofire proxy. To understand the fire-vegetation linkage,  $d^{13}C_{C29}$  of *n*-alkanes has also been measured. The *n*-alkane distribution pattern, carbon preference index ( $CPI_{25-33}$ ) and average chain length ( $ACL_{15-33}$ ) helps in delineate the source apportionment of organic matter (OM) in the alluvial soils which suggest a dominant contribution from terrestrial plants. Three samples of lower  $CPI_{25-33}$  (~1.0) and  $ACL_{15-33}$  (~23.0) observed which suggest enhanced degradation of OM. The lower  $CPI_{25-33}$  sample shows a particular predominance of mid to short-chain even-numbered carbon (maximum at *n*-C<sub>16</sub> or *n*-C<sub>18</sub>) which was also observed in the previous study from the archaeological site (Eckmeier et al., 2009). Additionally, micro-charcoal analyses in paleosols (n=48) were performed. The degraded paleosols exhibit micro-charcoals which endorse its exposure to fire. However, micro-charcoal concentration peaked at ~8 ka BP. Hence, the paleofire observed in the Belan valley at i) ~97 ka BP, ii) ~58 ka BP, iii) ~26 ka BP and iv) ~8 ka BP. The  $d^{13}C_{C29}$  of *n*-alkanes showed the dominance of grassland between ~30 to ~25 ka BP with the cool and dry environment due to Large Glacial Maximum (LGM) which was favorable for wildfires. Further, the fire event at ~26 ka BP temporarily overlaps with Mahagara and Koldihwa archaeological site. The absence of any major sign of thermal alteration of paleosols (supported by *n*-alkanes) in Koldihwa and Mahagara indicates the local nature of the paleofire events. Therefore, the present study observation of paleofire events was mostly induced by hominin groups living in the Belan valley. The fire disturbance increases in the early Holocene to mid-Holocene overlaps with the timing of domestication of agriculture in the Belan valley.

E. Eckmeier., GLB.Wiesenberg., 2009. Short-chain *n*-alkanes (C<sub>16</sub>-C<sub>20</sub>) in ancient soil are useful molecular markers for prehistoric biomass burning. *Journal of Archaeological Science*, 36, 7, 1590-1596.

P-4236

## Sex-specific protein markers as a tool for exploring animal population structure and dynamics

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Faunal remains hold a wealth of information and can provide important insights into animal populations from the past. In order to study population structures and changes, faunal assemblages need to provide key pieces of information: species ID, sex and age at death. Age can be determined through traditional morphological methods, while species ID and sex can be more problematic as they rely on certain elements of the skeleton surviving and being associated with other morphologically identifiable parts. Analytical methods can be applied to these faunal assemblages to help provide species identification and sex, allowing information about population structure and diversity over a variety of time periods and environments. For example, ancient DNA (aDNA) analysis can be applied to provide both identification and sex information, but it is dependent on the level of molecular preservation, which is greatly influenced by age and environmental factors. Zooarchaeology by mass spectrometry (ZooMS) can provide good species distinction based on the more stable proteins in cases where aDNA preservation is poor; however the sex of an animal can not currently be identified. ZooMS is also a relatively rapid and inexpensive testing method allowing larger collections and assemblages to be analysed.

The goal of this research is to further develop a method of sex identification based on current proteomic methods applying nanoflow-liquid chromatography coupled with tandem mass spectrometry (nanoLC-MS/MS) to large assemblages of ancient teeth. Enamel, which commonly survives in archaeological sites, contains low concentrations of endogenous protein. One of the proteins present is amelogenin, which is expressed from genes on both the X and Y chromosome. The peptide sequences expressed differ between these genes, and therefore could be used as a possible indicator of sex. Through a combination of amino acid composition, racemisation and proteomic analysis of modern and subfossil tooth enamel, we are going to explore the preservation of sex-specific sequence differences to provide an alternative method for sex identification. This method, coupled with ZooMS and morphological analysis could result in the age, species and sex of an individual being identifiable from one single tooth. The potential of this method is that it will allow the rich faunal assemblages from palaeontological and archaeological deposits to yield more detailed information about mammalian population structure. This will allow better interrogation of the responses of ecosystems to human occupancy (particularly with respect to domestication and migration).

**P-4237**

## **Carbon source and production rate influence carbon sequestration in Rostherne Mere**

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We explored the roles of phytoplankton production, carbon source, and human activity on carbon accumulation in a eutrophic lake to understand how catchment management can influence carbon sequestration in lake sediments. Water samples were analysed to investigate contemporary carbon sources.  $\Delta^{14}\text{C}$  measurements from dissolved organic carbon indicated a terrestrial source linked with roadway construction in the catchment. We used multiple proxies to determine production rates and carbon sources in a 55 cm sediment core from Rostherne Mere ((RM), UK). Alterations to net primary production were linked with nutrient input from sewage treatment works in the catchment. Stepped combustion radiocarbon was used to separate carbon fractions by sequentially combusting the sample at 400°C and 850°C and collecting the  $\text{CO}_2$  after each combustion. This method identified that RM sediment comprised between 11% and 69% recalcitrant carbon in the depths analysed, with changes in carbon character coinciding with peaks of accumulation rate. The quantity of autochthonous carbon buried was related to diatom biovolume accumulation rate (DBAR) and decreased when diatom accumulation rate and valve size declined, despite an overall increase in net carbon burial. High performance liquid chromatography pigment analysis indicated that the changes in diatom accumulation were related to proliferation of non-siliceous algae. We found that total algal accumulation rate controlled sediment organic carbon accumulation rate while DBAR was correlated with how much of each carbon source was buried.

To further delineate carbon sources in the lake, sediment samples will be analysed in the new Ramped Pyrolysis/Combustion facility in the <sup>14</sup>CHRONO Centre in Queen's University Belfast. Ramped Pyrolysis (RP) is a technique that incrementally heats a sample, and allows for collection of the  $\text{CO}_2$  produced for isotopic and radiocarbon analyses.  $\text{CO}_2$  is produced from sediment according to the degradative properties of the sample analysed as temperatures increase. RM sediment will undergo this method and  $\text{CO}_2$  will be collected from multiple fractions as  $\text{CO}_2$  peaks are identified. Labile and recalcitrant carbon identified with stepped combustion can be attributed to multiple autochthonous or allochthonous sources using RP. Water DOC and POC will also undergo RP to distinguish contemporary carbon sources in the lake.

P-4238

### The diatom-inferred pH reconstructions for an alpine lake in the Tatra Mountains using two different training sets

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The reconstruction of water pH based on diatom communities (diatom-inferred pH; DI-pH) for Przedni Staw Polski (PSP) was performed using AL:PE training set and the Polish-Slovak training set (POL\_SLOV). A modern AL:PE diatom pH calibration dataset consists of diatom data together with water environment parameters from 118 high-latitude or high-altitude lakes in the Alps, Norway, Spain, Svalbard, Kola Peninsula, Slovak, Poland, Slovenia, Portugal and UK. The POL\_SLOV training set consists of data from 11 lakes located in the Polish part of the Tatra Mts. and 22 lakes located in the Slovak part of the Tatra Mts. To reconstruct of the water pH in PSP was used the weighted average method (WA) with the inverse deshinking, as this method gave the highest squared correlation between inferred and observed values ( $R^2$ ) and the lowest root mean squared error for the training sets (apparent RMSE). The WA pH-inference model based on AL:PE dataset gave  $R^2$  of 0.78 and RMSE of 0.36 units pH. However, for the POL\_SLOV training set these parameters of reconstruction were better to compare with AL:PE dataset;  $R^2$  equaled 0.94 and RMSE – 0.16 units pH. Fossil diatom flora from PSP is well represented in the modern POL\_SLOV training set: the species that occurred in both the fossil samples and the training set varied between 93.5 and 100 %. The values of DI-pH based on AL:PE dataset were wider range (DI-pH = 6.69-7.07) than based on the POL\_SLOV dataset (DI-pH = 6.65-7.28). General trend of the pH curves is similar with the exception of period since the end of the 1960s to today. In this time, PSP was dominated by planktonic *Discostella pseudostelligera* (Hustedt) Houk & Klee and *Fragilaria nanana* Lange-Bertalot. The reconstruction of water pH based on AL:PE training set indicates decreasing trend in contrast to curve of pH performed using POL\_SLOV dataset. Probably, it is an effect of big differences in frequency of some diatoms in the modern training set and fossil samples. In AL:PE dataset, the maximal frequency of *Discostella pseudostelligera* and *Fragilaria nanana* amounted to 3.7 and 3.4 %, respectively, while in the sediments of PSP these diatoms occurred at between 52 to above 28 %. The maximum frequency of both diatom species noted in POL\_SLOV dataset was approximately 50 %. For that reason the values of DI-pH based on AL:PE training set should be treated with caution (worse fit between modern and fossil diatoms).

**P-4239**

## **Regional scale synthesis to separate human impacts from variability – floodplain lakes of the River Murray, Australia**

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Sediment records have been extracted from over fifty floodplain and coastal lakes down the length of the Murray River. The sequences from several lakes extend for 1000 -5000 years suggesting that they were inundated permanently through that time. These largely comprise large oxbow lakes located towards the humid uplands or near the confluence of large rivers, or coastal lakes and lagoons. The records of most others extend only to ~ 200 years or even as recently as since the onset of water resource development which had commenced by the 1890s.

The long records provide evidence of the historical range of conditions experienced by the more permanent floodplain lakes before the arrival of European settlers. Upland sites were perennially fresh supporting rich communities of aquatic plants while others in the lowlands experienced episodes of salinity as well as close connection with the River likely in response to a variable climate. The climate also mediated the balance between tidal and river waters in the coastal lakes near the River mouth. In general, sedimentation rates were low and there is little or no evidence for eutrophication or acidification despite the floodplain and its resources being utilised, and even managed, by first peoples.

Floodplain lake sequences pose particular challenges for radiometric and other dating and so the identification of the first point of impact by European settlers remains unclear. In Australia however, the relatively late settlement by technologically rich European cultures saw abrupt, substantial and extensive changes to rivers and their catchments and these are evident in lake records. Sedimentation rates increased universally on account of forest clearance and intensive grazing, but also owing to the mobilisation of many million cubic metres of topsoil during the goldrush times in Victoria and NSW. The impact of the mobilisation of fine clays included increased turbidity and the release of nutrients into water columns, both of which likely played important roles in the collapse of aquatic plant communities.

The diatom-inferred state of all wetlands is currently outside their long term ecological character attesting to the pervasive impact of European catchment development and hydrological change on the lake ecosystems. That some wetlands responded soon after settlement, yet others responded much later, suggests a variable resilience to the catchment-scale drivers of change owing to lake morphology and hydrological setting. Here, naturally variable lakes may have been able to resist the impact of the increased flux of sediments, at least until the regulation of flow and shift to permanence from a natural wet-dry regime reduced their capacity to reset ecologically.

P-4240

## 6600 years of human impact on lake-catchment and vegetation at Lake Bohinj (Julian Alps, Slovenia)

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The Holocene vegetation history and sedimentary processes in the catchment area of Lake Bohinj (Julian Alps, Slovenia) were investigated in order to better understand the impact of people (agriculture, grazing and mining) on the environment, and climate-human interactions. A multi-proxy study of a 12-m-long sedimentary core which was collected in central part of the Lake Bohinj basin included mineralogical, sedimentological, geochemical, stable isotope ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ), and pollen analyses to reconstruct environmental changes in the last 6600 years.

Sedimentological research (Rapuc et al. 2018) identified 29 homogenite-type deposits related to earthquakes, including a major seismic event at  $6617 \pm 94$  cal. BP (4.4–10 m) that partially reworked previously deposited sediment. Therefore, a detailed palaeoenvironmental reconstruction was performed only for the top 4.4 m of the core (i.e. the last 6600 years).

The results of palynological research suggest that at ca. 6000 cal. BP Lake Bohinj was surrounded by mixed forest (*Picea*, *Abies*, *Quercus* and *Fagus*, which became dominant after ca. 3300 cal. BP). In the Bronze and especially the Iron Ages (3500–2500 cal BP), when the region was densely populated, a substantial clearing of forests due to metallurgical activities, agriculture and livestock production (*Cerealia* t. pollen, *Plantago l.*, decline of *Abies*), was detected. These probably triggered soil erosion and faster sedimentation rates. In the subsequent centuries human impact on the environment continued (increased), but it seems that the watershed was not destabilised again. Several periods of high terrigenous input were recorded (6100–6000, 5700–5550, 5000–4600, 3900, 3700–3550, 2300–2200 cal. BP) with a different mineralogical and geochemical composition of the sediment (high content of quartz and illite, K,  $\delta^{13}\text{C}$ , *Fagus*, and low pollen concentration). These events could be associated with a mobilisation of inflow from the eastern, flysch bearing catchment due to river migration during periods of wetter climate.

**P-4241**

## **Carbon burial variability in high altitude Pyrenean Lakes during the last two millennia**

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Lakes are a central component of the carbon cycle and several paleolimnological studies have shown organic carbon burial rate increases during the last century, although, the rates and controls on OC burial by lakes remain uncertain, as do the possible effects of future global change processes. We used short sediment cores from eight high altitude lakes along a West - East transect in the Pyrenees to reconstruct the OC production and preservation during the last two millennia. Several sediment cores from the lakes - Acherito, La Sierra, Sabocos, Marboré, Urdiceto, Basa de la Mora, Cregüeña and Montmalús - were retrieved to characterize the depositional environments. The cores were dated with <sup>210</sup>Pb, <sup>137</sup>Cs and <sup>14</sup>C techniques, sedimentologically described and analyzed for textural, mineralogical and geochemical properties, including TOC, TN, TS, XRF scanner,  $\delta^{13}\text{C}$ , and  $\delta^{15}\text{N}$ . Sediment traps were deployed and limnological parameters (temperature, pH, conductivity, oxygen content) were measured in mid Summer and early Autumn. The drainage network, geology, geomorphology and soils of the watersheds were characterized from available information and field surveys. Climate variability during the last millennia in the Pyrenees was summarized from instrumental data and available regional reconstructions.

Sediment traps data show that recent sediment fluxes range between 16 and 400 g/m<sup>2</sup>/yr. The TOC content in the lake sequences ranges between 1 and 13 %. Sediment trap samples show lower C/N and  $\delta^{13}\text{C}$  than surface and core sediment samples. Relatively high C/N ratios suggest a significant contribution of terrestrial carbon, even in lakes located at high altitude with watersheds almost devoid of soils, likely due to the low bioproductivity in these settings. Most lakes show changes in carbon dynamics associated to the Roman period, the Medieval Ages, the Little Ice Age and the Current Global Warming, with higher carbon accumulation in the sediments during warmer phases and higher clastic sediment input during colder periods with increased glacial activity. During the last decades, higher TOC and Br/Ti, lower  $\delta^{13}\text{C}$  and C/N suggest an increase in carbon accumulation in most sites. The  $\delta^{15}\text{N}$  signatures show a large variability likely controlled by site-specific limnological parameters: several lakes show a decreasing trend, others have a smaller variability, but lower  $\delta^{15}\text{N}$  during the recent decades that could indicate an increase in atmospheric deposition of reactive nitrogen due to human activities in the valleys. The effects of damming are clear in Urdiceto Lake as finer, relatively more organic sediments dominate since 1930s. Climate change seems to be the main responsible of increasing carbon deposition fluxes during the last two millennia. However, recent trends in carbon accumulation could also have been favored by higher productivity as fluxes from anthropically-derived nutrient have increased even in these high altitude settings.

P-4242

## Ecological regime shifts of shallow lakes in the middle and lower Yangtze floodplain under coupled natural and human disturbance

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Global lake systems have undergone rapid degradation over the past century. Scientists and managers are struggling to manage the highly degraded lake systems to cope with escalating anthropogenic pressures. Improved knowledge of how lakes and social systems co-evolved up to the present is vital for understanding, modeling, and anticipating the current and future ecological status of lakes. Here, we showcase the long-term ecological dynamics of >10 shallow floodplain lakes in the middle and lower reaches of Yangtze River (China), which evidenced by monitoring records and using a multi-proxy palaeolimnological approach to statistically analyse time series. Records on water quality and ecological structure over the past five decades from four typical lakes (Taihu Lake, Poyang Lake, Donghu Lake and Honghu Lake) illustrated the type and magnitude of such changes. Palaeolimnological record from ten lakes in Yangtze floodplain exhibited two rapid shifts occurred in synchrony during the 1950s and 1980s, suggesting common large-scale extrinsic drivers (hydrological modification and nutrient enrichment). However, significant discrepancy on the time and rate of shifts was found among different biological communities (e.g. diatom, chironomid and cladocera) and different lake types (geographical background or ecological type). This inconsistent response pattern, even exist in a single lake (different basins), reflects the intrinsic ecological process may vary due to the different resilience and ecological mechanisms. Understanding the drivers and mechanisms leading to regime shifts is crucial for developing ecosystem-based management strategies and establishing early-warning systems to avoid catastrophic ecosystem changes.

**P-4243**

## **Recent history of anthropogenic metals accumulation in NE China lake sediments**

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Cores (15 to 40 cm of depth) were collected from 11 lakes of the Songnen Plain in northeastern China to reconstruct changes in potentially harmful trace element (PHTe) inputs as tracers of human activities. In each profile, most PHTe enrichment factors do not differ significantly from the pre-industrial values ( $EF < 1.5$ ), except for Cd ( $EF = 2-5.5$ ). This shows that detrital material accounts for a large part of the PHTe supply to the Songnen Plain lakes. Radiometric dating of the cores ( $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$ ) showed that Cd contamination started from the mid-20th century and sharply increased in the 1980s', a pattern that matches the rapid economic and industrial growth of China. Comparison with other records in China suggests that a large part of the anthropogenic Cd in these lakes is likely local in origin. Although the Cd inputs, controlled by carbonate minerals, probably originated from a combination of sources, an intensification in agricultural practices, through the use of chemical fertilizers, manure and wastewater would explain these discrepancies between records. These findings highlight the importance of local factors on the Cd geochemical cycle in China. The large anthropogenic component of the Cd inventory compared to other PHTes (Cu, Ni, Pb, Sb, V, Zn) and its high toxicity indicate that it should be prioritized in future environmental management.

**P-4244**

## **Recent eutrophication and deposition of varved sediments in lakes: case study of Lake Dubie in northwestern Poland**

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Recent environment history is profoundly affected by human activity and climate change. Land-use changes such as deforestations, agriculture development, and higher nutrient inputs are affecting biological, chemical and physical processes in lakes. Most commonly, these changes lead to eutrophication and oxygen depletion in the bottom waters. What is more, current climate change induces stronger thermal stratification of lakes, making them more suitable for the formation of laminated sediments.

In our study, we analyzed a 1 m-long topmost sediment core from Lake Dubie (northwestern Poland). The lake is relatively small (12.5 ha) and deep (27.5 m). Its catchment land-use is characterized by mixed forest and agriculture. The sediment core shows a significant change from homogenous to laminated structure. In order to identify the timing and reasons of this change, we performed detailed investigation of geochemical composition ( $\mu$ XRF) and biological proxies (cladocerans, diatoms). Sediment chronology is based on varve counting, Pb-210 and Cs-137 dates. Obtained results were confronted with existing cartographic materials and documentary sources.

The basal part of the core shows highly organic sediments of homogenous structure. First major change was observed at 60 cm sediment depth, where faintly laminated sediments occur. This is a transition from stable trophic state towards higher variability and eutrophication. Moreover, paleoecological diversity began to decrease, while an input of minerogenic matter from the catchment started to increase. A second distinct change occurred at around 20 cm sediment depth, where faint lamination is replaced by well-preserved annual lamination. Such differentiation came about most probably due to the strong eutrophication that occurred after 1945 CE. At this time, the catchments input decreased, resulting in formation of typical biogenic (calcite) varves. According to historical data, changes in land cover and land-use could be regarded as the drivers of the observed transitions in sediment structure.

**P-4245**

## **Lake Constance: Reconstructing the Eukaryotic community using SedhDNA**

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In the second half of the 20th century, the once oligotrophic Lake Constance was exposed to major inputs of matter associated with population growth in the form of untreated sewage and agricultural runoff. This caused a dramatic eutrophication of the lake starting in the 1950s until the 1990s. As a consequence, damage control measures were implemented by the authorities most specifically in the form of waste water treatment plants. Soon after, the water quality indices returned to their 1950s levels.

Since multiple decades, the lake has been closely monitored by plankton sampling and identification using microscopy methods and an extensive long-term dataset exists.

Complimentary to the existing data, the current study aims to investigate the effect of environmental change, i.e. changes in anthropogenic phosphorus loads, on the local eukaryotic community applying a metabarcoding approach to sedimentary historical DNA spanning the past century. DNA extracts covering a high resolution time series of the lake's different trophic phases were processed according to conformed environmental DNA restrictions. A universal assay was then used to amplify and sequence a portion of the V7 region of the 18S rDNA gene representing the major plankton communities.

A total of 7 757 taxa, were retrieved in the complete dataset of which 2 408 were taxonomically assigned to diverse phyla following strict bioinformatics filtering steps. Overall changes in the communities recovered with sedimentary DNA trace the different trophic phases of the lake through time very well. Diversity measures (Shannon diversity, Simpson dominance, Chao richness estimate) indicate a return to pre-eutrophication biodiversity after lowering of phosphate levels in the lake, indicating reversibility of perturbations in diversity.

However, further in-depths analysis of the different phyla detected, demonstrate that those perturbations may not only be due to fluctuations of existing biota but also due to the introduction of new taxonomic groups during the eutrophic phase. Distinct patterns were also observed in response to the changes in phosphorus loads with several taxonomic groups, i.e. Lophotrochozoa, Bacillariophyta, Chrysophyceae, Chlorophyta and Ciliophora. Despite the reversibility of the disturbances in diversity inferred, the marked variations in the structure of the lake community following eutrophication and its stagnancy in the following years, indicate a non-resilient system.

The patterns revealed by this genomic data will further be compared with existing long-term and ongoing routine sampling datasets for method comparison purposes.

SedhDNA : sedimentary historical DNA

P-4246

## Understanding human-driven ecosystem change in a tropical Southeast Asian wetland

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Tropical areas are undergoing rapid environmental change as a combined result of climate change and human impact on the landscape, which significantly threatens the quality and biodiversity of freshwater ecosystems. Tasik (Lake) Chini is a flood pulse wetland located on the Malaysian Peninsula, and is a critically endangered site comprising twelve interconnected lake basins. The natural vegetation of the lake's catchment and surrounding area has become increasingly influenced in recent years by rubber and oil palm plantations, mining, fruit farms, logging, and tourism, which have resulted in pollution, soil erosion, and external nutrient loading to the lake. The main outflow river was also dammed in 1995 to help stabilise the water level. Together, these activities have changed the hydrological balance of the lake, influenced biodiversity causing species and habitat loss, and decreased the sustainability of the ecosystem due to eutrophication. To understand the influence of major changes in catchment land use on the lake and to investigate the key drivers of ecosystem degradation, gravity cores were recovered in 2015 from three sub-basins of Tasik Chini. The first core is from a site adjacent to a tourist resort, the second core is from a basin situated close to mining activity and rubber plantations, and the final core was retrieved from a site furthest from major catchment disturbance. An established chronology based on <sup>210</sup>Pb dating shows each gravity core dates back to the late 19<sup>th</sup> century and covers the transition to enhanced human impact within the catchment. Organic geochemistry (%C, C/N,  $\delta^{13}\text{C}$ , Rock-Eval pyrolysis), diatom assemblage, elemental concentrations, and sedimentary pigments have all been analysed on each core to reconstruct past environmental conditions within the basin. Data show how past variability compares to recent anthropogenic-induced environmental change and define how different catchment disturbances have contributed to ecological change at this internationally important wetland site. This information is vital to assess ongoing human impacts at the site as a means to provide future science-based management and conservation strategies and thereby counter the main drivers of ecosystem degradation.

**P-4247**

## **Ecological response of a shallow mesotrophic lake to multiple environmental stressors**

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White Lake is a large, shallow (mean depth 3.1 m) mesotrophic (total phosphorous  $\sim 10\mu\text{g/L}$ ) lake located in Eastern Ontario, Canada, and an important recreation and tourism site in the region. Similar to many lakes in the area White Lake is experiencing multiple environmental stressors including nutrient enrichment, climate warming, and the recent colonization by the invasive zebra mussels (*Dreissena polymorpha*). Lake users and property owners are increasingly concerned about water quality changes in the lake and management plans for the lake require an understanding of how these multiple environmental stressors are interacting to impact water quality. Unfortunately monitoring data for White Lake only begins in 2014 and therefore no information exists on pre-impact conditions in the lake and how these environmental stressors have interacted to alter water quality in the system. To assess long-term water quality changes in White Lake in response to these multiple environmental stressors, two sets of replicate sediment cores have been obtained from the lake, dated using  $^{210}\text{Pb}$ , and sectioned at 0.5 cm intervals for organic content and diatom analysis. Two distinct shifts in the diatom community occurred, both showing changes in the ratio of benthic to planktonic diatoms. Recent communities are dominated by benthic species, suggesting lower water levels and clear water conditions. These data, along with the colonization of zebra mussels, suggest that White Lake is becoming an increasingly benthic system and that colonial benthic algae and/or macrophyte cover will expand within the lake. This research provides insight into how multiple stressors impact primary producers in shallow lakes that are sensitive to shifts in nutrients and turbidity.

**P-4248**

## **Regional heterogeneity in the sediment signals of atmospheric deposition in alpine lakes of southeast Tibet**

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It has been established that atmospheric deposition can significantly impact pristine lakes in high-latitude and alpine regions in the context of climate warming over the last century. Specifically, nitrogen isotopic and contaminant signals derived from lake sediments have been widely used in tracking the temporal trajectory of regional atmospheric deposition. However, recent studies have revealed strong spatial heterogeneity in regional deposition and sediment signals. Processes such as climate change can also modulate lake response to atmospheric deposition through altering catchment and lake properties. Therefore, it is necessary to refine the independent roles and interaction of atmospheric deposition and confounding factors in altering lake biogeochemical cycling and ecological changes over time. In this study, trace metal and associated index for air-borne pollutants revealed that atmospheric deposition started from the late 19<sup>th</sup> century with an accelerating increase since the middle of 20<sup>th</sup> century, well consistent with the trajectory of regional atmospheric deposition. Furthermore, this process has led to the change of lake-water chemistry (i.e. acidification). However, the nitrogen isotopic variation was strongly associated with the fluctuation of sediment organic matter (OM) and catchment runoff. Meanwhile, algal production, predominantly enhanced by warmer climate, showed a significant increase over the last few decades. Increased temperature was linked with the decrease of planktonic diatoms, while the intensification of acid deposition and catchment erosion caused an increase in acid-tolerant benthic taxa. Our sediment evidence collectively revealed the significant impact of climate and catchment processes on lake-water chemistry, contaminant concentration and algal shift in the context of atmospheric deposition in SE Tibet, and highlighted an increasing link of external forcing with in-lake processes in driving sediment signals over the last few decades.

**P-4249**

## **Assessing feral animal impacts on World Heritage sub-Antarctic Macquarie Island**

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Animals introduced by human activities to remote islands can be ecologically devastating as they often have a large proportion of endemic species with limited resilience to non-indigenous ones. Sub-Antarctic islands are remote, small islands in the vast Southern Ocean. Most have experienced some form of impact from non-indigenous fauna (e.g. rabbits, rats, mice, cats) that became feral pests soon after their deliberate and unintended introductions. Conservation and management efforts are increasingly focused on their control and/or eradication.

World Heritage UNESCO Biosphere listed Macquarie Island (54°S) is one of the most impacted sub-Antarctic islands, in particular due to the introduction of rabbits in 1879, to the extent that its World Heritage values were considered threatened in the early 2000s. The values relate to Macquarie Island's geological, geomorphic and physiographic features, and exceptional natural beauty and aesthetic importance. The latter includes the presence of a large number of lakes, tarns and ponds, and extensive peat beds.

The largest rabbit and rodent eradication program for any sub-Antarctic island was undertaken from 2010-2014. Monitoring to assess recovery focused on geomorphological (including erosion) processes, vegetation and some fauna (i.e. invertebrates, burrowing petrels and albatross species) using previous studies as baselines. All of these studies were undertaken after rabbits were introduced, and no pre-introduction data exist beyond some limited historical documents after its discovery in 1810. No monitoring to assess recovery of the lakes, tarns, ponds or peat beds was undertaken.

In the absence of long term data, palaeoecology may be used to determine the nature, magnitude and spatial extent of impacts in the context of long term natural variability. To provide a long-term context for assessing the island's pre-invasion state, invasion impacts, and to provide baseline information for the waterbodies, we undertook a palaeoecological study using high-resolution x-ray fluorescence scanning and hyperspectral imaging together with biological (diatoms), geochemical (total organic carbon and nitrogen) and sedimentological (grain size) analyses of lake sediment cores in two different areas of Macquarie Island.

Results showed that Macquarie Island lakes have undergone unprecedented and statistically significant environmental changes since the introduction of rabbits in 1879. Sediment accumulation rates increased by more than 10 times at one site, 100 times at another, due to enhanced catchment inputs and within-lake production. Total organic carbon and total nitrogen contents of the sediments increased by a factor of four. The diatom flora became dominated by two previously rare species in both lakes.

This study provides an example of how palaeoecology may be used to determine baseline conditions prior to the introduction of non-indigenous species, quantify the timing and extent of changes, and help identify a basis for monitoring the recovery of waterbodies following successful non-indigenous species eradication programs

P-4250

## A Holocene high-resolution multi-proxy record of aquatic productivity, soil erosion and meromixis from varved Lake Rzesniki, NE Poland

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Climate change and anthropogenic activities are influencing aquatic ecosystems (IPCC, 2013). The physical and biochemical cycles in water bodies are tightly linked to environmental and climatic conditions, so that they respond sensitively to changes in these background conditions. Emerging anoxia and meromictic conditions in lakes have substantial consequences on lake ecology (Jenny et al. 2016, Steffen et al. 2015) and it is important to understand their development and effects on ecosystems over long time-scales. Understanding of the paleoenvironmental history provides important insights into natural and environmental factors, which is important in light of future development of freshwater systems. To date only few studies aimed at a better understanding of factors contributing to and ecosystem consequences of meromixis have been conducted so far.

Lake Rzesniki, a small dead ice lake in NE Poland, is an interesting site to study how productivity and meromixis operated in tandem in lake system characterized by a dense forest catchment with limited runoff and input of soil substrates. Almost the entire sedimentary record of Lake Rzesniki is varved making it suitable for a high resolution paleoenvironmental study. The aim of this study is to reconstruct the environmental history of Lake Rzesniki in course of the Holocene, specifically with the focus on the evolution of meromixis and paleoproductivity in the context of a low erosional input and mass movement events. Key question to be tackled include: Are changes in productivity and meromixis climate-related, human-induced, related to within-lake processes or influenced by changes in catchment dynamics? To what extent are the specific background conditions of the lake displayed in the proxy record and how are these influencing the in-lake productivity and meromixis?

We use high-resolution hyperspectral imaging (HSI) proxies, total chlorophyll for aquatic primary production and bacteriopheophytin *a* (Bphe *a*) for meromixis (Butz et al. 2016). The pigment degradation product Bphe *a* is produced by anoxygenic phototrophic bacteria in the chemocline of meromictic lakes. Additionally, sedimentary pigments are extracted and measured by the HPLC to calibrate the HSI data. The multi-proxy record is completed by scanning XRF data and measurements of total organic and inorganic carbon, and biogenic silica determined by Fourier transform Infrared Spectroscopy (FTIRS) (Vogel et al. 2008). The core chronology is based on radiocarbon dating of abundant terrestrial plant macrofossils.

Preliminary analysis of the XRF data reveals extraordinary low lithogenic input (extremely low lithogenic element intensities) throughout the Holocene. The most productive phase is indicated by enhanced counts of Si (here biogenic Si in the absence of lithogenic silicates), Ba and Br during the mid-Holocene. A detailed multi-proxy data analysis focusing on these high productivity phase is in progress with concomitant changes in land use and climatic conditions being determined by palynological analyses.

**P-4251**

## **Assessing the impact of aquaculture in the Philippines using palaeolimnology**

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In the Philippines, aquaculture in freshwater lakes contributes significantly to its economy, food security and employment. However, intensive aquaculture often leads to degradation in lake ecosystem integrity because of nutrient fertilisation resulting in harmful algal blooms (HABs), introduction of toxins and invasive species. The few limnological studies that have been carried out to date demonstrate a link between aquaculture activity and degraded water quality. However, the functioning of lakes in the warm tropics is generally poorly understood, with detailed limnological research and long runs of monitoring data relatively rare. In particular, there is a lack of information to help define how lakes have reacted over time to changing intensities of aquaculture and other drivers of aquatic change, including variations in catchment and climate conditions. This research, adopts a palaeolimnological approach to assess the impact of aquaculture on the Seven Lakes of San Pablo (Luzon Island). A multi-proxy approach is employed to reconstruct environmental change in several lakes over the last c. 100 years, specifically, using chlorophyll and carotenoid pigments as indicators of algal communities (including possible HAB taxa) and carbon and nitrogen isotope ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) and C/N ratios to link ecosystem state with organic matter cycling. The lakes have been subjected to different timings and intensities of aquaculture, allowing comparisons between the farmed and 'control' (no aquaculture) lakes over the past century. Such comparisons allow the lake-specific effects of aquaculture to be disentangled from effects of regional drivers. Using this experimental design across individual lake ecosystems allows more critical interpretation of the pigment and isotope records. Preliminary results suggest that  $\delta^{15}\text{N}$  show an increase proportional to the development of aquaculture leading to the possibility that  $\delta^{15}\text{N}$  could be an effective marker for aquaculture. Furthermore, the scale of change in the algal communities is higher in the intensively farmed lakes (Sampaloc) compared to the 'pristine' lakes (Yambo) suggesting higher development of aquaculture causes larger changes in lake ecology. The ultimate goal of the research will be to determine the aquaculture densities at which each lake exceeded critical loads to define sustainable aquaculture targets.

P-4252

## The impacts of intensive mining on terrestrial and aquatic ecosystems: a case study from cool temperate Tasmania, Australia

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Mining has caused extensive damage to aquatic systems worldwide with acidification, heavy metal pollution, increased sediment loading and Ca decline of freshwaters. While some aquatic ecosystems are thought to be recovering from past mining, a long-term context is needed to determine if pre-impact conditions have been restored. Here we explore the palaeoenvironmental history of Owen Tarn, western Tasmania, to assess the impacts of mining from Mt. Lyell on aquatic ecosystems. Analysis of a new sediment core using radiometric dating, sediment geochemistry, pollen, and diatoms are used to examine the full extent of mining and heavy metal pollution on aquatic and terrestrial ecosystems pre- and post-mining in this region. Our analysis indicates four key phases of environmental change: (1) A pre-mining phase (550-1160 CE); (2) an early impact phase (British invasion) shows land clearance and vegetation removal by burning during mineral exploration; (3) an intense mining period (1950 CE) had severe negative impact on the diatom community in which sediment pollution from a lack of vegetation and heavy erosion, rather than acidification, was the main driver of change; and (4) a post-mining phase (2006 CE) in which vegetation on the landscape began to recover and aquatic productivity increased. Despite this apparent recovery of the system, the aquatic community continues to experience impacts from mining. The diatom community has not returned to its pre-impact state, but rather there is evidence of a secondary impact from declining Ca in the system. The relevance of these findings demonstrates the importance of well dated palaeoecological records to inform management and mitigate human impacts on the environment.

**P-4253**

## **Beginning of the anthropogenic change and the Anthropocene in the Lake Ladoga basin.**

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Lake Ladoga is the largest lake in Europe and changes of its ecosystem is a great importance for the lots of people living on Ladoga catchment area. Numerous studies of the sediment sequences of Ladoga and small lakes in its basin have made it possible to establish the first anthropogenic changes sediments. The study of archaeological site in the Lake Ladoga basin of the studied lakes helps to separate anthropogenic changes from natural. According to the pollen data it has been established that substantially changes in lake landscapes from the Atlantic period is associated with anthropogenic influence, and these changes are confirmed by a comprehensive study of the lakes. The beginning of the industrial period in the region about 300 years ago is recorded in the change in the composition of lake sediments, changes in flora and fauna. This period can be called the beginning of the Anthropocene. The novel method for separating the influence of natural and anthropogenic factors on lake ecosystems according to paleolimnological data has been developed over the past time at the Institute of Limnology of the Russian Academy of Sciences. Method is developed on the base of lithological, geochemistry, pollen, diatom, chironomid, radiocarbon data and other analyses data. Age is determined by pollen and radiocarbon analyzes. It considers qualitative and quantitative characteristics. As a result, we are able to calculate the probability of anthropogenic impact on the accumulation of organic matter, phosphorus and metals in the lake sediments. As a result, we can to quantify the timing and onset of human disturbance in lake systems and to disentangle this from other signals recorded in lake sediment. The study is being performed within the framework theme № 0154-2019-0001(Institute of Limnology RAS).

P-4254

## Sediment and heavy metals flows recorded across an altitudinal transect in the central Pyrenees for the last 2 millennia

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In this work, a comparative study has been undertaken in three lakes across an altitudinal gradient within the Southern Central Pyrenees: Lake Estaña (located in the External Ranges, close to the northern boundary of the Ebro River Basin) and the alpine lakes Basa de la Mora and Marboré (located in high-elevation areas of the Pyrenees Axial Zone).

Mountain lakes register atmospheric pollution with great efficiency. Nevertheless the biogeochemical cycles including heavy metals are specific to each individual lake. Therefore, a site-specific detailed understanding of metal depositional processes should be achieved before using these natural archives as proxies for past regional pollution. For this reason, we compared the depositional evolution of the lake systems during the last millennia with the MAF (Mass Accumulation Flux) variability and changes in the lead concentration of the lakes.

The MAF shows a large spatial and temporal variability, both in each lake and along the transect, likely due to the different environmental processes and varied climate and anthropic forcings. Estaña, located at lower altitudes, showed a large increase in sedimentation rates during medieval times, mainly due to deforestation and agropastoral activities that increased run-off processes in the watershed. Recent rural depopulation in the Pyrenean mountains does not seem to have a strong impact in sediment delivery to Estaña lake, as farming in the watershed has not decreased. On the other hand, Basa de la Mora and Marboré are hardly affected by anthropic activity in their watersheds and their sedimentation is more dependent on climate and surface hydrological processes.

Lead shows similar behavior in these lakes, with low Pb enrichment in the central Pyrenees during the pre-industrial period, a progressive increase since the end of the eighteenth century, paralleling the industrialization process in Europe, and peaking at the late twentieth century. Between 1860 and 1930, the mining and smelting activities in the Central Pyrenees would have been the main Pb source in the area. The sharp drop in Pb in the mid 20<sup>th</sup> century is probably related to the reduction of emissions associated with the economic recession and the closure of the local Pb mines. The use of leaded gasoline is the main factor controlling the Pb enrichment increase during the Great Acceleration (since 1950), and the subsequent reduction after 1990s.

The integration of the depositional evolution of the lake systems with the heavy metal fluxes demonstrates how local environmental conditions are key to understand changes in heavy metal fluxes and erosion and deposition of sediments from the watersheds. This integrated approach exemplifies the different sensitiveness of lacustrine systems to record past changes in sediment, heavy metal fluxes and biogeochemical cycles and highlights the need of multi-archive studies to conduct regional environmental reconstructions.

P-4255

## Exploring the main drivers of change in western Uganda crater lakes: separating anthropogenic from climatic impacts

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Tropical freshwater lakes are critical natural systems of global importance. In western Uganda, crater lakes and their catchments provide vital ecosystem services (e.g. potable water, aquaculture, and ecotourism) to some of Earth's fastest growing and most vulnerable human populations. However, these key services are under increasing threat due to climate change and the impact of human activities. Anthropogenic impacts include rapid change in many crater lake catchments as a result of clearance and land use alteration, while climatic impacts consist of an increase of temperature (0.9°C in the last 20 years in Uganda) and has also led to alterations in aquatic ecosystems in crater lakes. Both climatic and anthropogenic impacts on these fragile ecosystems, such as ecological and biogeochemical functioning, are largely unknown.

Previous research done on these crater lakes has focussed upon the use of lake sediment records as palaeoclimatic archives, with little attention given to the effect of human-driven changes on lake ecosystem structure and functioning. This project targets a number of crater lakes in western Uganda (Bunyaruguru region) with contrasting catchments (i.e. "natural" vs heavily impacted by human activity) to test the hypothesis that agricultural intensification in these lake catchments has led to a significant increase in aquatic primary production, with climate change a subordinate factor. Sediment cores (spanning the last c. 100-200 years) will be analysed for fossilized pollen, charcoal, and diatoms to study the impact of human activity and recent surface water warming on biogeochemical cycling and its associated impacts on the ecological functioning of these lake systems. Contemporary remote sensing, vegetation and pollen data will be used to develop a pollen-land cover calibration set for understanding landscape change over the past ~20 years, which will then be applied to the palaeoecological records of vegetation through pollen analysis.

Preliminary results demonstrate that these crater lakes are sensitive to environmental change in the recent past, and have experienced substantial changes in lake level. New results show that lakes heavily impacted by humans also have substantial changes in lake level over the past 100 – 200 years, however, these changes are dissimilar compared to the more "natural" lakes. Understanding past anthropogenic and climatic influences on these ecosystems can act as a guide to their future resilience and sustainability as natural resources providing vital ecosystem services for local populations under increasing environmental change.

P-4256

## Climate and human drivers in the geo-environmental evolution of Northern Iberian watersheds during the Anthropocene: integrating lacustrine and coastal records

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Understanding past environmental change and identifying its main drivers is essential to predict how watersheds will respond to climate change under increasing human pressure. To achieve this goal, we need to extend our temporal records back in time to pre-industrial conditions, so we can understand the natural variability of the main processes involved.

The Cantabrian region (N Spain) represents a perfect playground to address these questions as it has experienced high human pressure during the last centuries, especially when compared to other areas of Iberia. This research aims at understanding how recent (19<sup>th</sup> to 21<sup>st</sup> centuries) warming and increasing human activities have affected the geomorphological and geochemical dynamics of the Cantabrian watersheds. In this work, we use a multi-archive and multi-site approach, integrating high-resolution lake (Somiedo, Ausente, Isoba, Enol, Fuentes Carrionas, Pozo-Tremeo and Antuzanos) and estuarine (Tina-Menor, San Vicente, Rabia, Suances, Maruca, Santander, Santoña, Muskiz and Urdaibai) records located across a W to E longitudinal and altitudinal (0-2200 m.a.s.l.) transects, covering a wide range of climatic conditions and land uses in this region. To unravel human and climate drivers of environmental change, we use a multidisciplinary strategy, including geomorphological and paleolimnological approaches. Thus, we investigate current and past dynamics at both watershed and lake/estuary scales, current and past dynamics using geomorphologic analyses, long-term instrumental climate records, limnological surveys and multiproxy analyses of sediment cores (sedimentology, geochemistry and paleoecology) and socioeconomic data. We particularly focus on three main components of watershed dynamics: i) sediment delivery and depositional dynamics, ii) heavy metal loads and iii) carbon fluxes. Available data indicate increasing sedimentation rates in lakes and estuaries since the mid-20<sup>th</sup> century, coinciding with the Great Acceleration.

This research will contribute to understand the nature, timing, spatial variability and consequences of the synergistic effects of human activities and climate change on watershed scale, helping environmental stakeholders and policymakers to design adaptation and mitigation policies on global change.

**P-4257**

## **Vulnerability of small lakes in the district of Ouinhi (Benin republic) to the effects of climate change and human pressures**

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Inherent in the more or less recent hydro-geomorphological processes in southern Benin, the small lakes of the district of Ouinhi are of ecological and socio-economic importance and deserve to be preserved. But these ecosystems are not immune to the combined effects of natural and human pressures. The present research aims to analyze the vulnerability of these small lakes to the effects of climate change and human pressures already visible or to come.

The climate datas (rainfall and temperature) for period 1941-2015 period, and those for remote sensing (Landsat TM 1988, ETM + 2002 and OLI TIRS 2017) are used without forgetting information from observations / field surveys. The use of frequency analysis, standardized indices and the non-parametric Pettiit test made it possible to characterize the current climatic variability in the environment. Cartographic software (IDRISI SELVA and ARC GIS) was used to analyze the dynamics of land use around small lakes. To describe the future climatic physiognomies, the scenarios IPCC (2013), RCP 2.6 (optimistic) and RCP 8.5 (pessimistic), were used by 2050. The " pessimistic " and " optimistic " modeling was made to explore the environmental degradation levels of the environment at the same time horizon.

The environment of small lakes is currently characterized by unambiguous thermal warming associated with instability of annual rainfall totals with a high occurrence of extreme values. Added to this is the degradation of vegetation cover due to human activities which exposes the soil to any kind of degradation. The result is a tendency to fill small lakes and reduce their services. All climate scenarios predict an uncomfortable hydro-climatic context by 2050, coupled with a degradation of the lake environment. If the trend continues 20 to 35% of small lakes could disappear and the rest will be seriously affected. These observations suggest the definition of a concerted adaptation policy to reduce the socio-economic and environmental vulnerability of small lakes to future hydro-climate shocks.

**P-4258**

## **Climate change and erosive dynamics around Lake Ahiémé in Benin, West Africa**

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### **Abstract**

Climate change effects and extreme climate events have various impacts on water bodies and rivers. Lake Ahiémé has been exposed in recent decades to the adverse effects of storm erosion, the direct consequences of which are bank erosion, fillings and sedimentation of the lake. The purpose of this research is to study the relationship between climate change and erosive dynamics around Lake Ahiémé.

To assess the effects of climate change and the manifestation of land erodibility in the study environment, rainfall, demographic and land use data are collected. Field surveys were used to identify vulnerable areas and public perception of the phenomenon of rainfall erosion. Descriptive statistics and the PEIR model were used to analysis the results. Areas of vulnerability to storm erosion have been mapped.

As a result of this study, the “Ahiémé” Lake area was the centre of several climate changes over time. Comparative study of climatological data between normal 1991-2010 and 1961-1990 shows an increase in extreme rainfall frequency of about 16% as temperatures increased overall by +1°C in the study area. These changes are at the root of the lake’s vulnerability to storm erosion. For 60 % of the population, clearances for season crops, destruction of vegetation by wildland fire and exploitation of galleries for firewood expose the lake’s banks to erosive. According to 55 % of respondents, eroded particles are transported and deposited in the lake, contributing to ecosystem sedimentation. As a result, local authorities and people are forced to spend more than 20 % of their annual budget to develop a sustainable shoreline management scheme for future climate change. In doing so, the populations and the town hall have developed adaptation strategies that deserve to be improved.

**Keywords:** Lake Ahiémé, storm water erosion, climate change, sedimentation

**P-4259**

## **Environmental degradation of lakes in the middle Yangtze Basin since the 1980s**

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Intensification of human activities and associated pollutant transport into freshwater bodies have resulted in the deterioration of lake ecosystems. The middle and lower reaches of the Yangtze Basin, inhabited by more than 300 million people, is one of the most developed areas in China. Over the last several decades, lakes in this area have suffered from problems such as eutrophication and declines in biodiversity due to strong human perturbations. In addition, hydrology is a key factor controlling ecosystem wellbeing of floodplain lakes. Because long-term monitoring of these lakes is lacking, we used paleolimnology to understand the extent and consequences of the rapid intensification of human impacts. Analysis of chlorophyll and carotenoid pigments remains in dated sediment cores allowed us to track ecological changes in the lakes. Our study based on six lakes spanning the middle Yangtze Basin illustrates that pigments showed a sharp breakpoint around the 1980s consistent with an increase in primary producers, including potentially bloom-forming cyanobacteria. This change coincides with the major period of rapid development in the region when nutrient loading increased due to agricultural and industrial development and urban expansion. The changes recorded by our sediment cores record an unambiguous and widespread degradation of environment across the middle Yangtze Basin lakes, which probably increased the size and frequency of cyanobacterial blooms around 35 years ago. In addition, pigment biomarkers of N<sub>2</sub>-fixing (aphanizopyll) and colonial (canthaxanthin) cyanobacteria showed a spatial pattern along the middle Yangtze River with low concentrations in the upper stream and high concentrations in the lower stream. This may be attributed to the different source of N and P in the Yangtze Basin and the variable effectiveness of upstream lakes and reservoirs at reducing pollutants from point and non-point sources.

P-4260

## Danube floodplain lakes formation and evolution in the Mid and Late Holocene: natural versus anthropogenic influences

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Floodplain lakes are very important archives for reconstructing fluvial dynamics associated with climate changes and human impact (land use changes). In this study, we present the preliminary results of the multi-proxy analysis of the Danube floodplain lakes which allow for the reconstruction of the landscape changes occurred during the last 5000 years which is the average age of the floodplain lake inception. The methodology includes geochronological (AMS), sedimentological (grain-size, loss on ignition, magnetic susceptibility), geochemical and paleo-ecological (pollen, seeds, ostracods, dinoflagellates) analyses focused on the changes in the sedimentary record of the 7 lakes. In each lake, we sampled sealed tubes from medium deep cores (the bottom of the core is between 8 and 18 m which in all cases is lower than the lacustrine unit), which position was chosen using several historical maps (1770; 1849; 1916; 1970) and satellite images. The preliminary results allowed for the identification of the main common phases characterizing the floodplain lake formation and evolution. Thus, most of the lacustrine stratigraphies and age-depth models show similar patterns with turning points correlated with human history and marked differences in sedimentation rates and organic matter content imposed mainly by human activities mainly through forest clearings, agriculture, grazing and later through dredgings and canal. Recently, seeds and cereals spores analyses enabled the assessment of agricultural activities practices which further contributes to tracing the ratio between the natural and anthropogenic sedimentation drivers (e.g. in Somova Lake Neolithic age cereals have been found which together with the organic dark layers provide information on sedimentation rates influenced by human activity through deforestation, crops and later, through civil works) (e.g. in Somova Lake Neolithic age cereals have been found which together with the organic dark layers provide information on sedimentation rates influenced by human activity through deforestation, crops and later, through civil works).

P-4261

## Water quality changes in Eastern Ontario recreational lakes over the last 150 years in relation to climate and land-use changes

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Eastern Ontario, Canada, is lake-rich region whose economy benefits from tourism associated with aquatic recreational activities. Residents of this region are becoming increasingly concerned about water quality changes including nuisance algal bloom despite fairly low total phosphorus (less than  $20\mu\text{mTP}$ ) concentration. Land-use and climate change are known to negatively impact water quality by increasing the likelihood of algal blooms. Changing climate may lead to a variety of different environmental conditions such as increasing ice-free seasons, warmer water temperatures and increasing precipitation. However, the combined impact of TP and climate change on water quality in this region is not clearly understood. To investigate the combined impact on water quality in Eastern Ontario lakes, Diatom based paleolimnological records (top and bottom layer of sediment core) from 15 nutrient poor (on an average  $12.5\mu\text{mTP}$ ), non-acidic lakes of this region were analysed. Paleolimnological records detected shifts in the composition of diatom species assemblages, mostly from benthic taxa, such as *Fragilaria* or tytoplanktonic *Aulacoseria* groups, to more planktonic-dominated taxa, such as *Cyclotella* and elongated diatom taxa such as *Asterionella* in the study lakes. Climate change induced warming causes extensions in photic zones as well as stable water columns, which are known to be favorable for small planktonic diatoms. These conditions favour planktonic species as opposed to tytoplanktonic and benthic diatoms. Therefore, this study reveals a strong climate change signal across the study region. Furthermore, a sharp declining trend in Chrysophytes cyst to Diatom ratio was observed since pre-impact (pre-1850) age to the present days. Chrysophytes are abundant in oligotrophic conditions and therefore declining trend in cyst to diatom ratio suggests a shift to nutrient rich aquatic ecosystem.

P-4262

## Reconstructing Lake ecosystem history using carbon stable isotopes in resting *Daphnia* eggs

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Freshwater ecosystems are under severe pressure through multitude of anthropogenic stressors. Lake Constance, one of the largest Lake in Europe, has been affected by several environmental stressors including eutrophication and climate change. Eutrophication as an ecological stressor has been the main concern during the 1960s to 1980s, after which the lake has attained its oligotrophic level and beyond. The effects of these long-term changes on the lake ecosystem is archived as a 'unique fingerprint' in stable isotope values of *Daphnia* resting eggs (ephippia), remaining egg shells, and sediment core bio-chemistry. These values provide important information on past changes in diet of invertebrates and higher level consumers. Here, using carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) of multiple ephippia from sediment core and surface sediments over 1960-2000, we show a significant change in stable isotope values. Ehippia  $\delta^{13}\text{C}$  values are close to values typical for algae and living daphnia ( $-35.4\text{‰}$ ) during recent oligotrophic phases. This variability is likely driven by seasonal and inter-annual variability in algae  $\delta^{13}\text{C}$  values. When using shell  $\delta^{13}\text{C}$ , we identify two distinct isotopic patterns, which may reflect separate production peaks and resource uses between the eutrophication and oligotrophic process. For both resting eggs and shells, we report a significant shift (increase) in  $\delta^{15}\text{N}$  values between the years 1960 and 2000. These results assist refining the assessments of past *Daphnia* trophic level and nitrogen cycling in the Lake food webs. Further investigation using sediments and multiple isotopes is being considered.

**P-4263**

## **Criticism of fantastic ideas about the extraordinary antiquity of the first ceramics in the Transbaikal, Russia**

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In some recent publications (Razgildeeva et al., 2008, 2013), early pottery recovered from the Studenoe 1 and Ust'-Menza 1 sites of the Transbaikal region (Russia) are radiocarbon dated to be from the late Pleistocene. Ceramics from layer 7 at Ust-Karenga-12 in the Transbaikal are suggested to have appeared about 14 to 13 thousand years ago, claimed as among the oldest in East Asia (Kuzmin and Vetrov 2007; Vetrov, 2008, 2010, 2011). However, we argue that the true age of the oldest ceramics in the Transbaikalia is about seven thousand years ago.

At Studenoe 1 and at Ust'-Menza 1, cultural layers belong to the late Upper Paleolithic, Mesolithic, Neolithic, and Bronze ages. The oldest ceramics, in the early Neolithic, were excavated from layers 8 and 9 at Studenoe 1, and from layers 7 and 8, at Ust'-Menza 1. Ceramics have pointed- and rounded-bases, and stamped decorations. The pottery-containing cultural layers are associated with thin black layers developed during the Atlantic optimum. The age assignment of these deposits by geologists, S.M. Tseitlin, D.B. Bazarov, LD Bazarova, I.N. Rezanov, A.F. Yamskikh, and others, agrees with ours. We suggest the antiquity of the cultural layers of the early Neolithic in the lower part (but not at the base) of the deposits of the Atlantic optimum to be seven to six thousand years ago.

Additionally, a comparison of artifact chronology and stratigraphic contexts suggests that below the Neolithic horizons, there are layers of the late Mesolithic corresponding to the beginning of the Atlantic optimum, and the early Mesolithic and the late Upper Paleolithic corresponding to later stages of the Sartan glaciation. If the stratigraphy-based artifact chronology is valid, the assignment of Neolithic horizons to the late Pleistocene requires an explanation.

At Ust-Karenga-12, the ceramic materials are associated with a humus-rich, very black layer of the middle to the second half of the Atlantic optimum. This led us to attribute those layers to about 6-4 thousand years ago. Ceramics with combed decoration are found from this context. These ceramics are similar to the pottery technology of the middle Neolithic in Yakutia.

In the Baikal region, radiocarbon dates, and deposits and archaeological materials from the Atlantic optimum and sub-boreal clearly have up to a thousand years of time gap (Konstantinov et al., 1989, Konstantinov, 1994, p. 110, Konstantinov, 2009a, 2009 b, Konstantinov M., Konstantinov A., p. 20-21). Failure to understand this problem leads to a mixture of different time periods, and creates a ground for misunderstanding the true ages of the earliest pottery there. We suggest that ceramics began to be produced in the Transbaikal when the Taiga forest and favorable natural environment developed, and continental Neolithic hunters and fishers changed their subsistence economy.

P-4264

## The nature and timing of the dispersal of *Homo sapiens* in the western region of southern Patagonia (52°)

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The Late Pleistocene cold environments of southern Patagonia were classically considered geographically marginal and relatively difficult to colonize. The extensive Patagonian ice sheet continuously present from 44° to 52° S added further difficulties to western regions near the Andean cordillera. Finding the habitats first occupied by *Homo sapiens* at the end of the Pleistocene along the Andes is challenging, since most of the areas near the Andes were only occupied at the beginning of the Holocene. Most of the early archaeological evidence was obtained in the eastern Patagonian steppes. The only region in Southern Patagonia where Late Pleistocene human occupation was detected, in the vicinity of the Pacific Ocean is at Cerro Benitez, Ultima Esperanza, Chile. Approximately one millenium after the retreat of the Pleistocene glaciers, the region of Cerro Benitez was successfully colonized from the east by a rich fauna that included *Mylodon*, *Hippidion*, *Macrauchenia*, *Lama gracilis* and other camelids, two hyper-carnivores -*Smilodon* and *Panthera onca mesembrina*- and *Arctotherium*. During the Late Glacial there is evidence, such as ice wedge casts and vegetation changes to suggest a return to cold conditions coeval with the Antarctic Cold Reversal (ACR). However, the continuous presence of the diverse fauna made it a viable habitat for *Homo sapiens*, although it was only by the end of the ACR that the first indications of human habitation were present. Human habitation for the period 10.8-10.4 ka BP has been established at Cueva del Medio, with important complementary information from Cueva Lago Sofía 1 and Cueva del Milodón in the form of hearths, projectile points, a diversity of stone tools, some of them made on exotic rocks and cut-marked bone fragments dated by a suite of 46 radiocarbon dates. These are clear signals of interaction with *Hippidion* and camelids, including an extinct clade of *Lama guanicoe*. It remains an open question whether people arrived before to the southern latitudes (Support from FONDECYT 1100822, 1180272).

**P-4265**

## **Cultural Interactions between the Late Stone Age and Iron Age at the Island of Deserters**

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The Island of Deserters located in south western Uganda is at a spot where the Kagera river turns west in an area popularly known as Nsongezi. Herodotus suggested that the Island of Deserters was where the Nile turned to the Western direction. Given that there is a thinking that the Nile might be hailing from the Kagera this place was named the Island of Deserters. While Nsongezi is where the first Stone Age artefacts were identified in Uganda, not much has been done in this place in terms of examining its ceramic potential and its implications as if the Late Stone Age people simply disappeared and never interacted with the Iron Age people. The objective of this paper is therefore to justify the use of the name Island of Deserters. Secondly, it also shows the interaction between the Late Stone and Iron Age cultural periods. This is because the Island of Deserters is a site with evidence spanning from the Middle Stone Age to the Iron Age where typical Kansyore a Late Stone Age pottery tradition co-exists with the Iron Age pottery tradition. The study employed archaeological survey and excavation and ancient historical records. The finds indicated that this is probably the Island of Deserters talked about in ancient historical records with evidence of interaction between the Late Stone and Iron Age periods that is instrumental in examining theories of cultural interactions such as displacement and coexistence, with reference to the Island of Deserters in south western Uganda.

**P-4266**

## **The southernmost Neanderthals? Stone tool technologies from Shukbah Cave**

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The expansion of modern humans out of Africa has led our species to colonise a variety of habitats, engaging with a diversity of extreme environments that is unparalleled amongst our closest relatives and ancestors. Yet, examining the ecological range and the geographical extent of our closest, extinct relatives offers an important approach to understanding what constituted extreme environments to Pleistocene hunter-gatherers, as well as to illuminate the similarities and differences between alternate hominin populations' behavioural responses to such environments. This presentation focuses on Shukbah Cave, where Dorothy Garrod undertook the first in a series of excavations in Palestine. While many of the later sites excavated by Garrod have become pivotal in debate surrounding hominin occupation and behaviour in the Levant during the later Middle and Late Pleistocene, the Middle Palaeolithic occupation of Shukbah Cave has been overlooked. The small number of hominin fossils recovered at the site have been attributed to Neanderthals, making them the southernmost specimens of the species, and Garrod drew close comparisons between stone tool assemblages from Shukbah and the late Mousterian layer D at Tabun. The results of ongoing analysis of the stone tool collections from Shukbah will be presented and placed in the modern research landscape to explore questions regarding ecological engagement and expansion of alternate hominin populations in South-West Asia during the Late Pleistocene.

P-4267

## Millennial-scale climate fluctuations in the Shuidonggou site in north China and influences on human's occupation during the last 40-10 ka

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During the last 40-10 ka, the northern Hemisphere has experienced a series of dramatic climatic fluctuations including the last glacial maximum (LGM) and coupled millennial-scale climate changes known as Dansgaard-Oeschger (D-O) and Heinrich (H) events, with temperature shifted as much as 15-20°C. Studies indicate that the extreme cold climate may have played a significant role in modern human evolution. However, how did these abrupt, millennial climate changes influence human's occupation and migration in north China especially in the desert areas are still ambiguous. To address this issue, the Shuidonggou Locality 2 paleolithic site located near the Mu Us desert was studied, where a large number of artifacts including Levallois, mammalian fossils and decorations have been unearthed. In this study, reliable chronological framework was firstly constructed using the optically stimulated luminescence (OSL) dating and climatostratigraphic correlation, and then the detailed climate changes were reconstructed by sediments grain size and pollen analysis.

Our results show the quartz grains are well-bleached and qualified for OSL dating, and then yielded an independent chronology of 43-14 ka generated by 24 OSL samples, which is rather consistent with the chronologic sequences by the AMS<sup>14</sup>C dating and climatostratigraphic correlation. Thus we obtained the detailed ages for the seven artifact layers of 42-40ka, 37-36ka, 36-35ka, 34-33ka, 33-32ka, 32-31ka and 30-28ka based on this high-resolution dating sequence, indicating millennial cyclic occupation of human in this areas, similar to rhythm of the global climate fluctuations. Our dating results also suggest that the occurrence of blade artifacts representing the Levallois technology from the Europe took place in this place at 40 ka ago and then was replaced by the typical flake technology carried by the local population in north China. Combined with sediments grain size data and pollen data, we found that the human's occupation in this area during the last glacial period mainly occurred in periods of relatively warm and humid climate conditions when drainage area expansion and the forest-steppe landscape development facilitated the occupation. While in the relatively cold climate, the sandstorm intensity enhanced due to desert expansion and the vegetation cover declined, thus caused the migration of the human. In addition, the Heinrich event obviously had played an important role in modulating human's occupation in Shuidonggou areas, during which ancient human was obliged to leave owing to the harsh environment. When the H3 and H4 event terminated, humans reoccupy this areas quickly, however, after the H2 event, the subsequent LGM prolonged the extremely cold climate and severely deteriorated environment and caused Shuidonggou area discarded by human for a long while until the early Holocene.

**P-4268**

## **The Initial Dispersions of Modern Humans into the Siberian Arctic: A View from Archaeological and Paleo-environmental Research**

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Understanding of the dispersal processes of modern humans into various regions of the Arctic can provide us with key information about their adaptive capabilities in extreme environmental conditions. This is also important to know the processes of the initial peopling of Americas occurred during the Late Pleistocene. Recent archaeological research in the Upper Paleolithic sites of Siberia can allow us to examine when and how the initial expansions of modern humans into the Siberian Arctic occurred. In this paper, I attempt to review the current state of the archaeological studies concerning this topic and evaluate environmental constraints of modern human dispersals into the Siberian Arctic by comparing the archaeological evidence and the paleo-environmental reconstruction for the time period and region of interest. Here, I would like to present contradictory hypotheses examining the patterning of archaeological records in the Siberian Arctic during the Marine Isotope Stage 3. Furthermore, I introduce the analytical procedure to predict the dispersal routes into the Arctic regions from southern Siberia and elucidate research- and/or taphonomic bias responsible for preservation and visibility of archaeological materials. The results of such integrated assessment may provide new insights into the studies of site formation processes in the Siberian Upper Paleolithic.

**P-4269**

## **The projection of the high-altitude settlement-subsistence patterns in the past temperate region from the modern hunter-gardener's behaviour in Taiwan**

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The purpose of this paper is to project the high-altitude settlement-subsistence patterns in the temperate region in the past from the modern hunter-gardener's behavioral adaptation to the forest environment in mid-latitude regions.

Tadao Kano, who practiced ethnographic and biogeographic research, conducted a survey of the fauna in the mountainous area of Taiwan in the 1920-30s. He concluded from his research that Taiwan's high-altitude fauna had the feature of northern Mainland China in Pliocene and low-altitude fauna did the feature of the subtropical zone of Mainland in Pliocene. He hypothesized that they were transferred to Taiwan early in Pleistocene and subsequently divided into Taiwan island after late Pleistocene (Kano 1933).

The list of mammals that Kano showed when conducting this study includes hunting games for Taiwan indigenous people who have lived in the area. Taiwan indigenous tribes have been engaged in hunting activities in mountainous areas and slash-and-burn farming for millet and cultivation of root crops such as taro and sweet potato. On the other hand, they have the diversity on language, religion, social organization and settlement pattern. It means that different ethnic population existed simultaneously and independently in the same niche.

In this study, the author analyzed the correlation between mammalian altitude distribution and the tendency of indigenous population inhabitation. The obtained results can be summarized as follows:

1) The residence of the indigenous populations tended to place in the range 1000 to 1500 m sea level. 2) Some groups which residence placed in relative lower altitude introduced rice cultivation and practiced marine fishing and gathering. 3) Fauna lower than 1500 m sea level had the diversity of low rank resource such as muntjac, flying squirrel, masked mustang except for wild boar. 4) The peak of distribution of middle-sized mammals such as deer, bear and mountain goat was in more than 1500m sea level. It placed higher than human residential areas.

From ethnographic research, we understand that hunting activities of the indigenous populations had two types; one was to hunt wild boars or forage the low rank animals around their villages and the other was by the hunting trip departing from the villages. They also hunted low rank animals by the hunting trips. The decision making for the selection of residential place might be concerned with the distribution of their hunted games.

This paper shows the correlation between the distribution of fauna and that of indigenous residential areas and hunting behaviours to project the high-altitude settlement-subsistence patterns in the temperate region in the past.

P-4270

## Pleistocene geomorphology and geology of the Hrazdan valley, Armenia: linking volcanism and the Palaeolithic archaeological record in the Southern Caucasus

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The Southern Caucasus, lying at the intersection between Africa, the Levant and Eurasia, is of considerable paleogeographic significance in our understanding of hominin population dynamics and behaviour during the Pleistocene. Several archaeological sites in the region attest to its importance, including Dmanisi, Georgia, in which earliest evidence for *Homo* species outside of Africa has been recovered (Ferring et al., 2001), and Nor Geghi-1, Armenia, in which there is early evidence for local technological evolution (Adler et al., 2014). However, a further understanding of the chronology and nature of climatic and geomorphic changes in the region is needed to fully understand its rich archaeological record.

The Hrazdan river valley, central Armenia, has the potential to offer unique insights into geomorphic, volcanic and archaeological behaviour in the Southern Caucasus during the Pleistocene. It possesses extensive fluvial and lacustrine archives, and a rich Palaeolithic record, while chronometric dating and geochemical correlation of volcanic deposits, enable the development of precise chronologies. This presentation discusses the Pleistocene record of the Hrazdan valley based on the results of extensive geological and geomorphic mapping, archaeological survey and excavation within the valley. Using these mapping data and published chronometric results (<sup>40</sup>Ar/<sup>39</sup>Ar and K-Ar), we present a stratigraphic framework for environmental change and hominin activity during the Middle Pleistocene. We demonstrate that the onset of volcanic activity in the Gegham range to the east of the valley occurred around 700 ka BP, after which there were several phases of volcanism lasting until 200 ka BP. Interbedded with lava emplaced by these eruptions are sedimentary sequences, several of which have yielded archaeological remains. Sedimentological analysis of these sequences suggests that lava emplacement in the Hrazdan valley led to damming of the palaeo-Hrazdan and the subsequent development of lakes. This was followed by a period of predominately fluvial deposition and the development of floodplain soils. Based on our current stratigraphic framework, it is clear that this cycle was repeated at least seven times. Chrono- and lithostratigraphic evidence from these sequences indicates that during this period, hominin populations were exploiting the floodplain during humid interglacial conditions. Despite the fragmentary nature of the sequences they collectively provide a record covering an important phase of early Human development and dispersal during the Middle Pleistocene.

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**P-4271**

## **The Late Pleistocene hunter-gatherer adaptation to altitude differences? : a case in the Central Highland in the Japanese Archipelago**

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The number of archaeological sites in the early phase of Upper Palaeolithic (EUP) in the Japanese Archipelago shows abrupt increasing while only a few assumed and controversial Middle Palaeolithic sites are recognized. It indicates rapid growth of population size during the period by immigration to almost unoccupied niche.

According to the comprehensive Palaeolithic site database by JPRA (JPRA-DB), the distribution of EUP sites is observed among entire the Palaeo-Honshu Island consisted of 3 major islands and adjacent small ones in the present. EUP sites are located in the high altitude zone including over 1,600m A.S.L. mainly in the Central Highland region. It is continued from the initial stage of EUP to the transition of UP and the Incipient Jomon, or the earliest stage of Holocene.

In this paper, the settlement pattern in the Central Highland region is examined upon quantified data from JPRA-DB in comparison with the pattern in the Plain region for discussion of long-term dynamics of hunter-gatherer adaptation to altitude differences in the late Pleistocene.

The focal reason of exploitation of high altitude zone in the region is the existence of the sources of fine obsidian. Utilization of obsidian from those sources are identified by geochemical provenancing. Perhaps the clusters of sites are recognized surrounding those obsidian sources from EUP to LUP. However there are archaeological sites in another high altitude zones and intermediate zones apart from obsidian sources. Distribution pattern shows continuous occupation from lower area, piedmont zone to highland. Lithic assemblage and technology in different altitudal zone looks almost similar. It indicates that adaptation to different altitude zone by the Pleistocene hunter-gatherer while sites in the higher zone were beyond timberline and the highest ones were beyond snow line during the LGM. This means that hunter-gatherer groups adapted to different ecological niches in different altitude zone.

In the terminal Upper Palaeolithic, distribution pattern of site shows changing. Site cluster surrounding obsidian sources disappeared while other site cluster appeared in different high altitude zone apart from obsidian sources. Average height of site location in the high altitude zone is also decreased. It would be corresponded to the change of vegetation and other environmental aspects during the terminal Pleistocene with change of lithic technology to the microblade assemblage.

P-4272

## A 600 kyr hydroclimate record from Chew Bahir, southern Ethiopia, and implications for Anatomically Modern Human dispersal out of Africa

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There are few long, continuous, terrestrial Pleistocene records from eastern Africa, so it is difficult to establish the relative influences of different climate forcings on the region's hydroclimate and to understand the climatic conditions through the time interval of anatomically modern human (AMH) origin and dispersal out of Africa. To address these gaps in our knowledge, we have cored lake sediments from Chew Bahir in southern Ethiopia, close to the Omo-Kibish, site of the oldest known eastern African AMH fossils. A 40 metre core is estimated to span the last 116 kyr. The proxy data show highly variable hydroclimate conditions from 116-66 kyr, with rapid shifts from very wet to extreme aridity. From 58-32 kyr, the proxies suggest a drier but much more stable regional hydrological setting, which facilitated the development of more habitable ecosystems. This shift, from more to less variable hydroclimate, may help account for the timing of the dispersal of some AMHs out of Africa. A longer, c. 280 m core from Chew Bahir is estimated to cover the past ~600 kyr, and the oxygen isotope data suggest significant fluctuations in water balance through this time period.

P-4273

## Coring for climatic context of human origins key sites: The ~600,000-year climate record from Chew Bahir, southern Ethiopia

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In order to understand the climatic component in human-climate interaction studies, the Chew Bahir Drilling project as part of the *Hominin Sites and Paleolakes Drilling Project* has recovered a ~280 m long sediment core from the Chew Bahir Basin in the southern Ethiopian Rift, in close proximity to some of the key hominin sites. Our age model for the core, based on Ar/Ar, OSL and radiocarbon ages, shows that the Chew Bahir record covers ~600,000 years of climatic history, a time period that includes the transition from the Acheulean to the Middle Stone Age, and the origin and dispersal of anatomically modern humans.

The Chew Bahir record shows long-term trends and cycles, wet-dry oscillations on shorter time scales, and pronounced climate events. We used a multi proxy approach to climatic reconstruction, including MSCL, grain-size analysis, XRF geochemistry and XRD. The results suggest dramatic shifts in eastern African climate between extreme aridity with vanishing water bodies, strongly decreased vegetation cover and highly alkaline and saline paleolakes, and returning humid phases, such as the well documented African Humid Period (~15-5 ka BP), marked by extensive fresh water lakes, a more extensive vegetation cover and plentiful resources for human populations. The high core recovery, the well-dated and independent age model and our developing understanding of site-specific proxy formation, give us a comprehensive record of environmental history on decadal to orbital timescales.

P-4274

## The timing of humid phases on the southwestern Arabian coast: the chronological and palaeoenvironmental record of an archaeology-rich tufa basin.

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The south-eastern Red Sea region may have served as a refuge during Quaternary arid phases for hominin populations migrating out of the Saharo-African region (Bailey, 2009). Wadi Dabsa, within the volcanic landscapes of Harrat al Birk contains the richest and highest density of lithic artifacts (~3000) in southwestern Saudi Arabia (Fould et al., 2015; Inglis et al., 2019). It drains the western side of the Harrat Al Birk for a few 10s of km and the southern tributary opens into a basin (where the lithics are located) that is dominated by a tufa sedimentary unit indicating significantly, and consistently, wetter conditions at various points during the Late Quaternary, making it an attractive site for hominin populations. The range of tufa morphologies within the basin indicate that these wetter phases involved both standing and running water. The stratigraphies include units of large tufa-cemented basalt bedload (boulder-sized) recording phases of high-energy fluvial flow, and units of tufa with little, or no bedload, recording a lower-energy surface water environment.

We investigate both a basalt handaxe that is partially encased in tufa as well as tufa units on which the surface lithic archaeology is located, in addition to a tufa unit ~ 1.5 m below the surface and a large tufa cascade downstream from the Wadi Dabsa basin. The palaeoenvironmental and chronological context of the tufa and the associated lithics can be reconstructed using facies descriptions in hand section and thin-section, geochemical analysis and stable isotopic data, alongside <sup>234</sup>U-<sup>230</sup>Th dating. Here we present the analysis of 12 tufa samples across the basin, including the surface units associated with the lithic finds, a deeper unit (~1.5 m below the surface) and a fan, containing a large tufa cascade at the distal end of the basin. The results indicate wetter conditions during MIS 7 and MIS 5 (into MIS4), from a meteoric water source (not deep thermal groundwater) and a catchment covered in C3 vegetation. Comparisons are made with the timing and composition of tufa deposits on the western side of the Red Sea.

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P-4275

## Interpreting the palaeoenvironment of archaeological sites within the Nihewan Basin, North China: a new multi-proxy approach.

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Important archaeological sites regarding the spread of early humans are situated in the fluvio-lacustrine Pleistocene stratigraphy of the Nihewan Basin. The Nihewan Basin is one of the most intensively studied areas of human occupation in higher latitude areas, due to the concentration and availability of archaeological sites between 2.0-0.8 Ma. However, for sites without an established geochronology correlation proves difficult, as the nature of the sediments impedes accurate correlation. Nonetheless, preliminary results have shown that it is possible to correlate sites without prioritising the use of magnetostratigraphy. New and previously studied sites have been investigated using a range of analyses. The sites that have been analysed with this multi-proxy approach include Majuangou (MJG) and Banshan, Shigou (SG), Xiantai, Xiaochangliang, Feiliang, Madigou and Cenjiawan.

The micropalaeontological analysis includes a systematic approach to analysing ostracod taxa that has revealed 13 different species that occur within both MJG and SG. The ostracods *Ilyocypris* and *Leucomythere/Limnocythere* are the most dominant in both sections, suggesting an environmental relationship between the two sites. However, taxa including *Heterocypris*, *Eucypris*, *Fabaeformiscandona*, *Pseudocandona* and *Cytherissa lacustris*, occur within both sections, providing evidence that the environment within the both sites fluctuated regularly. The microfossil and macrofossil data have allowed for a more accurate palaeoenvironmental reconstruction and the results of the palaeontological analysis suggest that the overall palaeoenvironment was changeable. The ostracod analysis and results confirm that the studied sites were part of a semi-stable aqueous environment

Sedimentary analysis has provided detailed sedimentary logs of the Nihewan Basin, revealing erosive, transitional and sharp boundaries, aiding in correlation of sediments. Analyses and results show that it is possible to correlate MJG and SG using two erosive boundaries in SG, *Cytherissa lacustris* (used as a marker ostracod in both MJG and SG) and sedimentary features indicative of flooding, such as mud balls and silt drapes. With the use of this new multi-proxy approach, it is hoped that this project will help develop a method with the ability to efficiently correlate exposed sediment sections within the Nihewan Basin without the prioritisation of magnetostratigraphy. Furthermore, these results will help aid the interpretation of the palaeoenvironment in which early hominin occupied higher northern latitudes.

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P-4276

## The earliest evidence of hominin occupation in North Africa: chronological framework of Ain Boucherit site, Algeria

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Sahnouni et al (2018) recently reported the discovery of Oldowan lithic tools and cut-marked bones from two archaeological levels at Ain Boucherit locality, Algeria. A multi-method dating approach based on magnetostratigraphy, Electron Spin Resonance and biochronology was used to chronologically constrain the deposits. This combination provided an Olduvai and early Matuyama age for the upper (AB-Up) and lower (AB-Lw) archaeological levels, respectively. Refined age estimates of  $1.92 \pm 0.05$  Ma (AB-Up) and  $2.44 \pm 0.14$  Ma (AB-Lw) were finally derived from the sediment accumulation rate values. This discovery pushes back by about 0.6 Ma the earliest evidence of hominin occupation in North Africa, which was previously documented at the nearby site of Ain Hanech (~1.8 Ma).

Details of the dating study published by Sahnouni et al (2018) will be presented, and the different sources of uncertainty that may impact the dating results will be evaluated and discussed.

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P-4277

## A new chronology for the Middle Stone Age site of Florisbad, South Africa, using luminescence dating

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Florisbad is a key Middle Stone Age (MSA) archaeological site in South Africa. It is primarily known for the discovery of a well-preserved cranium of a late archaic *Homo sapiens*, in addition to abundant MSA artefacts. Grün *et al.* (1996) provide a limited chronology for the Florisbad sequence using optically stimulated (OSL) and electron spin resonance (ESR) dating, suggesting that the cranium dates to ca. 259 ka. This makes it similar in age to newly discovered *H. sapiens* remains from Jebel Irhoud, Morocco, dated to ca. 315 ka by Richter *et al.* (2017). However, at Florisbad there are no technical details or analysis of the OSL or ESR data, and only part of the sequence was dated. This makes evaluation and interpretation of these ages problematic. Significant developments in luminescence dating over the last 20 years, particularly the development of the single-aliquot regenerative-dose (SAR) protocol, make it timely to establish a new chronology at Florisbad.

A set of 33 samples covering the whole sedimentary sequence preserved at Florisbad have been collected for luminescence dating. Three sections (Pit 3, the Dreyer section and the Western Eye section (Toffolo *et al.*, 2017)) were sampled. Luminescence ages based on analysis of two signals from quartz have been determined for samples taken above the Middle Stone Age occupation horizon. The signals used were derived from multiple and single grain optically stimulated luminescence (OSL), and thermally transferred optically stimulated luminescence (TT-OSL) measurements. The three sets of ages agree well, giving confidence in the reliability of the ages and of both signals. The quartz OSL signal in samples from beneath the Middle Stone Age occupation horizon is affected by saturation, and hence cannot be used for reliable dating. Instead, the TT-OSL signal from older samples is used.

These luminescence ages are used to construct the first robust chronology for the sedimentary sequence at Florisbad, allowing the archaeological record and palaeoenvironmental changes (Toffolo *et al.* 2017) to be set in the wider context of southern African palaeoclimatic changes, and providing a better understanding of the palaeoclimatic context of the Florisbad cranium.

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**P-4278**

## **Lake Magadi sediments: Deciphering primary and diagenetic features**

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Lake Magadi, Kenya, a saline-alkaline lake located in the East African Rift valley, is known for its siliceous sediments including unique varieties of chert, magadiite, and abundant zeolites. Core drilling at Lake Magadi in 2014, as part of the Hominin Sites and Paleolakes Drilling Project (HSPDP), has provided the materials for detailed study of chert and other siliceous sediments. Two cores, 137.3 and 197.9 m in depth, drilled to trachyte bedrock, dated at 1.08 Ma, present an opportunity to interpret siliceous minerals in the context of evolving Magadi Basin paleoenvironments over the past one million years.

Cores contain terrigenous muds to sand-sized grains with abundant feldspars (albite, sanidine, and anorthoclase) eroded from surrounding trachyte bedrock. Finely laminated chemogenic layers of magadiite and chert derived from siliceous gel also occur in the cores. Magadiite is a hydrous sodium-silicate which forms distinctive 20  $\mu\text{m}$  lepispheres. Biogenic-rich layers contain pollen and plant fragments; volcanogenic layers have abundant pumice fragments. Many of these deposits are overprinted by early diagenesis in the saline-alkaline environment. X-ray diffraction (XRD) of Lake Magadi sediments reveals a suite of zeolites including, analcime, erionite, philipsite, and [\[T6\]](#)clinoptilolite. Scanning electron microscopy (SEM) shows diagenetic formation of zeolites, including the replacement of pumice by Na-erionite, growth of erionite in pore spaces between sediments, and replacement of feldspars by erionite. XRD analysis of pure siliceous laminae with quartz and magadiite indicates partial conversion of magadiite to quartz (chert) with an intermediate quartz phase, moganite. Understanding the magadiite to chert timing is crucial for Uranium-Thorium radiometric dating.

Fluctuating silicate mineralogy can yield important paleolimnological data which can improve the overall paleoenvironmental interpretation of the Magadi Basin.

P-4279

## The Little Ice Age and its impact on human activities in the Baiyangdian drainage, North China Plain

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Climate change, especially dry and wet changes, has an important impact on human activities. In this study, based on three AMS-<sup>14</sup>C dating, the character of climate change, especially dry-wet change and its relationship with human activity intensity in the study area were discussed since the Little Ice Age with high resolution of 99 samples of pollen, charcoal and grain size. The results showed that: During the Little Ice Age (1340~1920A.D.), the pollen of the trees decreased to less than 15%, and the pollen contents of the Chenopodiaceae, *Urtica* and *Humulus* increased significantly compared with before, indicating that the climate had dried up, but there are significant differences in the degree of drying at different stages: In the early part of the LIA(1340~1580 A.D.), the percentages of *Pinus* were more than 20%, which was highest in the LIA, and some aquatic plants *Myriophyllum* can be recorded, On the contrary, the concentration of charcoal, and Chenopodiaceae which usually represented aridity environment were relatively lower, indicating that the climate is relatively humid. During this period, the crop pollen (Poaceae $\geq$ 35 $\mu$ m) and phosphorus elements (P) contents, which related to human activities were the lowest, indicating that the lake were not shrunk very seriously, that make the human activities and land use intensity were relatively weak. In the middle of LIA (1580~1800 AD), the pollen content of *Pinus* was decreased to less than 15%, and aquatic pollen grains were very rare but the pollen percentages of Chenopodiaceae reached the highest value, shows that the climate become more arid and the lake had shrunk seriously. In the mean time, the Percentage of *Urtica*, *Humulus* and crop pollen ( $\geq$ 35 $\mu$ m), which have some relations with human activities, the charcoal concentration, and phosphorus (P) contents reached the highest value, indicating that the activities of humans were significantly enhanced because of the shrinking of the lake. In the late Little Ice Age (1800~1920 AD), the pollen content of *Pinus* was lower than 10%, and the pollen content of Poaceae and aquatic plants *Myriophyllum*, reached the highest value, indicating that the climate became humid once again. At this stage, the crops pollen( $\geq$ 35 $\mu$ m), charcoal concentration and phosphorus (P) content were slightly lower than those of the previous period, indicating that the intensity of human activity and land use were slightly decreased confined by the enlarge of the lake.

**P-4280**

## **Holocene Vegetation and Climate Change in Northeast China**

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Northeast China is an essential area for studying the strength of East Asian Summer Monsoon, due to its northernmost location in EASM domain. Furthermore, this region distributed by temporal mixed forests is the largest forest resource of China. Understanding ecosystem-climate dynamics at a broad range of temporal scales in this region becomes of key importance for forest managements and projecting climate changes in the future. However, lacking of a certain quantity of high-resolution paleoclimatic records, particularly pollen records hinder the quantitative reconstruction of paleoenvironment in northeast of China. Hence, we selected two sites, one peatland in Changbaishan mountains (eastern part of study area) and one closed crater lakes in the middle of Greater Khingan Range (western part of study area) for pollen analysis. The two high-resolution pollen records together with collected high-resolution pollen data in study region will be used for quantitative reconstructions of past environment in order to 1) draw a preliminary picture of Holocene vegetation-climate changes, and 2) understand the Holocene vegetation-climate dynamics in northeastern China.

P-4281

## A multiple proxy approach to reconstruct landscape-scale vegetation in steppe-like environments: a case study from southern Kazakhstan

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Assessing landscape-scale vegetation mosaics based on pollen data is a challenge. In temperate environments, vegetation mosaics primarily correspond to the relative proportions of grasslands, crops and different types of forest cover. In steppe-like environments such as those of Central Asia, these mosaics consider the relative proportions of grasslands, *Artemisia* steppes, Chenopodiaceae steppes and semi-deserts, riverbanks and land-use categories. Most of these land cover types reflect open and semi-open landscapes, which increases the difficulties to identify some types of mosaic patterns. This leads us to the questions:

- Do pollen assemblages provide reliable information about landscape mosaics in steppe-like environments? and
- Can a multiproxy approach help us to disentangle such information?

To answer these questions, we conducted a vegetation study in the diverse semi-arid Ili River basin in southeast Kazakhstan. This area includes two national parks (Altyn Emel and Charyn Canyon) well known for their desert and canyon landscapes, biodiversity and red-listed species. It is characterized by a variety of desert, semi-desert and steppe landscapes. We sampled surface modern soils at 37 randomly selected locations within a radius of 55 km. At each site, we undertook botanical surveys within a 100 m radius from the soil samples following the protocol of the Crackles Bequest Project, as well as within a radius of 5 km from samples. A study of “relative pollen productivity estimates” is in progress. Maps of the major land cover types for the 37 sites have been created by using Sentinel-2 optical satellite images at a spatial resolution of 10 m, obtaining an iterative supervised classification approach within the remote sensing software SNAP. We extracted and analysed pollen, phytolith and biomarker assemblages from each soil sample. We compared the observed and proxy-based information using modelling and statistical methods. Indices of plant, pollen and phytolith composition and diversity, and biomarkers (distribution of GDGTs and n-alkanes in sediments), are used for comparison.

P-4282

## Reconstructing Holocene cultural landscapes in Australia using pollen-based models

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Creating effective land management approaches requires having a solid understanding of the degree of past landscape alterations by climate change, wildfires and human activity. The quantification of these past changes depends on our ability to reconstruct past landscape openness. Fossil pollen is the key proxy to track past vegetation changes, but pollen spectra suffer from some important biases e.g. taphonomy, pollen productivity, dispersal capability. Many pollen records are dominated by pollen from a few high pollen-producing plant taxa, which mask the less producing taxa. In effect, there is a non-linear relationship between pollen percentages and plant cover. Estimating past vegetation cover from sedimentary pollen composition requires to correct for these biases using empirical-based models of the pollen-vegetation relationship. Such models for quantitative vegetation reconstruction (e.g. REVEALS) have yet been mostly applied in the Northern Hemisphere in the last 10 years - here we present recent applications of this methodology from Australia.

Although the semi-quantitative nature of Australian palynology based on pollen proportions has allowed inferences of vegetation change from pollen data, quantifying past landscape openness remains a challenge. Information on vegetation structure is needed to address archaeological questions about the origin of cultural landscapes, especially given the lack of direct association between archaeological remains and paleoecologic sites. Humans colonised Tasmania around 40,000 years ago, and are thought to have imposed a substantial imprint on the vegetation landscape through fine-scale fire management that has lasted to European arrival. Nevertheless, the origin and evolution of the present-day landscape in western Tasmania, as a result of climate variations and past human activity, has been debated. According to some, present-day treeless landscape, mostly dominated by buttongrass moorland, originated in the late Holocene due to climatic and edaphic changes coupled with increased burning. Others have proposed that moorland was previously established across the region during the last glacial cycle (ca. 35 kyrs) and was then maintained by anthropogenic burning throughout this period.

Here we show the quantification of land-cover changes through the Holocene epoch using the REVEALS model on one large site from the Cradle Mountain National Park within the World Heritage Area of Tasmania. This recent application of pollen-vegetation models has proven that treeless vegetation has been dominating the Holocene landscape in this region. We will then show consistent results from the REVEALS application using multiple small sites from within the same area. Both applications of REVEALS (single large site and multiple small sites) in Tasmania proved the biases inherent in previous interpretations of pollen spectra from this region and confirmed that the landscape of western Tasmania is an ancient cultural landscape.

P-4283

## Exploring the potential of surface pollen deposition in the British Isles

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Recently there has been increasing interest in the potential of surface pollen samples to improve our understanding of the pollen-vegetation relationship and to provide modern analogues for Quaternary plant communities. However, there are concerns that too few plant communities have been sampled or that certain past communities lack modern analogues.

This new initiative aims to improve our understanding of the representation of modern plant communities in surface pollen data and to refine the interpretation of Holocene pollen data. A surface pollen dataset will be created, encompassing a range of unique and diverse plant communities from across the British Isles, including deciduous woodland (Snowdonia, southern England and Exmoor), heathland (Snowdonia, north-east England and Exmoor), fen communities (eastern and southern England) and hay meadows (north-east England). While some British data are held in the Eurasian Modern Pollen Database, the majority are held by individual palynologists and much remains unpublished. Fragmentary data from many sites will be compiled to produce a more coherent dataset of British surface pollen deposition, to facilitate the identification of regional trends, to distinguish different vegetation types, to increase the range of modern analogues for British Holocene studies and to identify temporal trends. Surface pollen may be used to address numerous questions associated with the relationship with vegetation, annual changes in the representation of individual taxa and assessment of the impact of land management regime. Published surface moss sample data highlight contrasts between different plant communities and land-use practices, for example, moss samples from eastern England were used to demonstrate that fen vegetation, subject to different management regimes, produce distinctive pollen signatures.

Issues associated with surface sampling are addressed. Surface deposits available include pollen traps, moss samples, soils and lake surface sediments, but current research indicates that the sampling medium has a significant effect on the composition of the pollen assemblage.

A fundamental problem is the large annual variation in the quantity of pollen produced by many taxa, dependent on natural physiological rhythms in the abundance of flowering; a major contributor to the complex relationship that exists between the abundance of taxa in the vegetation and the quantity of pollen deposited. Only by sampling annually, to produce long records, can the typical quantity of pollen deposited by a taxon be accurately assessed. The considerable annual variation of *Quercus* pollen production in deciduous woodland is illustrated by pollen accumulation rates (PARs) obtained using modified-Tauber traps on Exmoor and in Snowdonia. On Exmoor *Quercus* PARs ranged from 3,500 to 26,000 grains cm<sup>-2</sup> yr<sup>-1</sup> over a 3-year period from 1996, while in Snowdonia *Quercus* PARs ranged from <500 to almost 95,000 grains per cm<sup>-2</sup> yr<sup>-1</sup>, over a 7-year period from 1996. Such information is crucial to accurately reconstruct past plant communities.

P-4284

## Relative pollen productivity estimates for main forest species in mainland Spain.

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Relative Pollen productivity estimates (RPPEs) are one of the critical parameters for a quantitative reconstruction of past vegetation cover from fossil pollen records, moving forward from the qualitative assessment of abundances based in percentages that hardly can be related to vegetation cover. RPPEs have been calculated for many regions of northern Europe, North America, Africa or China, however they have rarely been addressed in the Mediterranean region while this is a critical area as its current ecosystem heterogeneity is partly linked to past environmental factors as intertwined climate changes and human activities. It is indeed essential to have RPPEs for the Mediterranean region and therefore a larger collection of modern pollen rain from this area. This is especially true in the Iberian Peninsula (PI), where the physiographic settings define complex biogeographical patterns difficult to reconstruct.

We present here a pioneer study for mainland Spain as we calculated RPPEs for the main woody taxa of the Iberian forests as Pinus, both evergreen and deciduous Quercus, Juniperus, Fagus, Castanea, Oleacea or Abies. We have combined new modern pollen data from PaleoIPE palynological team and the available set from the European Modern Pollen Database (EMPD) with estimation of the woody cover in vegetation surveys and the archived information at the National Forestry Inventory 3 (IFN3). The EMPD holds more than 1000 samples in the whole studied area including modern moss polsters and top cores from fossil sites. We calculated RPPEs using the 3 Extended R-Value (ERV) models using the inverse modelling approach implemented in the REVEALS model. PPEs are then taken from the model with the lowest likelihood function score. We also considered a buffer of relevant vegetation of 60 km around each point.

In order to compare the effect that different environmental settings may have in the RPPEs values we divided the studied area in three subregions based on physiographic and climate criteria: coastal, continental and mountain area and we also compared differences among altitude for the same species.

Our results are discussed in comparison with those of the mid-latitudes of the Northern Hemisphere so the calculated RPPEs are expected to be different from those of the rest of the Europe. These results will necessarily have an impact on the way that the patchy Mediterranean landscape has been reconstructed and therefore our results are expected to be useful for spatial ecologists and in applied areas of nature conservation.

**P-4285**

## **Understanding pollen representation of rare herb taxa at the local scale.**

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Palaeoecological data needs to be applicable to ecology. Models adjusting quantities of key pollen types are now routinely used in palaeoecology. Treeline shifts and regional vegetation change can be established and linked with climate and land-use change models to predict future trajectories. At the local-scale, in high-nature-value cultural landscapes, a fundamental mainstay of ecological change data are vegetation cover and biodiversity surveys. These surveys can be detailed, using vegetation data from a suitable number of quadrats to develop site categorisations such as the National Vegetation classification and the European Habitat descriptors in the UK and Europe. Ecological data and palaeoecological data at the local scale need to be tested further to assess the ability to link the two datasets at this scale. Since much of the vegetation recorded in biodiverse sites produces pollen or spores sporadically, or sparsely, how far can we go with links between pollen survey and ecological survey? This paper presents research that has been attempting to discover the analytical limits of ecological palaeoecology. Using rare type pollen taxa surveys in cultural upland landscapes a modern pollen-vegetation analysis provides binary and semi-quantitative data to link pollen presence and abundance to vegetation presence and abundance at different spatial scales. In addition, the density of grazing animals is tested by relating abundance of animals to coprophilous fungal spore data in the samples. A range of differing source areas for rare-type pollen are evident, some challenges to previous assumptions on source area for herbaceous types are evident. Although a range of pollen types are clearly stochastic in distribution through the landscape and therefore into palaeoenvironmental sediments, there are also some useful patterns that emerge for some taxa, which allow a more rigorous basis for future palaeoecological interpretation and ecological linkages and these will be discussed.

P-4286

## Discovering small scale vegetation patterns with the EDA

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Pollen is known to be a powerful and valuable proxy of past vegetation. Yet, only over the past decade methods for true quantitative interpretation of pollen data have become available. Model development and application has hitherto focused on single pollen records from large lakes or mires, which ideally represent mean regional vegetation composition. The results are well suited for syntheses on the regional to continental scale, e.g. within the PAGES LandCover 6K Working Group. Such syntheses are instrumental for a better understanding of e.g. general post glacial vegetation history and climate-landcover interactions. Other questions, e.g. about plant migration pathways, past communities and early human impact, require reconstructions with higher spatial resolution. The extended downscaling approach (EDA) is one of the approaches designed to reconstruct vegetation patterns within landscapes. To that end, the EDA combines analysis of numerous pollen records from across a landscape with analysis of known (or constructed) patterns in the landscape, e.g. the soil or relief pattern. The approach then randomly assigns vegetation composition to each unit of that pattern (e.g. each soil type) and uses a forward-modelling algorithm to explore, which vegetation composition best explains the observed pollen deposition in all the numerous records during selected time slices. As a result the EDA calculates vegetation composition associated with each unit of the given landscape pattern (e.g. with each soil type).

The approach is illustrated with pollen data from northern Germany and Poland, covering the mid to late Holocene. Using the EDA results first a number of ecological and archaeological questions are discussed: How were forests composed before neolithization? Did open patches remain in the landscape (which might explain the persistent presence of e.g. horse)? Did neolithic and bronze age settlers prefer particular sites? How did natural factors, i.e. the expansion of *Fagus sylvatica* and *Carpinus betulus* and human activity change forest composition?

Secondly, technical and methodological issues are discussed, e.g. concerning site selection and accuracy of the results.

Finally, needs and options for the further development of the method are discussed.

References:

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P-4287

## Dynamics of the wildscape: human impacts and land use change within a wetland landscape

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We explore changing dynamics and interactions between wetland landscape ecosystems and consider how archaeological activities and palaeoenvironmental records reflect land transformations and usage over time. Our focus is the Humberhead Levels, UK, (North Lincolnshire and South Yorkshire), just south of the Humber Estuary, where there has been a long history of palaeoenvironmental and archaeological study. The raised mires of Thorne and Hatfield Moors dominate the landscape, closely surrounded by the floodplains of the rivers Torne, Idle, Don and Went. The diverse and complex character of wetland development and human-environment interactions within the floodplains and mires is outlined through the combined use of extensive chronological Bayesian modelling, widespread geoarchaeological mapping, GIS and Lidar. These provide new insights into the temporal palaeogeography of the region. An extensive archaeological database of over 7000 points enables us to infer the nature and focus of human activity and land use, whilst thirteen pollen records provide detailed insights into the vegetational history and allow us to reconstruct the land cover history of key archaeological periods. Selected land cover reconstructions of prehistoric time slices together with archaeological data are presented, to highlight differing land use and land cover over time and how these compliment each other.

Early archaeological activity is focused alongside river systems and on higher elevations of dryland edges, especially during the Mesolithic and Neolithic. Oak and lime woodland likely dominated the higher elevations, with alder carr, wet grasslands and marsh dominating low-lying areas within the river valleys. Human impacts are evident from the early Neolithic (c. 3800 cal BC), whilst the development of raised mire and floodplain deposits from 3300 cal BC herald increasingly important wetland habitats. The continuing importance of these places for people is evidenced by a Neolithic pine corduroy trackway on Hatfield Moors (2800-2500 cal BC), a Bronze age trackway on Thorne Moors (1860-1300 cal BC), whilst the distribution of elaborate artefacts during the Bronze Age, frequently associated with wetlands and their edges, signify continued usage and importance of these areas. Woodland decline accelerates during the early Bronze age (c. 2300 cal BC) in the River Torne, Idle, Hampole Beck floodplains, with alluviation likely the consequence of agricultural clearance. After 500 cal BC, extensive woodland clearance occurred, especially widespread decline in lime woodlands. The development of an open landscape is supported by extensive archaeological finds and aerial photographic evidence, which shows large numbers of field systems and enclosures, and much of the evidence supporting continuity of landscape tenure from the Iron Age into the Roman period.

Only by reconstructing the dynamics of the wildscape of this region does it become possible to understand complex patterns of human impact and land use change, demonstrating the importance of such an approach to the study of past landscapes.

**P-4288**

## **Fire, rain and civilizations in the Horn of Africa during the last three millennia**

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Palaeoenvironmental records during the Pre-Aksumite and Aksumite periods in northern Ethiopia are interrogated using stable isotopic, elemental and charred plant remains in soils to provide local- and regional- scale records for environmental variability, including changes in rainfall, plant cover, & fire characteristics. This research is a multi-institutional initiative to examine patterns of past and present human-environmental interactions in the Horn of Africa. Specifically, the results from this transdisciplinary team aims to combine archaeological, paleoecological and traditional knowledge to understand early state formation during the Pre-Aksumite and Aksumite periods (1600 BC-AD 700). We have found charred plant remains to be ubiquitous in most soils throughout the mid-to-late Holocene and thus charcoal provides a valuable proxy for fire, climate forcing and land cover history. Previous work suggests that both Pre-Aksumite and Aksumite polities emerged during wet intervals and that the rise of the Pre-Aksumite followed a significant increase in C<sub>4</sub> relative to C<sub>3</sub> plant cover as well increased burning across multiple study sites on the Tigray Plateau. Increased intensity and magnitude of landscape burning prior to the Aksumite period was followed by reduced fire activity both locally and regionally. Changes in fire activity were likely modulated by increased human populations that are embedded in the natural climate variability coinciding with the Medieval Climate Anomaly (increased fire) and Little Ice Age (decreased fire) climates of the last millennia. The long-term effect of intensified human settlement is captured by changes in fire frequency, reduced fire episode magnitudes and suggests the Aksumite Polities created a fuel-limited landscape where most fires were likely managed.

**P-4289**

## **Long-term vegetation dynamics in the highlands of the Hyrcanian forest in northern Iran**

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The Hyrcanian forest hosts 3234 plant species including ca. 500 endemic plants. Along with the forests of northern Anatolia, Hyrcanian forests constitute the most important refugia and the last relicts of broad-leaved deciduous forests that covered the temperate zones of the northern hemisphere before the Quaternary. This area hosting many remnants of the Arcto-Tertiary and Indo-Malaysian flora, make this area as a centre of biodiversity with global importance. Anthropogenic forces have extensively modified the vegetation in the last centuries. Occurring in such changeable environmental conditions, investigating the Hyrcanian environmental history, including vegetation, plant diversity, climate, fire, human impact and sea level change, are of crucial importance. The isolated southern coast of the Caspian Sea to western Eurasia and its vegetation history can provide new insights into the refugium hypothesis for the west Eurasian temperate deciduous forest.

This study applies innovative multi-proxy analysis (pollen, spores, charcoal, geochemistry, and radiocarbon dating) on the Pounel sediment core, which is located in the highlands (2284 m a.s.l.) of Alborz mountain in Gilan, in order to reconstruct the alteration of vegetation since Bronze Age.

P-4290

## Vegetation dynamics since ~16ka from monsoon dominant region of western Himalaya: Inferences on glacial and landcover changes

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The geographical position and orientation of the Himalayas deeply governs the monsoon distribution and the vegetation and glacial dynamism. Absence of long continuous temporal vegetation records from various monsoon zones of the region limit the understanding on the vegetation and glacial dynamics in relation to major global climate events as well as landcover assessment. Here we reconstructed a continuous post LGM (~16ka to recent) vegetation based on the pollen data from a 2.5 m deep sandy to peaty sequence of subalpine meadow (~3500 masl) within the monsoon dominant Dokriani glacial valley, Uttarakhand, western Himalaya. Changes in the pollen assemblage correspond well with the major global climate events, also providing the glacial and landcover scenario since ~16ka. A major shift in the pollen assemblage at ~11.8ka differentiate the cool-dry pre-Holocene and warm-moist Holocene epochs. The pre-Holocene (~16 to 11.8ka) sequence recovered high pollen frequency of dry/steppe taxa (*Ephedra* 1-2%, Chenopodiaceae 5-20%, *Artemisia* 2-5%, Liguliflorae 2-10%, Tubuliflorae 1-4%) and conifers (*Pinus* 15-70%, *Abies* 3-9%, *Picea* 2-4% and *Cedrus* 1-3%) contrary to low frequency of broadleaved (*Betula* <1%, *Quercus* 5-15%, *Alnus* 1-3%) and mesic/moist taxa (Ranunculaceae, Apiaceae, Polygonaceae, Pteridophytes etc). Valley experienced less ground vegetation cover, mainly with the growth of steppe taxa at meadow site. Also the sandy/silty lithology indicates high erosion and deposition under fluvial environment. Pre-Holocene tree line remained much downstream than its present limit (~3500 masl) with *Pinus* and *Abies* as main treeline elements. Glacier snout was also much downstream than its present altitude of ~3900 masl. Climatically the valley experienced weak summer monsoons and strong westerlies. Commencement of the Holocene is significant at ~11.8ka by the sharp decline of arid/steppe taxa and diversification of mesic/moist ground vegetation (Ranunculaceae 5-10%, Apiaceae 10-40%, Polygonaceae 5-15%, Gentianaceae 2-5%, Cyperaceae & Pteridophytes 5-10%) that added in the development of peaty sequence under moist conditions due to strengthening of monsoon. Following the glacial retreat under warm conditions, tree line advanced to higher reaches with *Abies* (5-15%), *Betula* (1-3%) and *Quercus* (15%) as early Holocene treeline elements. *Pinus* (5-20%), *Picea* and *Cedrus* declined to their lowest limit. By ~8.5ka *Quercus* (40-55%) dominantly occupied the valley and the treeline might reached its present limit by mid-Holocene (5-4ka). Decreasing trend in the *Quercus* with increase of *Pinus* since ~1.5ka could indicate the monsoon weakening or high evapotranspiration due to rise in temperature at higher altitudes. Further, globally related pre-Holocene climate episodes (Older Dryas, Bolling-Allerod and Younger Dryas) are strongly captured by the proxies as compared to Holocene climate variability. This signifies a strong ITCZ interplay during pre-Holocene time and weak impact of Holocene North Atlantic cooling episodes (8.2ka, 4.2ka and LIA) at the monsoon dominant regions of Himalaya.

P-4291

## Quantifying Holocene human impact using pollen-indicator indexes: identifying pitfalls and possible solutions

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Anthropogenic pollen indicators in pollen records have been a traditional tool to reconstruct the history of human impact on the landscape and the biosphere. In addition, human indicators are essential to disentangle the influence of human activities and climatic variability on ecosystems. In this respect, the comprehensive anthropogenic pollen indicator approach developed by Behre (1981), has been widely used over extensive regions, in certain cases beyond its original geographical scope of Central and Western Europe. Uncritical adoption for other areas is risky because it might be that certain pollen-types considered as adventives (i.e. plant species introduced by humans, deliberately or not) in one region might actually be apophytes (i.e. native plant species favoured by human disturbances) in other regions, making the meaning of their presence and/or abundance very different across time and space. Some research efforts have been done to compile more specific lists of pollen types associated to human activities for well-defined parts of the world (e.g. Brun, 2011), while in other cases selected anthropogenic pollen indicators have been combined into index-like algorithms to infer anthropogenic disturbance (e.g. Tinner et al., 2003). We have reviewed the most commonly used approaches to quantify anthropogenic impacts from pollen records in Europe and we assess their performance at five sites spanning a continental gradient. We present insights on how these methodologies can assist in the interpretation of pollen records, and on how a careful selection of both pollen types and their combination according to the specific geographical scope of each study is key to get meaningful reconstructions of human activity through time. We conclude that alongside the increasing wealth of pollen datasets there is a need for developing novel tools that may assist for numeric human-impact reconstructions.

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P-4292

## Pollen based quantitative reconstruction of landscape before and after the construction of Yin Ruins, Anyang, China

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Yin Ruins is the capital of the late Shang Dynasty located in the Anyang City, occupies an important position in the history of Chinese civilization. In what climatic and environmental background of the Yin Ruins was constructed? And how does climate and environment affect the culture of the late Shang Dynasty? In order to solve these problems, we quantitative reconstructed the regional landscape before and after the Yin Ruins was constructed based on pollen data and LRA method (Landscape Reconstruction Algorithm). The result shows that: Before the construction of the capital (4000-3600 cal year BP), forest developed in the Anyang region (34%); large areas of forest around the Yin Ruin area (42%), farmlands scattered along the Huan River and about 15% of regional landscape, mixed broadleaf-coniferous forest associated with evergreen broadleaf species occupied the western mountains and hills (47%), and extensive wetlands developed in the downstream of the Huan River. After the construction of the capital (ca. 3400 cal year BP), forest reduced (13%) and farmlands increased (33%) in the Anyang region. Combined with the archeological data and geological evidence, we suggested that: Before the construction of the capital, the climate around the Anyang City was warm and humid, and the region was rich in forest resources, which provided sufficient building materials and fuel resources for ancient Shang people; Villages and farmlands scatter distributed along the Huan River, which provided plentiful food for the people, and human resource for the city construction. In addition, regional topography and hydrological condition also provided favorable guarantee for the construction of the city. The construction of the capital, the expansion of human activities, especially the intensification of cultivation, had a significant influence on the natural landscape.

**P-4293**

## **Inferring natural vegetation before reclamation from historical literature : cases in China**

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The records on natural vegetation or landscape extracted from the historical literature could be used as proxy for reconstructing historical natural vegetation. China has an advantage in such a research for rich in historical records. The historical records that could be used to reconstruct the historical natural vegetation are mainly classified as following types : (1) the descriptions on both vegetation forms and distributions, which could be directly used to infer the natural vegetation; (2) the records on vegetation destruction for reclamation, which could indicate the natural vegetation before reclamation and the time to be destructed; (3) the information on the boundaries of the reclamation in different periods, beyond where the natural vegetation state could be maintained; (4) the productive activities associated with some specific types of forests, grasslands, etc., which could indicate the corresponding type of vegetation. Employing the GIS technology, and combining with modern vegetation maps or potential vegetation distribution, the above-mentioned records could be used to infer a broadly range of vegetation types. Some case studies are made by using the historical records to infer the regional natural vegetation or landscape distribution in the history of China.

P-4294

## Towards a new reconstruction of past regional land-cover in Central Asia

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Land cover and land use influence the climate system from regional to global scales through biogeochemical (e.g. CO<sub>2</sub>) and biophysical (e.g. energy exchanges in the biosphere) feedbacks. Quantitative information about these changes are critical for accurate vegetation and climate modelling in order to quantify their impacts on the climate system.

A long-term perspective (centuries to millennia) of changes in land cover and land use can be assessed by using pollen-based modelling approaches such as the REVEALS model. REVEALS estimates are now available for much of the northern Hemisphere. However, few data exist for the vast area in the centre of the Eurasian continent, the Central Asian steppes and piedmonts. Since this region is situated at the intersection between the major northern hemispheric climate subsystems, it is necessary to apply REVEALS to Central Asia in order to understand vegetation-climate feedbacks and dynamics on the world's largest continent.

Central Asia is characterized by a variety of environmental (deserts/steppes to forests) and topographical (ranging between 3000-7500 m for the highest peaks) factors that affect pollen-vegetation relationships and thereby REVEALS estimates. Available pollen records in this region substantially overestimate pollen types deriving from lowlands and steppe-like environments, in particular *Artemisia* and Chenopodiaceae taxa. Relative pollen productivity estimates (RPPs) of these taxa have been difficult to assess so far and correspond to a vast range of values. The greatest challenge for RPPs in this region include the selection of sites and approach to vegetation collection; the inclusion of different species into a unique pollen type and landscape characteristics may play an additional role.

The present study explores the pollen-vegetation relationships of steppe- and desert-like plant taxa, focusing on *Artemisia* and Chenopodiaceae pollen types. The study area is located in the Ili River basin lowlands of southeast Kazakhstan. We undertook botanical survey, created vegetation maps and took modern pollen samples at thirty-seven randomly selected locations dominated by steppe- and desert-like vegetation within a radius of 55km. Here, we 1) discuss pollen taphonomy in terms of preservation, production, dispersion and deposition, 2) estimate the relevant source area for pollen and 3) calculate RPPs for the major plant taxa. We used the Extended R-value model coupled with the Lagrangian Stochastic Model (LSM) and Gaussian Plume Model (GPM) for modelling. RPP outcomes based on both LSM and GPM models are required to analyze the effects of wind-driven uphill transport and the differential vertical dispersion of pollen, as well as the long-distance transport of pollen in the mountain ranges of Central Asia, and therefore to get accurate land-cover reconstructions for this region of the northern Hemisphere.

P-4295

## Towards quantifying Holocene changes in forest cover in the Araucaria forest grassland mosaic of southern Brazil

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Pollen based local and regional land cover reconstructions have been successfully carried out in the high latitudes of the northern Hemisphere, while tropical and subtropical settings with many insect pollinated taxa still provide a challenge. Southern Brazil is characterized by a natural mosaic of open grasslands and woodlands characterized by *Araucaria*, which has changed in proportion during the Holocene possibly due to changes in precipitation and fire regime. In order to estimate the changes in woodland cover quantitatively we studied the modern pollen deposition in two natural remnants of the mosaic of Grasslands with *Araucaria* forest to estimate the first rPPE's for this region. Surveys of surface pollen deposition and vegetation cover were carried out in Aparados da Serra National Park, Rio Grande do Sul State and Vila Velha State Park, Parana State. Preliminary results show that woodland taxa other than *Araucaria* are strongly underrepresented by their pollen, while some shrubs frequently occurring at the forest edge have a good pollen representation. We will compare the results from the two regions with different woodland composition and discuss the challenges of reconstructing the forest cover in this region. Applying the results to published Holocene pollen data from the region we will explore the strength of this approach for the area.

P-4296

## Pollen-based quantitative land-cover reconstruction for northern Asia during the last 40 ka

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We collected the available relative pollen productivity (RPP) estimates for 27 major pollen taxa from Eurasia and applied them to estimate plant abundances during the last 40 cal. ka BP (calibrated thousand-year before the present) using pollen counts from 203 fossil pollen records in northern Asia (north of 40°N). These pollen records were organised into 42 site groups; and regional mean plant abundances were calculated using the REVEALS (Regional Estimates of Vegetation Abundance from Large Sites) model. Time-series clustering, constrained hierarchical clustering, and detrended canonical correspondence analysis were performed to investigate the regional pattern, time, and strength of vegetation changes, respectively. Reconstructed regional land cover for each site group is generally consistent with *in situ* modern vegetation in that vegetation changes within the regions are characterized by minor changes in the abundance of major taxa rather than by invasions of new taxa, particularly during the Holocene. We argue that pollen-based REVEALS estimates of plant abundances should be a more reliable reflection of the vegetation as pollen may overestimate the turnover, particularly when a high pollen producer invades areas dominated by low pollen producers. Comparisons with vegetation-independent climate records show that climate change is the primary factor driving land-cover changes at broad spatial and temporal scales. Vegetation changes in certain regions or periods, however, could not be explained by direct climate change, for example inland Siberia, where a sharp increase in evergreen conifer tree abundance occurred at ca. 7~8 cal. ka BP despite an unchanging climate, potentially reflecting their response to complex climate-permafrost-fire-vegetation interactions and thus a possible lagged climate response.

**P-4297**

## **Insect assemblages and the development of culture steppe**

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The impact of insect species which are linked with man-made habitats and human dispersal has been of global significance. Their early expansion from their original niches into Europe is related to discussions of climate change, origins of domesticated plants and animals, the spread of agriculture and infectious diseases. In order to establish the possible development of anthropogenic landscapes from an insect point of view this paper will collate and examine assemblages from different periods, having as baseline the mesolithic prior to the introduction of agriculture, utilising the collation of data in the Bugs database. The importance of human induced change as a driver for changing insect faunas, the expansion of once marginal habitats into widespread ones and the restriction of others is evident from the Holocene fossil record, with the expansion of invasive species into new geographic areas. The results, in different chronological slices, show the development of faunas shaped by settlement pastoralism and farming. They also show links between mobility of farming groups and distribution of synanthropic insect species and produce a roadmap for the different cultural periods of the Late Holocene, based on dispersal of anthropochorous species. From storage of cereals and the introduction of domestic animals and agriculture to the spread pastoralism and expansion of exchange networks in the Neolithic, the distribution maps of these taxa provide evidence for biogeographic change and the first wave of ecological imperialism in Northwest Europe, the origins of the culture steppe. Alien insect introductions linked with itineraries of armies conquered the old world. The footsteps of the Roman army at the most northerly parts of the Empire are closely mapped by the recovery of granary weevils from well dated assemblages, but introductions also include less obviously synanthropic species, able to hitch a lift on the baggage and fodder train. From the Roman period onwards the assemblages become more strongly synanthropic, as a culture steppe develops, and this pattern continues up into the 19<sup>th</sup> century, where a transition begins to more homogenised industrially farmed environments. Urban as well as rural faunas show similar transitions as part of the development of anthropogenic environments, and these include pathogens and insect borne diseases which find new reservoirs and their distribution expands with the complexity of networks and settled areas from the first urban centres. From the medieval period, the fossil insect records indicate further expansion and changes which parallel the spread of epidemic diseases and the great biotic exchange which began with the settlement of the Americas. The overview of the expansion of human impacted faunas, its timing, geographic range and rate of change, provides information about the development of synanthropic environments and an understanding of the process leading to the current era of globalisation.

P-4298

## High resolution simulations of climate and vegetation in Europe at the Last Glacial Maximum

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This work presents a new gridded dataset of surface conditions in Europe during the Last Glacial Maximum (LGM, 21 kya) including climate, vegetation cover, and soil temperature. To obtain the new dataset, we carried out a 30-years simulation for LGM conditions performed by an iterative asynchronous coupling between the Weather Research and Forecasting (WRF) model and the Lund-Potsdam-Jena Dynamic Global Vegetation Model version LMfire (LPJ-LMfire). The domain encompasses Europe at 18 km spatial resolution. The iterative asynchronous coupling design consists of four parts: (i) the fully coupled Community Climate System Model version 4 (CCSM4) provides global atmospheric variables for the LGM conditions to generate the first approximation of land cover with LPJ-LMfire on a coarse grid (ca. 100 km), (ii) WRF is driven by CCSM4 and uses the surface variables obtained in step (i) to generate the first downscaled atmospheric variables for the LGM at 18 km grid size, (iii) LPJ is run with the downscaled atmospheric variables (of step ii) to produce the land cover at 18 km, (iv) same as in (ii) but WRF uses surface parameters at 18 km resolution. Parts (iii) and (iv) were carried out asynchronously over 8 iterations to achieve a stable equilibrium between land cover and climate. Focusing on vegetation and land use, the results show that vegetation cover is reduced progressively in each step of the iteration. The vegetation fraction decrease strongly from 60 to approximately 20 % from the present to the LGM conditions. The MODIS land use category of bare/sparsely vegetated land is mostly observed over Europe in the LGM compared to cropland in the present. Our results compare favourably with pollen-based land cover reconstructions for LGM Europe, and show that asynchronous coupling is still a valuable method for preparing high-resolution reconstructions of past land cover and climate. Thus, the new LGM surface cover at 18 km grid spacing enables us to have insights of the regional vegetation pattern, which together with reconstructed datasets can improve the characterisation of the LGM climate. The resulting dataset can not only be used by atmospheric models as an input to make the representation of the surface fluxes more realistic, but it will also be valuable for a range of studies that consider the environmental history of Europe including climate, ecology and biodiversity, and anthropology.

P-4299

## Historical land cover changes in Pannonia as inferred by REVEALS modelling of pollen spectra from Lake Balaton

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Pollen records from large lakes are ideal to infer regional vegetation cover (LRA-REVEALS), and in association with several small lakes they can be used to reconstruct local vegetation composition from small lakes in the same landscape (LRA-LOVE). Balaton is the largest lake in Central Europe with nearly 600 km<sup>2</sup> surface area. In scope of an ongoing project (GINOP-2.3.2-15-2016-00019) three continuous cores were retrieved from the lake with a special focus on the reconstruction of anthropogenic land cover changes (ALCC) in the area over the last 2000 years. <sup>210</sup>Pb and <sup>137</sup>Cs dating was applied in conjunction with AMS <sup>14</sup>C dating on pollen extracts and terrestrial plant macrofossils. These provide a firm absolute chronology for the sediment sequences. High resolution pollen study of the last 500 year deposits was used to run the REVEALS algorithm and obtain regional plant abundances using a set of 26 pollen types for which pollen productivity estimates were calculated in the neighbouring Moravia Region (Kuneš *et al.*, in review). This was followed by the comparison of the percentage share of land cover classes (deciduous forest, conifer forest, pasture/grassland) in the surface samples with the CORINE Land Cover inventory. Increasing the radius of the modern land area around the lake in consecutive circles, the best match between the surface pollen sample inferred modern land cover and the REVEALS based land cover was obtained at 200 km suggesting that the pollen source area of Lake Balaton is ~200 km.

If we look at the last 500 years, the most conspicuous change is the rapid decrease of beech forests around 1870 following the Austro-Hungarian Compromise in 1867, its partial replacement by oaks that shows very good agreement with the forestry literature. Forest industry favoured oak due to its valuable timber and good growth performance in beech forest habitats. The second drastic landscape change took place during the onset of the 2<sup>nd</sup> World War, around 1939 when the Pannonian landscape showed a massive decrease in all forests types, but particularly in oak forests. This change shows also good correspondence with the written sources.

Another significant result of the ALCC reconstruction was the demonstration of forest cover decrease between AD 1500 and today; the original 70% forest cover (excluding plough land) decreased to 35% at its minimum at the turn of the 20<sup>th</sup> century and during the Second World War and subsequent two decades. Forest cover increased since the 1970's to a small extent.

The significance of this research lies in the demonstration of good correspondence between written sources and reconstructed ALCC for the last 500 yrs. Our next attempt is to extend the LCC reconstruction back to the entire Holocene and identify periods with ALCC.

P-4300

## Reconstructing spatial and temporal dynamics of slash-and-burn cultivation practiced in Central Russia

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It is believed that the slash-and-burn cultivation (SABC) was practiced at least since the Bronze Age. Numerous archaeological cultures were associated with the SABC subsistence based on the evidence for plant cultivation in the absence of agricultural implements and frequent changes in the location of dwelling sites. Given the short cropping phase and a long rotation cycle of SABC, it is assumed to have been ubiquitous in the past, affecting many forested landscapes. However, its diagnostic features in the soil were formulated only recently, thanks to the work of Tomson et al (2018) who found sites affected by the SABC in 19th century, localized them in the landscape and showed the importance of soil charcoal assemblages for determining whether a site was involved in the SABC cycle in the past. A multi-proxy analysis of the historically documented swiddens (Ponomarenko et al. 2018) showed that the swidden layers appeared as 5 to 10cm thick, dark-coloured “humus” layers with a characteristic scalloped lower boundary, formed by numerous constructions of fossorial insects, predominantly sweat bees (Fig. 1). The dark coloration originates from high concentrations of charcoal fragments with a median length of 4 to 5 mm, pebbly shape and silt coating, uniformly distributed within the swidden layers. Swidden charcoal assemblages contained a low proportion of bark (<10%), with foliage (buds and needles) being a common component, in contrast to the products of forest fires dominated by charred bark. Phytolith content of SABC layers varied from tens to hundreds of thousands per gram of soil, with up to 50% of phytoliths being charred. SABC layers contained dendritic and/or panicoid phytoliths and cereal glumes and paleas indicative of in situ cultivation of crops. These diagnostic features laid a methodological base for our current project “Temporal and Spatial Dynamics of SABC in Central Russia” (RFBR project 19-04-01246A) using a network of sites located along the major waterways that acted as traditional migration routes and presented opportunities for swidden cultivation on river banks. According to the analysis of the first 20 sites within this network, the oldest traces of the Early Iron Age SABC were found so far in the sites located on Mid-Volga, within a modern forest-steppe zone. A greater number of sites will be analyzed to create a preliminary map of SABC and draw possible routes of the swidden technology transfer/migration within the Russian Plain. All interested researchers are invited to collaborate on the project, contributing locations of sites where the soil morphology diagnostic of SABC (Fig. 1) was recorded to the database.



Fig.1. Cinder-grey swidden layer (Apyr) dotted by numerous chambers of sweat bees, found under a burial mound of 11th century, Busharino, Russia.

P-4401

## Enhanced surface melting of the Fennoscandian Ice Sheet during periods of North Atlantic cooling leads to Heinrich Events

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Heinrich Events (HEs) are dramatic episodes of ice melting and rafting during periods of exceptionally cold North Atlantic climate. However, the causal chain of events that leads to their occurrence is unresolved. Here, we demonstrate that enhanced summertime melting of the Fennoscandian Ice Sheet (FIS) is a recurring feature of Heinrich Stadials (HSs), the cold periods during which HEs occur. We use neodymium isotopes to show that the Channel River transported detrital sediments from the eastern interior of Europe to the Bay of Biscay ca. 158 to 154 ka. Based on similar evidence from the last glacial period, we infer that this interval corresponds to the melting and retreat of the southeastern Fennoscandian Ice Sheet (FIS) margin despite contemporaneous cooling in the North Atlantic and central Europe. The FIS melting episode occurred just prior to a HE, consistent with findings from the more recent HSs 1, 2, and 3. In this way, we elucidate the sequence of events that leads to HEs. Precursor melting of North Atlantic-adjacent ice sheets induces an initial AMOC slowdown. Atmospheric changes during the resulting HS cause the summertime warming in northern Europe that drives enhanced FIS surface melting. Subsequent meltwater injection to the North Atlantic causes further weakening of the AMOC and the warming of intermediate water masses that triggers HEs.

P-4402

## Melting of the Alpine Ice Sheet during Heinrich Stadials: A view from the Danube sediment routing system

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During the last glacial period, the Black Sea was a giant lake that collected sediment-laden meltwater from the Fennoscandian (FIS) and Alpine (AIS) ice sheets through the Dnieper and Danube rivers, respectively, making this basin a suitable location to investigate past fluctuations of the European ice-sheets. As a prominent example, the Black Sea sediments revealed abrupt drainage cycles of the FIS at the end of the last glacial period, and during Heinrich Stadial 1 (~18-15 ka BP) in particular (Soulet et al., 2013). In contrast, the evolution of the AIS has never been explored from the Black Sea sediments and the Danube depositional system. Here we bridge this gap by studying the Calypso long-piston core GAS-CS01 (33.4 m), collected by 240 meters water depth during the GHASS cruise (Ifremer, 2015), and ideally located next to the Danube Canyon (NW Black Sea). The chronological framework reveals that GAS-CS01 core extends back to ~32 cal kyr BP with sedimentation rates reaching up to ~6 m/kyr. Core GAS-CS01 consists of even, parallel clastic rhythmites, with ~3050 silty to sandy laminae revealed by X-ray imagery. Accurate observations of the sandy beds reveal well-developed inversely graded facies, sedimentary structures and erosional contacts characteristics of hyperpycnal turbidity-current deposits. Hence, GAS-CS01 core provides a high-resolution flood record of the Danube River. The precise count of clastic rhythmites per time interval (250 years) suggest four main periods, each of 2-3 kyr duration, of enhanced flood frequency between ~32-15 ka BP, precisely at ~32-29 (Heinrich Stadial -HS- 3), 25-24 (HS 2), 21-19 (end of the Last Glacial Maximum) and 17.5-16 ka BP (HS 1). Interestingly, during the same periods, the sedimentary record also displays significant changes in clay mineralogy assemblage, with prominent (*i.e.* metamorphic) Alpine signatures (except for the HS 1 event that shows a Fennoscandian origin; Soulet et al., 2013). Such increases in flood frequency require an increase freshwater volume in the upper Danube drainage area, and because HSs are coeval with general cold, arid conditions in Central Europe (*e.g.* Fletcher et al., 2010), we assume Alpine melting episodes during HSs in response to summertime warming. These results, consistent with those obtained for the Fennoscandian Ice-Sheet during HS1, HS2 and HS3 (Toucanne et al., 2015), confirm that HSs were highly seasonal in character.

**P-4403**

## **Using Bayesian techniques to reconstruct the Antarctic Ice Sheet at the Last Glacial Maximum.**

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Understanding the way ice sheets are affected by warming is vital for accurate projections of climate change. By better understanding the past size and shape of the Antarctic ice sheet, we may be better able to understand how it may change in the future. This research uses a combination of Bayesian analysis and proxy data to create a model of the Antarctic ice sheet at the Last Glacial Maximum (LGM). We do this by finding the relationship between the ice sheet shape and water isotopes measured in ice cores.

A prior model developed using existing reconstructions of the ice sheet describes its size and shape during the LGM. Outputs of this model, determined by a consultation with experts, have been run through the general circulation model HadCM3, providing us with a set of water isotope estimates. The relationship between ice sheet shape and water isotopes is explored using a Gaussian Process emulator of HadCM3 and water isotope observations collected from ice cores. We can then find an ice sheet shape that will create isotopic values that match as closely as possible to the observations collected from ice cores, and therefore create a more accurate estimate of the ice sheet at the LGM. This allows us to quantify the uncertainty in the shape and incorporate expert beliefs about the Antarctic ice sheet.

**P-4405**

## **Estimating climate variability during the last Glacial and Holocene from pollen records**

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Climate variability influences the probability of extreme events and is therefore of great importance for risk management. Nevertheless, the changes of climate variability over time are much less studied than changes in the mean state of the climate system, especially for the hydroclimate. Proxy records can be used to estimate the dependency of climate variability on the state and timescale, but their climate signal is perturbed by non-climatic processes and dating uncertainties. Studies show that climate variability during the last Glacial was much larger than in the Holocene and that the changes in variability depend on latitude. Our goal is to estimate climate variability on centennial to millennial time scales during the last Glacial and the Holocene at mid-to-low latitudes from pollen records. This complements previous estimates from ice cores and marine sediments. The proxy-based estimates can be used for benchmarking climate models and to give new insight on the mismatch between climate simulations and proxy based reconstructions.

Based on existing approaches from the literature, we apply Bayesian reconstruction models for pollen percentage data which can include multiple types of uncertainty stemming from the pollen-climate relation and age-depth modelling. The statistically rigorous quantification of transient uncertainties facilitates robust estimates of climate variability. Joint reconstructions of temperature in the growing season and moisture availability are planned. To account for the effect of lower CO<sub>2</sub> concentrations during the last Glacial, analytic corrections of the modern calibration will be incorporated in the Bayesian framework. The method is applied to publicly available pollen records.

An extension of the Bayesian framework to multi-proxy reconstructions by inverting forward models for other proxy types is envisaged in later stages of the project to borrow strength of the estimates.

**P-4406**

## **A Bayesian statistical model for reconstructing and analysing former sea levels**

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In order to understand the present we must first gain insight into the past. Therefore, to understand and have historical context for current rates of sea-level rise we need to be informed about past changes that have occurred. Sea-level reconstructions can provide this information by giving us insight into the magnitude and rates of past sea levels.

We have produced sea-level reconstructions along the U.S Atlantic East coast using biological and geochemical sea-level indicators preserved in dated cores of salt-marsh sediment. I have developed statistical models that can help us to bridge the gap between the information held in these raw proxy data and a high-resolution sea-level reconstruction. Using a Bayesian framework for these models aids in the understanding and quantification of the uncertainty that is inherent in these data and the resulting records of former sea levels.

We present A Bayesian transfer function modeling approach that is used to produce reconstructions of past sea level through the calibration of a biological proxy (e.g., foraminifera) into tidal elevation. The first step in the transfer function approach is building a model that captures the relationship between a biological proxy and tidal elevation in a modern environment. The second step uses this relationship to produce estimates of paleo-tidal elevation with uncertainty for each layer in a sediment core. Additional proxies (e.g., <sup>13</sup>C) can be used to further constrain these estimates and potentially reduce uncertainty.

Combining output from the Bayesian transfer function with a core chronology provides us with a reconstruction of relative sea level through time. With the aim of estimating rates of sea-level change, reconstructions are analyzed using an errors-in-variables integrated Gaussian process model. Ultimately, through the combination of these statistical models we can capture the continuous and dynamic evolution of rates of RSL change with a full consideration and propagation of available uncertainties. Results show that 20<sup>th</sup> century sea-level rise along the U.S. Atlantic coast is the highest it's been in at least the last 15 centuries.

P-4407

## Spatial patterns of ocean circulation and their uncertainty: Combining Bayesian statistics and climate networks

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Correlations between time series lay at the core of many techniques of multivariate time series analysis, for example, EOF analysis or functional climate networks. Still, comparing paleoclimate time series is complicated by a variety of typical features, including irregular sampling, age model uncertainty (e.g., errors due to interpolation between radiocarbon sampling points) and time uncertainty (uncertainty in calibration), which, taken together, result in unequal and uncertain observation times of the individual time series to be correlated. Several methods have been proposed to approximate the joint probability distribution needed to estimate correlations, most of which rely either on interpolation or temporal downsampling.

Here, we compare the performance of some popular approximation methods using synthetic data resembling common properties of real world marine sediment records. Correlations are determined by estimating the parameters of a bivariate Gaussian model from the data using Markov Chain Monte Carlo sampling. The results of these pseudoproxy experiments are used to construct functional climate networks from a set of benthic foraminifera stable isotope records from the Atlantic ocean over the last deglaciation.

We find that methods based upon interpolation yield better results in terms of precision and accuracy than those which reduce the number of observations. In all cases, the specific characteristics of the studied time series are, however, more important than the choice of a particular interpolation method. Relevant features include the number of observations, the persistence of each record, and the imposed coupling strength between the paired series. In most of our pseudoproxy experiments, uncertainty in observation times introduces less additional uncertainty than unequal sampling and errors in observation times do. Thus, it can be reasonable to rely on published time scales as long as calibration uncertainties are not known.

By constructing functional climate networks based upon 33 records covering the last deglaciation, we find that the Bayesian approach yields robust and reliable results in real world applications. In order to enable a meaningful comparison among different records, we first construct new age models, using variable, model based estimates of reservoir ages for each record. Correlations are then estimated by shifting all records such, that the onset of deglaciation is concurrent. Networks are then constructed by mutual correlations between records. These networks show many known features of Atlantic ocean variability during the last deglaciation, including high synchronicity of oxygen isotope ratios during the transition and a bipolar pattern for carbon isotopes, illustrating the millennial scale changes in ocean circulation.

**P-4408**

## **Why and How to do Bayesian Palaeoclimate Reconstruction**

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We compare and contrast climate reconstructions from proxy data in a range of settings using commonly used methods, both Bayesian and non-Bayesian. The key contribution of Bayesian methodology is the ability to combine multiple sources of uncertainty and propagate these through the model coherently to provide a final posterior probability distribution on unseen palaeoclimate conditional on observed proxy data. Such a distribution captures everything we know and don't know about unobserved palaeoclimate, conditional on the observed calibration and fossil datasets. The framework is applicable in a range of settings and we demonstrate the flexibility and usefulness of the approach for a range of climate-proxy models wherein a model for proxy given climate is fit to the data before being inverted to yield a model for climate given fossil proxy. Although the approach is demonstrated to be robust to some common climate reconstruction pitfalls, there are challenges to be overcome in it becoming widely used. Firstly, it is conceptually different from the more well known frequentist statistical paradigm. Computational overhead is often a concern as the models are typically sampled from using costly Markov Chain Monte Carlo algorithms. Efficiency and reliability of the algorithms is not always straightforward to check and tuning them in this regard may require technical expertise. However, some key advancements have been made generally in the field of Bayesian analysis with new tools available to perform model building, model comparison, and automatic algorithm creation and tuning. Furthermore, new flexible tools for Bayesian palaeoclimate reconstruction are now available. We discuss these challenges and point to solutions in the context of some motivating examples.

**P-4409**

## **Data assimilation of sea surface temperature reconstructions from various proxy types in the North Atlantic over the last two millennia**

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The assimilation of paleo-sea surface temperature (SST) reconstructions from proxies into climate models allows combining those two complementary sources of information to better estimate past climate variability. Up until now, its application has been limited due to the mismatch in model-data variance and to the spatio-temporal heterogeneity of SST proxy signals. This study aims at combining SST reconstructions from various proxy types with climate model results across the North Atlantic region via data assimilation experiments over the last two millennia. SST reconstructions used include: 1) cores from the Ocean2k synthesis database; 2) a dataset solely composed of dinoflagellate cysts, and 3) additional cores from the North Atlantic meeting the Ocean2k quality control criteria. As a first step, simulated and reconstructed SST time series are standardized in order to dismiss the mismatch in variances. The assimilation of those time series works well at the local scale even when combining proxies carrying contrasting seasonal and ocean depth signals. The best results are obtained with the summer SST reconstructions from the dinoflagellate cysts database. In a second step, a model-data scaling experiment based on satellite observations and on the change in variance with timescale is presented. Assimilating scaled time series leads to more robust results at the regional scale compared to the assimilation of simple standardized series. Regional reconstructions are then compared to higher-resolution terrestrial archives, and potential and limitations of the method are discussed.

**P-4410**

## **New monthly indices for the East Atlantic and the Scandinavian patterns beyond the 20th century**

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Climate variability in the North Atlantic sector is commonly ascribed to the North Atlantic Oscillation. However, recent studies have shown that taking into account the second and third mode of variability (namely the East Atlantic – EA – and the Scandinavian – SCA – patterns) greatly improves our understanding of their controlling mechanisms, as well as their impact on climate. The most commonly used EA and SCA indices span the period from 1950 to present, which is too short, for example, to calibrate palaeoclimate records or assess their variability over multi-decadal scales. To tackle this, here, we create new EOF-based (empirical orthogonal function) monthly EA and SCA indices covering the period from 1851 to present, and compare them with their equivalent instrumental indices. We also review and discuss the value of these new records and provide insights into the reasons why different sources of data may give slightly different time series. Furthermore, we demonstrate that using these patterns to explain climate variability beyond the winter season needs to be done carefully due to their non-stationary behaviour. The datasets are available at <https://doi.org/10.1594/PANGAEA.892769>.

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**P-4411**

## **What can we learn from Cladocera subfossil assemblages: a training set from Central Europe.**

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The main interest of presented study was to create the Cladocera based training set to be able to quantitatively reconstruct environmental changes that have occurred in the territory of Central Europe since last glaciation retreat. Firstly we evaluated the relationship between subfossil Cladocera community composition and environmental properties of lakes of different trophy status. We hypothesized that Cladocera species composition depends mainly on the trophic state of the lake and lake depth. Therefore we sampled 30 lakes of oligotrophic, mesotrophic and eutrophic character and sediment was taken from 3 different depths: deepest part, sublittoral (2-4m) and littoral (1-2m). The 61 sediment samples were collected. At each site important water quality parameters were measured: Secchi depth (m), Chlorophyll ( $\mu\text{g/l}$ ), cyanobacteria (phycocyanin BGA,  $\mu\text{g/l}$ ), dissolved oxygen (mg/l), total dissolved solids TDS (mg/l), pH, temperature using multiparameter measuring device YSI. Moreover water samples were taken and analysed in the laboratory to determine  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$ ,  $\text{P}_{\text{tot}}$  and  $\text{PO}_4^{3-}$ . The field campaign took place in July 2018. The timing was chosen because earlier hydrochemical studies on the annual dynamics of water trophy indicators (TP, TN) from Lakes Żabińskie, Łazduny and Rzęśniki revealed that mid-summer values were best approximation of 8-year median of these parameters. The upper 4cm sediment layer was taken for the analysis as a representation of material sedimenting in Polish lakes annually (informations obtained from project CLIMPOL and studies of Gościąż lake sediments dynamics).

The water properties measured in situ during the fieldworks in July 2018 using YSI device showed that studied lakes represent a wide gradient of values a particularly: Secchi depth (5,96-0,88 m), conductivity (152,4-479  $\mu\text{S}$ ), Chlorophyll (0,45-29,22  $\mu\text{g/l}$ ) and phycocyanin BGA (0-3,28  $\mu\text{g/l}$ ).

The preliminary results of the subfossil Cladocera analysis showed considerable changes in Cladocera distribution according to water parameters and depth of the site. The 34 Cladocera species were identified so far. In the pelagic samples species from Bosminidae family predominate, littoral species reaches higher abundance in near shore localities. Redundancy analysis (RDA) was applied to describe the relationship between the species composition and selected variables (depth, SECCHI depth, Chlorophyll, Conductivity, cyanobacteria, total dissolved solids, water temperature and pH). The results obtained so far indicate that Cladocera training set for reconstructing one of lake trophy parameters and water depth can be established. However, more lake need to be sampled which will be done in the current year.

This study is a contribution to project founded by National Science Centre 2016/23/D/ST10/03071.

P-4412

## Diatom distributions in the north-eastern Poland lakes surface sediments and their relationship to modern environmental variables

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Lakes ecosystems are very sensitive to climatic and environmental changes. In lake sediments, there are preserved remains of plant and animals that lived in the lake and its surroundings in the past. The species composition of past assemblages is a basis for the quantitative and qualitative reconstruction of the past environmental changes. Subfossil diatoms act as one of the most commonly used paleoenvironmental bio-proxies which enable reconstructions of lake water pH, nutrient status, salinity and temperature.

In this poster, we present preliminary results from ongoing research project aiming at quantifying the relationships between modern diatom assemblages and present-day environmental conditions. These relationships will be used to develop diatom-based training set that will be applied to future studies of environmental change in Polish lakes.

Surface sediments for diatom and chemical analyses were collected from 30 lakes located in Masuria and the Suwałki region (NE Poland). At each site, a suite of important water quality parameters was collected, including chemical (e.g. phosphorous, pH) and physical (e.g., SECCHI depth) variables. Diatom assemblages from each site were counted and identified to the most specific taxonomic level possible. Diatom data were compiled for comparison to corresponding environmental data and development of indicator models.

The first results of the analysis show changes in diatom distribution as well as the chemical and physical water properties. We found 146 taxa of diatoms with 40 species with minimum 2% abundance. Redundancy analysis (RDA) was used to describe the relationship between the species composition and selected variables (depth, SECCHI depth, Chlorophyll, Conductivity, phycocyanin (BGA), total dissolved solids (TDS), water temperature and pH). In the Monte Carlo test of selected variables, 1 out of 9 environmental parameters appeared significant, including SECCHI depth.

The most abundant species from the north-eastern training set were: *Stephanodiscus parvus*, *Pantocsekiella comensis*, *Stausosira construens*, *Stausosirella lapponica*, and *Aulacoseira ambigua*.

This study provides new insights to the ecology of lakes and provides the basis for the development of training sets for north-eastern Poland lakes, useful in environmental reconstructions with the transfer function.

This study is a contribution to project founded by National Science Centre 2016/23/D/ST10/03071.

**P-4413**

## **On the validity of foraminifera-based ENSO reconstructions**

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A complete understanding of past El Niño-Southern Oscillation (ENSO) fluctuations is important for the future predictions of regional climate using climate models. Reconstructions of past ENSO dynamics use oxygen isotope ratios ( $\delta^{18}\text{O}_c$ ) and trace metal geochemistry (Mg/Ca) recorded by planktonic foraminifera to reconstruct past spatiotemporal changes in upper ocean conditions. We investigate whether planktonic foraminifera-based proxies offer sufficient spatiotemporal continuity with which to reconstruct past ENSO dynamics. Concentrating upon the period of the instrumental record, we use the *Foraminifera as Modelled Entities* (FAME) model to statistically test whether or not  $\delta^{18}\text{O}_c$  and the Temperature signal ( $T_c$ ) in planktonic foraminifera directly records the ENSO cycle. Our results show that it is possible to use  $\delta^{18}\text{O}_c$  from foraminifera to disentangle the ENSO signal only in certain parts of the Pacific Ocean. Furthermore, a large proportion of these areas coincide with sea-floor regions exhibiting a low sedimentation rate and/or water depth below the carbonate compensation depth, thus precluding the extraction of a temporally valid palaeoclimate signal using long-standing palaeoceanographic methods.

**P-4414**

## **A new bias-correction method for precipitation over complex terrain suitable for different climate states**

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This work presents a new bias-correction method that considers orographic characteristics. The correction method provides a tool to improve the accuracy of the input data, e.g. precipitation and temperature, used by the hydrological and glacier models. To present the new bias correction, we carry out a simulation for present day conditions performed with the Weather Research and Forecasting model (WRF) at a resolution of 2 km that is driven by the coupled model Climate Community System Model version 4 (CCSM4). The domain simulated encompasses the Alps and its forelands. The bias correction consists of two main steps: (i) separation with respect to different orographic characteristics and (ii) Empirical Quantile Mapping method. Different orographic characteristics are tested in the first step; namely, height-intervals (400 m), the slope-orientation (north, east, south and west) and the combination of both. The Alpine region is separated in two regions, Switzerland and the rest of the Alps. Fitting the bias correction to one region and applying it to the other delivers an independent test of the quality of the method. Focusing on precipitation, the results show that all three settings of the orographic characteristics are able to correct the biases in both regions. Hence, the mean values of precipitation over the flatlands and the annual cycle are adequately adjusted; moreover, the biases related to mountain peaks are mostly corrected. However, the method slightly corrects the biases in very deep valleys. One reason for the moderate adjustment is that the observational dataset uncertainties, which may be more than 30% above 1500 m.a.s.l., make it impossible to obtain a fully adequate correction. The bias correction related to the height-intervals seems to be the optimal method because the other ones yield only a minimal gain with a high computational cost. Thus, the new bias correction provides a flexible tool which can be also used in studies where orography strongly changes, e.g. during glacial times.

**P-4415**

## **The PALEOLINK working project: The missing link in the Past – Downscaling paleoclimatic Earth System Models**

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The comparison of climate model simulations of past climates with proxy-based climate reconstructions allows assessing the validity of climate models under the impact of different boundary conditions (particularly when considering glacial climates). However, this comparison is burdened by the fact that most climate reconstructions are based on local or regional data, whereas the Earth System Models' paleoclimate simulations have a rather coarse spatial resolution that leads to large biases over extensive regions and inhibits a realistic representation of the small scale features that affect proxy records.

To overcome this scale gap, different techniques are applied, ranging from a 'naive' approach based on selecting the closest grid point of the climate model to complex approaches that refine the simulated large-scale fields with the help of statistical or dynamical methods, i.e. Regional Climate Models. Although the latter has proven to be a valuable tool, the computational resources involved in long climate simulations normally addressed by climate reconstructions are large. The associated cost has limited the number of studies based on this approach. Currently, few regions have been subject to dynamical downscaling efforts, with a negligible number of high-resolution simulations compared to the number of coarse, global-scale simulations.

The PALEOLINK working group, hosted within the PAGES 2k network, aims at evaluating and developing new downscaling strategies that allows linking coarse Earth System Model simulations with climate reconstructions. It promotes reviewing, coordinating and stimulating future efforts trying to bridge the scale gap between the coarse resolution of state-of-the-art Earth System Models used in paleoclimate simulations and local and regional climate reconstructions. Both dynamical and statistical approaches to downscaling are considered, as well as novel combinations of both, including the use of forward models driven by downscaled climate model data reproducing the local climate and its variability.

This contribution reviews the latest news within this group, such as the output of a workshop that is being organised in February 2019.

**P-4416**

## **Constructing synthetic analogues for Climate Field Reconstructions using Gaussian Processes**

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The analogue method is a data-driven function between predictor and predictand that is based on a look-up library of previously available predictor-predictand data. This method has been applied to paleo-climate field reconstructions using a set of proxy records as predictors and climate fields from regional or global climate simulations as predictands.

Some questions remain not clearly solved, for instance, when no clear analogues are found for a particular value of the predictor or, in contrast, when several diverging analogues are potentially possible. These situations require an 'extrapolation' or 'interpolation' of the available analogues. Both operations are not straight forward, since the predictor analogues are in general defined in a high-dimensional space, for instance large-scale sea-level-pressure patterns defined over the Northern Hemisphere. In this contribution we explore the application of a Gaussian Process theory to achieve a meaningful extrapolation of analogues in situations in which extreme events (previously not observed in the look-up table), or interpolation of analogues in situations where several, but none of them optimal, analogues can be identified in the available look-up table. A Gaussian Process is then defined to locally approximate the empirical function defined by the look-up table in the vicinity of a particular instance of the predictor. The definition of a Gaussian Process requires the prescription of the functional form of a covariance kernel. In the case of multidimensional predictands, the covariance kernel takes the form of a vector kernel, which further complicates the interpolation or extrapolation of the Gaussian Process.

The contribution will show preliminary results of the application of this approach to the reconstruction of spatially resolved climate of the past millennium based on sparse information provided by point proxy data, e.g. dendroclimatological data.

We test the method in the virtual reality provided by paleoclimate simulations with Earth System Models, in which pseudo-proxies can be constructed by sampling from simulated data at the grid-cell level, and in which the 'true' solution - the past climate fields - is also provided by the climate model.

**P-4417**

## **Insolation Variations in Eurasian Subarctic for the Holocene**

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Variation of the insolation is one of the global factors which determine the Earth's climate. Multi-periodic variations of the insolation determine the cyclicity of the Earth's climate. Research of the insolation variation makes it possible to relate the known centers of the genetic and morphological diversity in the model species, and the changes in the taxonomic composition and structure of the regional fauna of the Northern Eurasia with the geological events and the insolation model. The aim of the investigation is the estimation of the insolation of the Subarctic latitudes of the Urals and West Siberia during the Holocene. The calculation of insolation in the Eurasian Subarctic for the Holocene is carried out based on the model long-period evolution of the Earth's orbit La2004. That model is a numerical solution for full Solar System with the Earth's precession model based on LLR observations, orbital solution valid from -50 to +20 Ma BP. We have estimated the insolation for the latitudes from 55 to 70 degrees N. We have considered the mean daily and mean monthly insolation over 12 ka BP. The correlation of insolation is estimated with the temperature sequence of the Yamal Peninsula over 12 ka BP and global temperature indices of oxygen isotopes to investigate the insolation influence on the climatogenic dynamics. The study is supported by RFBR, research project no. 19-04-00966.

**P-4418**

## **Combining environmental archaeological and modern species distribution data for the conservation of insect biodiversity**

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Global changes over the latest decades have triggered a biodiversity crisis, with decline in species abundance, changes in community composition and species range shifts in several taxonomic groups. Climate change, habitat loss and fragmentation, all resulting from human activities, have been identified as concurring main drivers of the current biodiversity crisis. Environmental archaeology provides unique tools to look back to previous periods of substantial environmental changes, which can help contextualizing the magnitude and dynamics of current trends. On the other hand, one of the challenges for archaeology is to make use of the existing large amount of information that is available in archives and to provide syntheses, which could inform conservation. For example, previous environmental archaeological studies found that species with declining distributional trends are the ones at highest risk of extinction. In this study, we combine existing databases of environmental archaeological and palaeoecological data with databases of current species distribution and status. Our focus is on beetles, a largely overlooked group in environmental archaeology. Beetles represent one of the most species-rich, abundant, environmentally sensitive and archaeologically preserved groups of terrestrial insects and are an excellent proxy of environmental changes. Using both modern and fossil biodiversity data, we test for patterns linking geographical distributional ranges with extinction risk for insects, and/or whether the species at strongest risk of extinction are associated to historically vulnerable habitats. For that, we analyzed the Strategic Environmental Archaeology Database (SEAD, [www.sead.se](http://www.sead.se)) and Bugs dataset ([www.bugscep.com](http://www.bugscep.com)). The SEAD database is an open access database that contains, among other proxies, data on the past distribution of beetles from over 1200 European archaeological and Quaternary geological sites. We studied the distributional dynamics of species in Quaternary fossil samples through time and compare them with present species distribution and conservation status. We obtained data of current species distribution from biodiversity data infrastructure, including Swedish LifeWatch and Artdatabanken, and data on conservation status from the IUCN red list. Understanding the mechanisms driving biodiversity fluctuations and species extinction risk will inform management and conservation.

P-4419

## Holocene heterogeneous changes of aquatic ecosystems in ACA and the MASM indicated by subfossil *Pediastrum* in different lakes

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Subfossil *Pediastrum*, a genus of green algae (Chlorophyceae), which is sensitive to changes in the aquatic environment, can serve as a proxy for the evolution of the aquatic ecosystem and climate change. This study synthesizes subfossil *Pediastrum* records from arid central Asia (ACA) and the marginal areas of the Asian summer monsoon (MASM) to discuss the process of lacustrine ecosystem evolution during the Holocene. It was found that aquatic ecosystems performed differently in two areas influenced by different climate systems. In the early Holocene, the low concentration records of *Pediastrum* in ACA resulted from the higher salinity caused by dry climate or lower lake level, while, higher temperature or summer insolation promote growth of *Pediastrum* in relatively humid alpine lakes as there may have no limitation of salinity. In the same period, the concentration of *Pediastrum* was higher in the lakes located in the MASM. In the middle Holocene, *Pediastrum* began to appear in freshwater lake in ACA with a higher concentration, while alpine lakes in inland areas and the MASM have significantly reduced because either cooling or reduced rainfall. In the late Holocene, the concentration of *Pediastrum* in lakes of ACA had large fluctuations, indicating an unstable climate condition, while, in the MASM area, the *Pediastrum* was generally lower in abundance because higher salinity or alkalinity with weakened summer monsoon, and different lakes had large differences because of local environmental factors. The asynchronous change of *Pediastrum* in ACA and the MASM actually reflects the moisture or precipitation variation characteristics of the monsoon or westerly dominated climate modes. The change of *Pediastrum* is mainly controlled by salinity and/or alkalinity. There is a clear consistency between high concentration of *Pediastrum* and high precipitation in the MASM during the early-mid-Holocene, which indicates that the East Asian monsoon intensively increased with more precipitation and water level of the lakes. Varieties of *Pediastrum* in lake at middle-high latitudes, such as Lake Kanas in Altai Mountains and Lake Hulun in inner Mongolia, may be related to temperature fluctuation or nutrient input during the Holocene. The ecological processes and ecological limitations of *Pediastrum* are not clear enough, which leads to difficulties in explaining the paleo-ecological and paleoclimatic significance indicated by the changes in *Pediastrum* in the strata.

P-4420

## The European Pollen Database (EPD) – New opportunities as a constituent database of Neotoma

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The European Pollen Database (EPD) was created nearly 30 years ago, and its importance as a data repository and research tool has steadily increased over this time, in parallel with the increased need for greater transparency in science. The latest version hosts pollen data from 2570 different sedimentary archives from 1993 sites across the European continent. The database was originally created in Paradox on MS-DOS, which has become a limiting factor for maintaining, updating, and using the database. The Neotoma Palaeoecological Database (neotomadb.org) was built as a cyberinfrastructure to host palaeoecological databases, built on state-of-the-art database software, with tools and resources needing to be developed only once while they are available for all constituent databases. Thus, Neotoma provides an ideal solution for managing the EPD. Neotoma was initially populated with data from the Global Pollen Database (GPD), which contained an older version of the EPD (pre-2007). Recent work by the active EPD community has updated many of the existing datasets, so that the migration of EPD data to Neotoma had to account for both new data entries and updated EPD datasets in Neotoma. This migration of datasets was therefore carried out dataset by dataset, which provided an opportunity for correcting inconsistencies in the data and for updating and adding additional metadata. In addition to the data migration, the EPD taxonomy support group worked to preserve and update the pollen taxonomic hierarchy, for which we have developed a corresponding R-function for combining pollen taxa at different hierarchical levels based on pollen morphology. Here we present the challenges and results of this process, highlighting the changes made to the database as well as the new opportunities of interacting with the EPD through Neotoma. We also invite conference participants to our poster to discuss desirable future developments, current problems, and opportunities for future involvement in the community.

P-4421

## Distributing a huge volume of paleoclimate model data: the successful collaboration between PMIP and ESGF

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The **Paleoclimate Modelling Intercomparison Project** (PMIP) is a long standing initiative that has provided an efficient mechanism for coordinating paleoclimate modelling activities. The resulting model output database is used not only by climate modellers, but also by multidisciplinary research dealing with environment and society, such as ecological niche modellers.

The amount of available PMIP model data has grown tremendously in each phase of PMIP, from almost 2 Gb in 1996 on a single server to a distributed 'unknown' number of Tb for PMIP4.

The fourth phase (PMIP4) has started in 2015 and the 20 modelling groups involved will run all or part of the following experiments: *Last Millennium, Mid-Holocene, Last Glacial Maximum, Last Interglacial, Mid Pliocene, transient simulations and sensitivity experiments.*

We will show how we have benefited from the standards and tools developed by the **Earth System Grid Federation** (ESGF) for maintaining the distributed **Coupled Model Intercomparison Project** (CMIP) database. Adopting and using strong community standards is a prerequisite to bring data from multiple data providers to multiple end users, and for making reproducible science. We also use ESGF tools for searching and downloading the available data, and then (re)processing the data to gain new insights. We will also give a few examples using PMIP data.

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**P-4422**

## **Large-scale vegetation history in China and its response to climate change since the Last Glacial Maximum**

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Large-scale palaeovegetation reconstruction plays a critical role in improving our understanding of the response of vegetation to climate change and in reducing the uncertainty in predictions of vegetation change under global warming scenarios. Here, we present quantitative vegetation reconstructions for China since the Last Glacial Maximum (LGM), using 286 selected fossil pollen records analyzed using the biomization method. The results show that from 23-19 ka (1 ka = 1000 cal yr BP), steppe and desert expanded southeastwards, dominating northern China, whereas forest in eastern China shrank southwards to near the middle and lower reaches of the Yangtze River; the percentage of forested sites at this time was the lowest during the studied interval. Forest then developed gradually during 18-12 ka. During the early and middle Holocene, tropical seasonal forest, broad-leaved evergreen/warm mixed forest, and temperate deciduous forest shifted northwards by 2°, 4° and 5° in latitude, respectively, relative to today, and then declined in the late Holocene. In detail, forest flourished in the middle Holocene (9-4 ka) in semi-arid and semi-humid northern China, whereas it reached a maximum in the early and middle Holocene (11.5-6 ka) in humid southern China. Our results suggest that although forest throughout China exhibited the expected response to the evolution of the East Asian summer monsoon, precipitation exerted a more significant effect on vegetation change in northern China, whereas temperature and precipitation played a more important role in southern China. Our results are a potentially useful reference for assessing future vegetation dynamics under global warming scenarios.

**P-4423**

## **The PAGES 2k Network: Understanding the climate of the past 2,000 years**

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The past 2,000 years (2k) provide critical context for the recent anthropogenic forcing of the Earth's climate. The PAGES 2k Network was created with the aim of using data from natural archives to reconstruct and understand changes in regional and global surface climate over this period.

During Phases 1 (2008-2013) and 2 (2014-2016), regional and trans-regional groupings focused on building reconstructions for terrestrial regions and the oceans. The conclusion of Phase 2 coincided with the release of an open and transparent global database of temperature-sensitive proxies spanning the Common Era (PAGES 2k Consortium, 2017). This database is primarily encoded using the Linked Paleo Data format, which ensures that the data is both structured and machine readable (McKay et al., 2016).

Phase 3 aims to use open data to address questions articulated around the themes "Climate Variability, Modes and Mechanisms", "Methods and Uncertainties" and "Proxy and Model Understanding". Research is organised as a network of projects, identified and led by 2k community members. We present the ten current projects that have been established by the PAGES 2k Network community, and summarise their key outputs to date:

- ARAMATE investigates the mechanisms of ecosystem variability in the North Atlantic region using annually resolved marine and terrestrial climate archives.
- CLIM-ARCH-DATE combines new absolutely-dated marine proxy archives with other dating techniques to determine the relative and absolute timing of cultural and environmental events in the past.
- MULTICHRON investigates multidecadal climatic signals in North Atlantic sclerochronological records.
- CLIVASH2k studies large scale modes of climate variability and the mechanisms and drivers of climate change in Antarctica, the sub-Antarctic and the wider Southern Hemisphere.
- CORALHYDRO2k investigates tropical ocean hydroclimate and temperature from coral archives.
- ISO2k is building a water isotope database to study hydroclimate at decadal to centennial-scales, as well as possible secular trends.
- PALEOLINK is developing new downscaling strategies that allow the linking of coarse Earth System Model simulations with local climate reconstructions (Ludwig et al., 2018).
- PSR2k studies ocean modes by combining marine proxy records and the output from isotope-enabled and traditional GCM simulations.
- "GMST (Global Mean Surface Temperature Reconstructions)" and "Global Temperature Climate Field Reconstruction" are estimating global temperatures by using the PAGES 2k database and an ensemble of different reconstruction techniques.



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**P-4424**

## **Overview of the Palaeoclimate Modelling Intercomparison Project and first PMIP4 results**

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The Palaeoclimate Modelling Intercomparison Project is a long-standing initiative set up to understand the response of the climate system to different climate forcings for documented climatic states very different from the present and historical climates. Through comparison with observations of the environmental impact of these climate changes, or with climate reconstructions based on physical, chemical, or biological records, PMIP also addresses the issue of how well state-of-the-art numerical models, used for climate projections, simulate climate change. Climate models are usually developed using the present and historical climates as references, but climate projections show that future climates will lie well outside these conditions. Palaeo-climates very different from these reference states therefore provide stringent tests for state-of-the-art models and a way to assess whether their sensitivity to forcings is compatible with palaeoclimatic evidence. PMIP, now starting its fourth phase, is therefore contributing to the Coupled Modelling Intercomparison Project (CMIP) and using the same model versions as those used to simulate future climates.

Simulations of five different periods have been designed to address the objectives of the sixth phase of the Coupled Model Intercomparison Project (CMIP6): the millennium prior to the industrial epoch; the mid-Holocene, 6000 years ago; the Last Glacial Maximum, 21 000 years ago; the Last Interglacial, 127 000 years ago; and the mid-Pliocene Warm Period, 3.2 million years ago. In this poster, we will give an overview of the motivation and the protocols for each of these periods and will show a first evaluation of the PMIP4 models for the mid-Holocene and the Last Glacial Maximum climates, which have been modelled since the beginning of PMIP. This will give us the opportunity to discuss about the models, the experimental protocols to run them, paleodata syntheses and methods to compare models and paleoclimatic reconstructions.

We acknowledge all PMIP participants for their contribution to simulations and data used in this work.

P-4425

## Integrating tephrochronology with environmental and historical data: Tephabase and dataARC

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Tephrochronology is a well-established technique employed by Quaternary scientists and archaeologists across the globe to build interconnected dating frameworks of unrivalled precision, linking the key environmental archives formed by ice cores, ocean sediments, lacustrine deposits, peats and terrestrial soils. Since the 1990s databases have provided rigorous, effective and pragmatic ways of accessing tephra-related data and new information technologies are allowing more sophisticated integration of tephra-data. Until now, these databases have not been linked to other environmental and historical databases. This linkage could provide new insights into understanding socio-environmental change.

The National Science Foundation-funded “dataARC” project aims to bring together a wide range of disparate palaeoenvironmental, historical, literary and archaeological datasets from across the North Atlantic to help us better understand socio-environmental change in the region. Initially the effort has been focussed on Iceland and the North Atlantic, with the ambition of crafting a system that is applicable to other geographic areas as well. Rather than producing one large complicated database, dataARC uses concept mapping and combinatorics to provide the framework through which a wide variety of datasets can be connected and accessed. Tephra data is being incorporated into the system through Tephabase, a tephrochronological database. As well as Tephabase, other data sources being incorporated into the dataARC discovery portal include the NABONE zooarchaeological database, the Orkney Faunal Database, the Strategic Environmental Archaeology Database (SEAD), the Icelandic Sagas Database and the Iceland Farm Histories Database.

Over the past 24 years, Tephabase has been continually developed and now contains details of over 4,500 tephra layers at over 1100 sites. A new stage of this process is its integration into the dataARC portal, allowing tephrochronological data to directly link archaeological and palaeoenvironmental records. The number of Icelandic tephra records stored in Tephabase is being greatly expanded to provide the wider environmental context for the new archaeological tephra data. In particular, data from the areas around Mývatn in northern Iceland, and Eyjafjallajökull and Mýrdalsjökull in southern Iceland are being targeted. At the same time, Tephabase’s capability for automated stratigraphic profile construction and sediment accumulation rate (SeAR) calculations has been expanded to all relevant Icelandic profiles. This will facilitate rapid comparison of SeARs and profiles within and between regions.

**P-4426**

## **Rising Novelty in Ecosystems and Climates: looking to the past to address the challenges of a human dominated world**

Alejandro Ordonez

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We live in a world of where humans are the dominant driver of biological and environmental change. Already, many communities have been transformed by human action and the legacies of past actions, and now comprise mixtures of species with no historical or evolutionary counterpart. This has resulted in many contemporary ecosystems already differ substantively from all historical counterparts (i.e., novel ecosystem). The emerge of novel ecosystems, and climates pose both opportunities and challenges for ecologists. In our efforts to predict, understand, and prepare for the behaviour of ecosystems in a strange new world, geological and historical data are essential sources of information about processes governing species and ecosystems for timescales and states of the earth system that are inaccessible to direct observation. In this talk I will address several critical questions regarding mechanisms do novel climates give rise to novel ecosystems, what metrics best represent the exposure of communities to climate-driven reorganisation, and how *Open Big Data* can help us address the challenge of a no-analog future.

**P-4427**

## **Late Pleistocene Isoscapes: Taking the big picture approach to faunal isotope studies**

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A wealth of faunal stable isotope data exists in the published literature, largely produced during site-specific archaeological and palaeontological research. Large-herbivore stable isotope signatures track that of their diets, thus providing a valuable proxy for the isotopic composition of past vegetation, and in turn climate and environment. Faunal isotope data therefore present a unique opportunity to examine past climates, ecosystems, and the landscapes of human activity. The approach has several advantages. First, because some species have home ranges similar in size to past human groups, their isotopic signatures can provide a homogenised environmental signature at a spatial scale relevant to understand the human experience of the landscape. Likewise, because an animal's signature reflects no greater time period than its lifespan, it provides a proxy record at an annual to decadal resolution. And finally, because analysed faunal remains often bear the marks of human hunting and butchery, and because they can most often be directly dated through radiocarbon methodologies, they provide a direct means to tie together palaeoenvironmental and archaeological information. Thus, by taking a big data approach to examine spatial patterns in the isotope data (creating 'isoscapes'), big picture questions related to the influence of climate change on biogeochemical systems and human utilisation of different ecosystems during these periods can be addressed.

However, despite this potential, large-scale analysis of this type data is rarely undertaken. Two main barriers currently exist; access to data is restrictive and requires scouring individual publications; and reporting of the data is inconsistent, often lacking vital information that allows for thorough assessment of the data quality. Furthermore, many data lack specific information on sample geographic origin and age. In this study, we have undertaken a large-scale data collation project, building a near complete quality-checked and geo-referenced database of published faunal stable isotope data from Eurasia spanning the Late Pleistocene and Early Holocene. We present time-sliced spatial analysis that show gradients in isotopic compositions across the Eurasian continent and discuss the impact that this approach has on climate change and archaeological research.

**P-4428**

## **Open Science by Design: a Vision for 21st Century Research**

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In July 2018, the National Academies of Sciences, Engineering, and Medicine released the report *Open Science by Design: Realizing a Vision for 21<sup>st</sup> Century Research* (DOI: <https://doi.org/10.17226/25116>). This consensus study describes the current state of open science, defined as “the free availability and usability of scholarly publications, the data that result from research, and the methodologies, including code or algorithms, that were used to generate those data.” The authoring committee developed the concept of “open science by design” as a future state of affairs in which researchers possess the knowledge, tools, and incentives necessary to pursue and support open science practices throughout the full research lifecycle of a given project. The report states that the research enterprise is already realizing benefits of open science including rigor and reliability; ability to address new questions; faster and more inclusive dissemination of knowledge; broader participation in research; effective use of resources; improved performance of research tasks; and open publication for public benefits. The report also explores the barriers and limitations that still exist, including costs and infrastructure; structure of scholarly communications; lack of supportive culture, incentives, and training; privacy, security, and proprietary barriers to sharing; and disciplinary differences. The authoring committee developed key findings and recommendations with specific implementation actions for specific stakeholder communities around five areas: (1) building a supportive culture, (2) training for open science by design, (3) ensuring long-term preservation and stewardship, (4) facilitating data discovery, reuse, and reproducibility, and (5) developing new approaches to fostering open science by design. A central focus of the study and its recommendations is to ensure that research data are made openly available under FAIR (findable - accessible - interoperable - reusable) principles. The importance of scientific collections and sample preservation was also discussed. This paper will review the key challenges and opportunities for open data identified in the consensus study, and draw implications for geoscientists and the wider geosciences community.

**P-4429**

## **Explosive Volcanism Triggers Chinese Dynastic Collapse**

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The need to understand human vulnerability to future climate change is driving research into the influence of climate on past societies. Capitalizing upon advances in palaeoclimatic reconstruction, prominent coincidences have been noted between climatic changes and the sudden “collapses” known or inferred from historical, archaeological and palaeoecological records. These are often associated with a reduction in socioeconomic complexity and/or political discontinuity, with climate deemed to play a role mainly through the disruption of a society’s agro-ecological base. China is unique in experiencing 68 well-defined dynastic collapses during the first two millennia CE. Their frequency and precise dating affords an unparalleled opportunity to test whether climate played a role amongst the debated suite of possible causes offered to date. Here we use a state-of-the-art multi-ice-core reconstruction of volcanism to show a repeated and statistically significant association between explosive eruptions and Chinese dynastic collapses, whether of long-lived dynasties controlling large territories or shorter-lived regional dynasties in periods of instability. Collapse often occurred amidst warfare: both a contributor to and consequence of collapse. Using a 1,062 year reconstruction of warfare intensity spanning China’s northernmost to southernmost extent, we further show that warfare during and following collapse scaled in intensity with the magnitude of volcanic forcing. This result is suggestive of the pathways by which explosive eruptions may trigger collapse, including intensified recourse competition under climate-induced scarcity, and opportunistic rivals exploiting reduced social cohesion alongside the material weakness and unpopularity of ruling families (associated with a perceived loss of the “mandate of heaven”) during times of socioeconomic stress. These results for the first time identify a systematic role for volcanic eruptions as historical actors in the political collapse of one of the world’s most populous, sophisticated, and long-lasting civilizations.

**P-4430**

## **Global temperature change induced by Samalas mega volcanic eruption based on CESM simulation**

Bin Liu

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Global warming is more and more severe, and the rise in Arctic surface air temperature has almost doubled the global average in recent decades. As a natural factor, volcanic eruption plays an important role in suppressing global warming. The 1257AD Samalas mega volcanic eruption on Indonesia is the largest eruption of the Common Era. How does the global temperature especially the polar region temperature response to this mega eruption that requires more discussion. We address this issue by using the Community Earth System Model to perform control experiment and volcanic sensitivity experiment. The result shows that global surface air temperature decreases obviously after the Samalas mega volcanic eruption. The temperature anomaly amplitude over high latitude is much larger than mid-low latitude. The significant cooling effect on mid-low latitude (40S-60N) lasts for five years, while the effect on high latitude could last for a decade. Besides, inter-hemispheric differences are apparent. The NH cooling (maximum is  $-3.97^{\circ}\text{C}$ ) is more pronounced than SH ( $-2.47^{\circ}\text{C}$ ). The Arctic experiences a stronger cooling with its maximum ( $-7.92^{\circ}\text{C}$ ) is almost twice of Antarctic ( $-4.26^{\circ}\text{C}$ ), and the cooling is significant and continued over a decade, whereas the Antarctic experiences a pronounced cooling for just 2 years, and followed by weak regional scale warming anomalies. The sea ice extent of Arctic and Antarctic increase simultaneously in first two post-eruption years, and there is a persistent expansion for Arctic sea ice and a retreat for Antarctic sea ice subsequently. This long-term asymmetry is mainly due to different geographical characteristic of Arctic and Antarctic, and it has an impact on the change of albedo and ocean-atmosphere heat transport over polar region. After the eruption, the first stage of temperature changes over polar region is year 0 to year 1, in which the Arctic and Antarctic basically cool, and temperature mainly reduces in local summer. This is due to the direct weakening of solar radiation induced by volcanic aerosol in polar local summer and the enhancement of solar radiation reflection caused by the increase of albedo. The second stage is the period from year 2 onwards, the temperature change over polar region is mainly in local winter, which is characterized by continuous cooling in Arctic winter and a slight warming in Antarctic winter. This is the result of ocean-atmosphere heat transport change caused by the asymmetric change of polar sea ice. In boreal winter, the expansion of Arctic sea ice hinders ocean transfers heat to atmosphere, resulting in less heat is added to atmosphere, which makes temperature drop more obvious. Whereas in Austral winter, the retreat of Antarctic sea ice promotes heat transfer from upper ocean to atmosphere, which gives more heat to atmosphere and leads to warm anomaly over the Antarctic.

**P-4431**

## **Simulation of drought persistency responses to volcanic eruptions at divergent drought phases basing on Community Earth System Model**

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Drought is a complex phenomenon that influenced by both internal variability as well as external forcing. Explosive volcanism is known to be a leading natural cause of aridity in monsoon regions.

The Ming dynasty drought (AD 1637-1643), which is the most severe extreme drought event in Eastern China in the past millennium, was initially triggered by internal variability and amplified by a volcanic eruption (Mt. Parker) in AD 1641 in south Philippines, according to our spectrum analysis as well as volcanic sensitivity experiments,

Subsequently, to identify whether the volcanic eruption took place in the prophase, metaphase nor anaphase of this drought, three kinds of volcanic sensitivity experiments were carried out on the basis of CESM. We selected 15 drought cases from a 500-year control run, and then added the volcano in AD 1641 to the last year, middle year and second year of each drought cases respectively.

The composited results show that, when volcano erupted in the last and middle year of the aridity, drought prolonged nearly five years, but the results in metaphase is not significant. When volcano erupted in the second year of the aridity, drought persisted merely three years, which is insignificant as well. That is to say, if the eruption time approaches the end of a drought, the duration of aridity may be longer and the magnitude may be larger. Conversely, if the eruption time is close to the beginning of a drought, the volcano is likely to weaken the initial drought trend.

The circulation field and spatial pattern of precipitation show that after explosive volcanism, drought mainly distributed in North China and the Yangtze-Huaihe region where summer monsoon decayed significantly. By comparing the sea surface temperature (SST) in both control runs and volcanic sensitivity tests, it was found that, the SST in Northwest Pacific, which is highly correlated with the variation of precipitation in eastern China, decreased significantly after volcanic eruption. In the initial stage of the drought, the low SST lasted shorter while in last stage persisted longer. The persistency of drought after volcanism is determined primitively by the persisting time of low SST in the Northwest Pacific, which is related to the SST in Northwest Pacific before eruption.

Furthermore, in the middle and early drought-stages, anticyclone occurred in the coastal area of Southeast China in the first and second year of the eruption, explaining why precipitation increased more rapidly when volcanic eruption occurred in earlier drought stages. To some extent, these findings indicated that during the Ming Dynasty drought, volcanic eruption is more likely to occur at the anaphase of the drought.

**P-4432**

## **Climatic and Human Impacts of Catastrophic Volcanic Events during the late Holocene**

Kenneth Tankersley

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This paper uses a variety of elemental analyses including high-magnification microscopy, inductively coupled plasma mass spectrometry (ICP-MS), scanning electron microscopy, energy-dispersive X-ray, energy dispersive X-ray fluorescence, and X-ray diffractometry to identify changes in the global atmospheric budget of volcanogenic elements and minerals, which correspond to explosive late Holocene volcanic eruptions in and Guatemala, Iceland, Mexico, the United States, and Vanuatu.

Pt anomalies occur in four widely separated regions across the Western Hemisphere (Caribbean, Maya Lowland, Southwestern and Midwestern United States), which date to three climate changing late Holocene high magnitude volcanic events: Laki, Iceland (CE 1783–1784), Kuwae, Vanuatu (CE 1452–1453), and Eldgjá, Iceland (CE 934). These anomalies indicate distinctive time-correlative atmospheric deposition rates of platinum-rich volcanic ash. Kuwae produced  $\sim 32\text{--}39 \text{ km}^3$  of magma and a stratospheric injection of  $\sim 175\text{--}700 \text{ Mt}$  of  $\text{H}_2\text{SO}_4$  and is considered one of the most explosive volcanic events of the Holocene. Laki produced a convective column of  $\sim 120 \text{ Mt}$  of  $\text{SO}_2$ , volcanic ash, and water vapor into the stratosphere, which reflected solar radiation, absorbed terrestrial radiation, and resulted in one the longest and coldest drops in historically recorded global temperatures. The Eldgjá eruption is the largest volcanic eruption historically recorded. It produced  $\sim 219 \text{ Mt}$  of  $\text{SO}_2$  and a  $\sim 6 \text{ km}^3$  terrestrial ash fall, resulted in global cooling, famine, and epidemics for almost 10 years following the eruption.

In the Maya Lowland, volcanic ash fell in the southern Yucatan Peninsula from late Holocene catastrophic eruptions in Guatemala and Mexico. Volcanic ash was crucial in the development and maintenance of ancient Maya agricultural soils. Ash fall in this regional is controlled by wind patterns and seasonal rainfall, which are linked to changes in the Intertropical Convergence Zone (ITCZ). Changes in the ITCZ likely cause changes in the deposition of volcanic ash, increased aridity, and drought frequency and severity, which likely disrupted the Maya economy.

In the southwestern United States, volcanic ash from the late Holocene eruptions of the Sunset Crater volcano in Arizona fell in Chaco Canyon, New Mexico and likely throughout the four-corners region during the Pueblo II cultural period. Volcanogenic mineral phenocrysts and anonymously high levels of Ni, Cr, and Pt anomalies occur in Ancestral Puebloan hydraulic features including a large suite of canals and reservoirs, which retain volcanogenic mineral phenocrysts from ash falls, which date to  $\sim 1085 \text{ CE}$ . These volcanic eruptions likely had a profound impact on Ancestral Puebloan culture.

Elemental and mineralogical anomalies provide new chronostratigraphic markers for late Holocene high magnitude volcanic eruptions, which are especially valuable in the Western Hemisphere in strata with limited chronometric control. These anomalies provide important tracers for the age of these volcanic events and ultimately a new chronostratigraphic marker in archaeological sediments.

**P-4433**

## **Socio-environmental dynamics and volcanic eruptions in the 500-1250 CE period deciphered from Lake Ljøgottjern sediment sequence (SE Norway)**

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Large volcanic eruptions are the major drivers of climate variability in the pre-industrial era of the last two millennia. Understanding their impacts on societies is necessary to consider future climate and socio-environmental interactions. Lake sediments can record these dynamics on a continuous time scale and include at the same time footprints from volcanic eruptions, climate changes and human activities associated to vegetation changes. Lake Ljøgottjern is located in southeastern Norway and is of glacial origin. The lake is 18 m depth, groundwater-fed and provide a sediment sequence covering the last 8000 years. The largest burial mound of Norway was built in the mid-6<sup>th</sup> century on the shore of this lake for King Rakni and makes this place an ideal site to study human-environmental interactions throughout the last millennia, confronting them to archaeological evidences.

Using a high-resolution multi-proxy analysis of this record, including <sup>14</sup>C dating, sedimentological and both mineral and organic geochemical analyses as well as palynological data, this study will allow reconstructing climate and socio-environmental changes in this area, with a focus on the 500-1250 CE (Common Era) period.

A previous palynological study evidenced the first openings of the environment linked to the development of agriculture between 3000 and 3500 yrs cal. BP. This change in land use was associated with changes in the geochemistry of the sediment. Maximum anthropogenic impacts were recorded in ca. 600 CE, when the mound was raised, and in the Little Ice Age, between the 13<sup>th</sup> and 17<sup>th</sup> centuries. The pollen diagram of Lake Ljøgottjern presents also three substantial decreases in charcoal particles between 500 and 1250 CE. An updated and high resolution dating of the new sequence will allow to associate or not these changes in fire regimes to major volcanic events (i.e., 536-540 unknown, 939 Eldgjà and 1257 Samalas).

The comparison of this record with other environmental archives from Norway, as well as climate reconstructions from ice cores and tree rings will allow us to discuss resilience times and adaptation of the Viking society in a changing Scandinavian environment.

**P-4434**

## **Influence of volcanic forcing on climate variability in transient simulations of the Holocene**

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Radiative forcing induced by variations of stratospheric sulfate aerosol from volcanic eruptions is one of the strongest natural drivers of climate variability. The primary effect of major eruptions is a short-term but substantial decrease in global mean surface temperature. In addition, volcanic forcing can influence oceanic and atmospheric circulation as well as sea ice, which may lead to long-lasting (decadal to centennial) climatic effects and spatially complex regional impacts.

Here we present results from two transient simulations covering the Holocene from 8kyr BP to 1850 CE using the comprehensive Earth system model MPI-ESM1.1. MPI-ESM is run at relatively high resolution for long-term paleo-applications. The ECHAM6 atmosphere includes the stratosphere up to 0.01 hPa and is run at T63 spectral horizontal resolution (1.9 degr.) and the MPIOM ocean model grid features variable resolution between 20 km and 180 km.

While one of our simulations is forced only by the slowly varying orbital parameters and changes in greenhouse-gas concentrations, the other includes additional, comparatively fast forcing agents including volcanic aerosols and variations in solar irradiance. In particular, we present the first application of a newly derived volcanic forcing data set for the Holocene.

Comparing the two simulations highlights in particular the effects of strong volcanic eruptions. In addition to the direct cooling effects by volcanic eruptions, we diagnose sustained changes in ocean and atmosphere circulation, and sea-ice cover. Feedbacks between these components introduce long-lasting variations in Northern Hemisphere climate. Over the Holocene, including the “fast” forcing agents introduces not only distinct climate anomalies in terms of occurrence and magnitude, but also changes the spectral characteristics of climate variability modes. This could potentially explain discrepancies between reconstructions and prior climate model simulations of the Holocene that have traditionally only included forcing associated with orbital changes.

**P-4435**

## **High-resolution lacustrine records of environmental changes in Scandinavia with a focus on the Migration period and the Viking age**

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The middle of the 6<sup>th</sup> century marked the beginning of a decadal-scale cooling period in Northern Europe due to the 536/540 CE volcanic eruptions. This period has been linked to crop failures, famines and to a number of other major societal crises in the Northern Hemisphere, such as the European outbreak of the plague of Justinian (541 CE). A comparable volcanic event, Eldgjá 939 CE, was so powerful that it must have had a severe effect on climate, environment and society during the Norse expansion of the Vikings in Scandinavia. Although published sediment records from Scandinavia give information about the general climatic evolution of the past 2000 years, they do not have the needed resolution to provide yearly or decadal information which is necessary to obtain a sufficient chronology for the studied period. In this study, we target varved lake sediments in order to construct a high-resolution timeline of geochemical information, vital to discuss and understand the environmental and climatic response to these volcanic eruptions.

We have cored two lakes in southeastern Norway in order to obtain high-resolution records from the time period of interest: Lake Sagtjernet and Lake Nordbytjern. Lake Sagtjernet (c. 12 m depth) provided a sediment sequence of 5 m. A previous study from this nonglacial lake highlighted varved sediments throughout the Holocene. Lake Nordbytjern has a depth of 24 m and is categorized as an endogenic meromictic lake of glacial origin with hydraulic influx about evenly divided between groundwater seepage and two small streams. It is located roughly 1.5 km northeast of the largest burial mound in Norway (mid-6<sup>th</sup> century). The first short gravity core retrieved from this lake is 1.80 m and displays finely laminated sediments. Based on high resolution geochemical and radiographical analyses including short lived radionuclides, AMS <sup>14</sup>C and CT scanning, we will discuss the varved potential of this lake sediment sequence. Mineral and organic geochemical methods are used to reconstruct climate variations.

By comparing our sedimentary records with other natural archives in Scandinavia this study will allow us to discuss the dynamics between climate and environmental changes and their role in facilitating societal changes of the Viking society in Scandinavia.

**P-4437**

## **The impact of the double volcanic eruption event 536/540 CE on the climate in southern Scandinavia**

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Here we present analyses of the impact of a double volcanic eruption event in 536/540 CE on the atmospheric circulation and surface climate, with a focus on southern Scandinavia, using climate model simulations, new and available paleo proxies.

The middle of the 6<sup>th</sup> century is an outstanding period marked by an unusual cold period that lasted several years to decades, due to the 536/540 CE double eruption event. Evidence from multiple tree ring records from the Alps to the Altai Mountains in Central Asia demonstrate a centennial cooling lasting from 536 up to 660 CE (Büntgen et al., 2016). In this period, glaciers advanced strongly throughout Eurasia which has motivated researchers to refer to the period as the “Late Antique Little Ice Age (LALIA)”.

Ensemble simulations with the Max Planck Institute Earth System Model (MPI-ESM) have been used to show that the double eruption led to a global decrease in temperature and an increase in Arctic sea-ice for at least a decade (Toohey et al., 2016), possibly initiating the long lasting cold period until ~660 CE. This study analyzes the model output from the MPI-ESM simulations for the effects on the polar vortex, stratospheric-tropospheric circulation, North Atlantic Oscillation/Northern Annular Mode variations, and the hydrological cycle, in particular for southern Scandinavia. As part of the VIKINGS project, new proxy data such as lake sediments and tree rings will be compared with the model output for the 536-550 CE period. The extent of agreement between available and new proxies and the simulations will be assessed and possibilities for further improvements discussed.

### References:

Büntgen, U., et al. (2016). Cooling and societal change during the Late Antique Little Ice Age from 536 to around 660 AD, *Nat Geosci*, 9, 231-236.

Toohey, M., Krüger, K., Sigl, M., Stordal, F., & Svensen, H. (2016). Climatic and societal impacts of a volcanic double event at the dawn of the Middle Ages. *Climatic Change*, 136(3-4), 401-412.

P-4438

## Palaeolimnological analysis of sulphate deposition events following large volcanic eruptions in historical times

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Major volcanic eruptions may have severe societal impacts as shown by ash dispersal and sulphur emissions from recent Icelandic eruptions. However, ice-core sulphur records in combination with written accounts demonstrate that these events were minor as compared to historical events of much larger magnitude. For example, the eight month-long fissure eruption of Laki in Iceland in AD 1783-84 is estimated to have produced over 200 megatons of sulphur. Within weeks of the start of the eruption in June 1783, a dry fog extended across Europe, which persisted until autumn. Following an unusually warm summer, the subsequent winter was one of the coldest on record in Europe and North America. Acid precipitation caused harvests to fail in large parts of Europe, and these effects combined led to many thousands of casualties in Iceland and beyond. We still lack a sufficient understanding of the environmental impacts of such colossal eruptions, which take place on average once per century and can be expected to recur at any time in the future. As part of a newly initiated project, we aim at estimating the extent of such sulphate deposition events in northern and central Europe, their typical duration and effects on aquatic biota, catchment vegetation and soils, including the potential release of highly toxic methyl mercury to lake waters. By freeze-core sampling of varved lake sediments at well-documented sites, we will target some selected volcanic events of known origin during the last millennium, such as Askja 1875, Tambora 1815, Laki 1783, Veidivötn 1477 and Samalas 1257. Their physical, chemical and biological impacts on the local ecosystems will be analysed at annual resolution, if possible aided by the identification of tephra particles from the respective eruptions. Established geochemical and palaeolimnological methods will be applied, including diatom analysis of biogenic varve sequences, and comparisons will be made with historical accounts when available. As part of ongoing efforts to establish instrumentation for synchrotron-based analysis of chemically unaltered, frozen sediment records at the MAX IV facility at Lund University, we will also perform high-resolution S, Fe and Hg speciation analyses of the varve records, using X-ray absorption spectroscopy. Apart from deeper insight into ecosystem responses to massive volcanic sulphur deposition and associated ashfall events, the project will pave the way for future applications of synchrotron-based techniques within palaeolimnology. Here we present the approach and the targeted archives, as well as some preliminary results based on diatom analysis of varved sediment records from Sweden.

P-4439

## High-resolution sulfur isotopes from ice cores: insights into climatic impacts of double eruptions over the past 2000 years

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The record of the volcanic forcing of climate over the past 2500 years is reconstructed primarily from sulfate concentrations in ice cores. Of particular interest are stratospheric eruptions, as these afford sulfate aerosols the longest residence time and largest dispersion in the atmosphere, and thus the greatest impact on radiative forcing. Identification of stratospheric eruptions currently relies on the successful matching of the same volcanic sulfate peak in ice cores from both the Northern and Southern hemispheres (a “bipolar event”). These are interpreted to reflect the global distribution of sulfur aerosols by the stratospheric winds. Despite its recent success, this method relies on precise and accurate dating of ice cores, in order to distinguish between a true ‘bipolar event’ and two separate eruptions that occurred in close temporal succession.

Sulfur isotopes can be used to distinguish between these two scenarios since stratospheric sulfur aerosols are exposed to UV radiation which imparts a mass independent fractionation (Baroni et al., 2007). Mass independent fractionation of sulfate in ice cores thus offers a novel method of fingerprinting stratospheric eruptions, and thus refining the historic record of explosive volcanism and its forcing of climate. Here we present new high-resolution (sub-annual) sulfur isotope data from the Tunu Ice core in Greenland and B40 ice cores from Antarctica over several eruptions, with a focus on major double eruptions that occurred within a few years of each other, and their climatic impact.

Baroni, M., Thieme, M. H., Delmas, R. J., & Savarino, J. (2007). Mass-independent sulfur isotopic compositions in stratospheric volcanic eruptions. *Science*, 315(5808), 84–87. <http://doi.org/10.1126/science.1131754>

**P-4440**

## **Blue-stained rings in ancient bristlecone pine as a volcanic proxy**

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Blue-stained rings, subannual ring features visible in some temperature-sensitive trees, including upper treeline bristlecone pine (*Pinus longaeva*), provide evidence for the timing of past rapid cooling often associated with large-scale volcanic eruptions. Blue-stained rings are discovered by cutting 15–20  $\mu\text{m}$  thin transverse sections from a wood sample and double staining. Cell walls that did not sufficiently lignify during the growing season take on the blue color, a result that has been linked to abrupt temperature reduction. Large-scale volcanic eruptions cause rapid cooling of surface temperatures. The climatic effects associated with these eruptions can have wide-ranging disruptive impacts on plant and animal communities including human societies. We examined upper treeline bristlecone pine samples from three different mountain ranges in western North America across both the 20<sup>th</sup> century AD and three ‘volcanically interesting’ time periods: the 6<sup>th</sup> century AD, 1700–1400 BCE, and 2300–2100 BCE. Blue-stained rings tend to co-occur but with frost rings, but are a more common and perhaps more sensitive indicator of cooling than these features. Blue-stained rings occurred during all time periods and can be associated with trees growing in the coldest topoclimatic positions on the landscape and with abrupt cold snaps in both the beginning and end of the growing season.

**P-4441**

## **The role of volcanism and solar irradiance on sea-ice conditions in Baffin Bay/Labrador Sea over the last 2000 years**

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Volcanic eruptions and variability in solar activity are important physical drivers of climate change. Large eruptions and grand solar minima have the potential to decrease air temperatures, affect patterns of atmospheric circulation and precipitation, and increase sea-ice extent and transport to lower latitudes (with climate feedbacks). Elucidating the impacts of these drivers via proxy records and climate model simulations provides essential knowledge of their importance in natural climate variability. In this study we reconstructed sea-ice conditions in the Baffin Bay/Labrador Sea system over the last 2000 years by analysing the sea-ice biomarker IP<sub>25</sub> from a well-dated core collected in Bonavista Bay, NE Newfoundland, a site that records sea-ice variability in and export from Baffin Bay. Marked step changes were identified in the IP<sub>25</sub> flux data, and the correlation between solar irradiance and the IP<sub>25</sub> record was assessed. March-May sea-ice concentrations for the Hudson and Baffin Bays were modelled using LOVECLIM, resulting in 10 ensemble simulations (and the mean of these) over the last two millennia. Based on the proxy records and long-term data on volcanic eruptions and solar irradiance, it appears that clear (step-wise) increases in sea-ice concentrations can be observed at times when repeated explosive volcanism and centuries of lower solar irradiance (grand minima) coincide, whereas either driver alone does not markedly change sea-ice conditions in the system. While there are quite large differences between the different LOVECLIM simulations, highlighting the chaotic property of the climate system, these step-wise increases in IP<sub>25</sub> can also be observed in the modelling results: there seems to be a transition around 500-600 AD in most simulations, which is when sea-ice export to the study site began based on proxy data. Further two transitions, although not detectable in all simulations, can be seen around 1200-1300 AD and 1600-1700 AD, when repeated volcanism and grand solar minima are recorded. These time periods coincide with the Dark Ages and the beginning and the height of the Little Ice Age – both cold climate periods, which had severe impacts on societies of the time.

**P-4442**

## **Timing of the initial Mediterranean response to major climate reorganization during the last interglacial-glacial transition**

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Millennial-scale Dansgaard-Oeschger (DO) variability in northern high latitudes has influenced climatic and environmental conditions in the Mediterranean during the last glacial period. There is evidence that the global transmission of the DO variability occurred at the end of DO 25; however, the exact timing and the trigger that activated the Mediterranean response remains incompletely understood. Here, we provide evidence that the rapid teleconnection between both regions started at ~111.44 ka forced by a sub-millennial scale cooling in Greenland (GI-25b) with immediate impact in the Mediterranean. High-resolution sediment proxies and the pollen record of the renowned Lago Grande di Monticchio (MON), Italy, reveal climatic instability during the last millennium of interglacial conditions, which was characterised by a first and short cooling episode MON 1 at 111.44 ka which coincides with the Greenland cold sub-event 'GI-25 b' in timing and duration. Monticchio and Greenland also agree in describing a subsequent rebound phase that culminated in an abrupt stadial oscillation MON 2/ GS-25 marking the transition into the last glacial period. Our results show an early response at Monticchio to centennial scale climate change in Greenland as a prelude to the millennial-scale global climate variability that was maintained during the glacial period.

**P-4443**

## **Millennial-scale climate variability in arid Central Asia: evidence from the Ili Basin loess**

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Central Asia lies at the core of the largest and most populous continent on Earth – Eurasia – however we know little about its role in global climate dynamics past and present. We know that the region lies at a critical transition zone between the major northern hemisphere climate subsystems, the intensity and scale of which waxed and waned throughout the climatic oscillations of the Quaternary. As yet, however, the history of climate dynamics in arid Central Asia, and its teleconnections with the better understood extremities of the continent, remains effectively unexplored. This is largely because we have yet to recognise the full potential of Eurasia's most widespread archives for past climates: loess.

Traditionally, the hypothesised link between loess and climate is relatively straightforward: loess accumulation intensifies during cold glacial phases, and decreases and is overprinted by soil formation under relatively milder climates. For the loess deposits draping the mountain piedmonts of arid Central Asia, however, the climatic link is more complex. The glaciers of the Asian high mountains respond more to changes in precipitation rather than temperature, resulting in an increase in loess accumulation rates both during glacial advance under warmer, wetter interstadials and during cold stadials. Extracting the climatic signal from loess, and what it means for climate dynamics, therefore represents a complex challenge requiring the reconstruction of quantitative palaeoclimate parameters, and at sufficiently high resolution to identify millennial-scale variability.

Here we provide the first quantitative record of last full glacial cycle climate from loess in arid Central Asia, at sufficiently high resolution to identify millennial-scale changes. Our dataset from the Remizovka profile in the northern Tien Shan foothills integrates centimetre-scale chronostratigraphies with estimates of past temperature, precipitation, and seasonality based on organic and stable isotope geochemistry, alongside established grain-size, palaeoecological and magnetic susceptibility analyses. Our results suggest that during warmer climate phases such as MIS3, northward expansion of monsoonal precipitation regimes and glacial advance impeded teleconnections with the temperate zone westerlies to the north. The resulting compression of synoptic-scale systems against the piedmont intensified wind strength and loess flux, particularly during short-term Heinrich Events which saw increased eastward penetration of westerly dust-storms. By contrast, the last glacial maximum was colder and drier, with reduced but sustained glacial ice volume providing fine-grained material for transport via persistent northerly and westerly wind regimes onto the piedmont. Our study provides a useful first glimpse into millennial-scale climate dynamics in the heart of the world's largest continent, and the first meaningful possibility to interrogate hypothesised climate teleconnections across Eurasia.

**P-4444**

## **Identifying cryptotephra in the ICDP Dead Sea deep core to synchronise past hydroclimate changes in the eastern Mediterranean**

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In the drought-affected eastern Mediterranean region, a better understanding of the past hydroclimate variability is a prerequisite to improve our capability for estimating future changes of the water balance. In this respect, palaeoclimate records from marine or lake sediments provide invaluable information about natural hydroclimate changes. The hypersaline Dead Sea is a key palaeoclimate archive in the south-eastern Mediterranean region, situated at a critical position between more humid Mediterranean climate and the hyper-arid Saharo-Arabian desert belt. The ca. 450 m long ICDP drill core 5017-1, from the deepest part of the Dead Sea, covers the last ~220,000 years, as constrained by radiocarbon, U-Th dating and floating  $\delta^{18}\text{O}$  stratigraphy methods. Nevertheless, an independent dating method is much needed because (i) radiocarbon dating is limited to the last ~40,000 years, (ii) U-Th dating of authigenic carbonates requires a comprehensive correction procedure leading to large age uncertainties, and (iii) wiggle matching of oxygen isotope data is not independent and, hence, does not allow the identification of lead- and lag-phase relationships of changing hydroclimate in comparison to other palaeoclimate records.

Tephrochronology has been demonstrated a powerful tool for dating and synchronisation of palaeoclimate records for regional and global comparison. Due to a lack of visible tephra layers in the Dead Sea sediment record, however, direct links with the eastern Mediterranean tephrostratigraphical lattice are still absent. The recent discovery of the first cryptotephra ever identified in Dead Sea sediments (the early Holocene S1-tephra from central Anatolia) encouraged the systematic search for tephra time-markers in the ICDP deep-basin core 5017-1, with the aim of improving the chronology of the deep record significantly. Here we present preliminary results of a new project focusing on the identification of widespread and well-dated Mediterranean tephra time-markers in the ICDP sediment cores from the deep Dead Sea basin.

**P-4445**

## **Forager adaptations to MIS 3-2 rapid climate variability in central-eastern Europe**

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Tracking environmental changes at the time of modern human dispersal within Europe during Marine Isotope Stages (MIS) 3 and 2 when past climate conditions varied rapidly, often on decadal to millennial timescales, is still challenging. The emergence of palaeoclimate records including lake sediments, speleothems and loess for central-eastern Europe, and the significant progress recently achieved in studying the Late Quaternary environments provide crucial insights (i) for understanding past human-environment interactions in the light of INTIMATE chronostratigraphy and (ii) the cultural development during the Upper Palaeolithic in central-eastern Europe.

Here we discuss latest results arising from an archaeological-chronological investigation of Upper Palaeolithic habitation contexts within the Bistrita valley, Eastern Carpathians. Bistrita valley hosts the largest inventory of Upper Palaeolithic sites in Romania with condensed loess and colluvium sequences and settlements located on river terraces, and largely assigned to the Late Aurignacian/Gravettian and Epigravettian technocomplexes. Notwithstanding their unusual density, very few of these pluristratified settlements rely on reliable numerical chronologies or on accurate palaeoenvironmental contextualization.

In order to augment the cultural considerations we applied a multi-method chronological research. This includes optically stimulated luminescence dating of sediment and direct thermoluminescence dating of burned flints, whereas charcoal remains were dated via multi-protocol radiocarbon dating. The contextualization of the sedimentary environments and integration of numerical dating results (e.g. luminescence, radiocarbon, tephrochronology) has been achieved via detailed sedimentological and environmental magnetic proxies that indicate a loess depositional setting, modulated by slope processes and possibly by anthropogenic activities such as periodic large-scale vegetation burning. We show that the Bistrita valley provides reference records from multi-disciplinary research into the interaction between humans and their environment during late Quaternary, more closely integrating archaeological and paleoclimate. In exploring the contextual basis for understanding human dynamics in close connection to biodiversity changes during MIS 2-3 in the Eastern Carpathians as possibly modulated by past climate and environmental conditions, a review of available regional palaeoclimate records (palaeovegetation, stable isotopes, palaeodust dynamics) is also presented.

P-4446

## Investigating timing of rapid climate shifts in northern Europe during the LGIT using a new tephra study from southernmost Sweden

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This work in progress employs the method of tephrochronology to establish linkages between the previously published palaeoclimate record of the Körslättamossen fen in southernmost Sweden (Hammarlund & Lemdahl 1994) and other reconstructions of climate change in northern Europe during the Last Glacial–Interglacial Transition (c. 15–8 ka b2k). The identifications of four cryptotephra horizons (distinct concentrations of volcanic ashes not visible to the naked eye, extracted from the sediments and geochemically analysed by electron probe microanalyser) at this site has enabled correlations to a multitude of palaeoclimatic investigations in the region, including linkages based on the Laacher See Tephra as it is one of the tephras identified at Körslättamossen—the first discovery of the Laacher See Tephra on Swedish mainland (Larsson & Wastegård 2018). The other identified tephras are the Hässeldalen Tephra, the Vedde Ash, and the Borrobol or Penifiler Tephra.

By examining the palaeoclimate records of sites geographically distant from each other through the correlations enabled by tephrochronological synchronisation, the issues of temporal and spatial evolution of rapid climate changes are assessed. These event, including abrupt, large-scale events such as the Younger Dryas stadial, are as of yet not entirely understood in terms of causes or behaviour—though such knowledge is crucial to understand the climate system and its development in the past. Tephrochronology is a highly useful method for this purpose due to its precision and geographical coverage (as volcanic ashes tend to spread far and wide over, geologically speaking, short periods of time before settling) and this study represents one of several recent opportunities to gain new, detailed knowledge on past climate change.

### References:

Hammarlund, D. & Lemdahl, G. (1994) A Late Weichselian stable isotope stratigraphy compared with biostratigraphical data: a case study from southern Sweden. *Journal of Quaternary Science*, vol. 9, pp. 13–31.

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**P-4447**

## **Environmental change at Esthwaite Water, English Lake District: re-visiting lacustrine sediments with new chronological and proxy techniques.**

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This study presents a new geochronological, lithological and organic geochemical analysis of the Late Pleistocene and Holocene sediments from an 8.45-m long sediment core from Esthwaite Water in the English Lake District. Due to the limitations of dating techniques when the first lithological and palynological studies were carried out (e.g. Franks and Pennington, 1961) uncertainty remains regarding the timing of the Dimlington Stadial ice retreat in the Southern Lake District and the (a)synchronicity of climate records from the Late Glacial and Holocene with other Northern Hemisphere records. We present an independent age model for the entire core using short-lived radionuclides <sup>210</sup>Pb and <sup>137</sup>Cs, radiocarbon (n = 11), tephra (n=2) and varve counting across the 1.83-m section of varved basal sediments. We show the geochemistry of two tephra horizons in the Pleistocene – Holocene transition, which will allow this record to be independently linked with others in the North Atlantic region and for the first time; North America. The new age model for Esthwaite Water is constructed using Bayesian statistics and provides constraints on events inferred from the lithostratigraphic description and magnetic susceptibility, organic content and grain size analysis. Organic proxies; C/N, algal lipids and plant leaf waxes are used to reconstruct environmental change across the last glacial – interglacial transition. The age model and varve counts show the site could have been contact with ice during the Dimlington Stadial as late as 15 919 cal BP. Lithology and climate proxies show stadial climate conditions ended, at latest 15 204- 14 542 cal BP. We see a response in lithology and environmental proxies to Bølling/Allerød interstadial climate change and the Younger Dryas climate deterioration. Lithology and proxy data show a delayed response to the onset of the Holocene when compared to temperature data from Greenland oxygen isotope records.

### Reference

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P-4448

## Lake Suigetsu update: final judgement on the synchrony / asynchrony of global warming events during the last deglaciation

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The high-precision chronology of varved sediment from Lake Suigetsu, combined with its high-resolution climate reconstruction based on pollen, has the potential to enable robust assessments of climatic leads and lags with other key palaeoclimatic archives. Indeed, the lead author presented our preliminary results at a plenary session of Nagoya INQUA (2015), where we concluded that two abrupt warming episodes at the onsets of the Holocene and the Lateglacial interstadial have different spatio-temporal structures (i.e. the Holocene onset was synchronous between Japan and the North Atlantic, whereas the onset of the Lateglacial interstadial was earlier in Japan by about two centuries). However, those interim conclusions in 2015 were essentially hypothetical because the site-specific age scales of Lake Suigetsu (SG06<sub>2012</sub>yr BP) and Greenland (GICC05 yr BP) were not precisely synchronised with each other.

Recently, the GICC05 and IntCal13 chronologies were synchronised by wiggle matching cosmogenic isotopes (<sup>10</sup>Be in ice and <sup>14</sup>C in tree rings; Muscheler et al. 2014; Adolphi et al. 2018). Similarly, we performed Bayesian modelling of Suigetsu's <sup>14</sup>C dataset onto the IntCal13 radiocarbon calibration model, by which we could put the Suigetsu proxy record onto the IntCal13 age scale. This enables robust assessment of the relative timing of climatic events at Suigetsu and Greenland, as well as in other archives that have been synchronised to either GICC05 or IntCal13. In our presentation, we report whether our 2015 Nagoya hypotheses of synchrony and asynchrony are accepted or rejected.

P-4449

## Sedimentation responses to Younger Dryas climate change in a three lake cascade in northern Poland

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Annually laminated (varved) lake sediments are suitable high-resolution climate archives. However, local factors including lake bathymetry and catchment morphology may influence lacustrine sedimentation processes and modify the sediment response to climate change. Therefore, differentiation between local factors and regional climate signals is crucial for using lake sediments as robust climate archives.

Here, we compare three partly varved sediment records within a lake cascade for their response to the Younger Dryas (YD) climate change by using a multiproxy approach (varve-microfacies, stable isotopes, XRF element scanning). The YD is an appropriate time window to study lake response to large-scale and abrupt climate change.

The basins of Lake Głębobczek (JG), palaeolake Trzechowskie (TRZ) and Lake Czechowskie (JC) were formed by glacial hydrodynamic processes and form a cascade chain. Their catchment is mainly composed of outwash plain deposits and subordinated by glacial till. We investigate the time interval from 13100 to 11200 BP to compare lake specific sediment responses to rapid climate change. The sediment records are synchronized through well-defined biostratigraphic boundaries (Allerød/YD and YD/ Preboreal) as well as the Askja-S cryptotephra.

All three records show a cessation of varve formation and an increase of detrital influx at the onset of the YD, reflecting increased windiness and catchment erosion. However, the timing of varve disappearance at the onset of the YD is delayed by 160 varve years in JG compared to TRZ and JC, where varve cessation is synchronous with the most prominent vegetation change. More stable conditions in JG with respect to varve formation is explained by the small surface area and the wind sheltered position of JG. At the YD/ Holocene transition, varve preservation in JG starts earliest for the same reason, while varves in JC recurred with an offset of 60 years. In TRZ, varve preservation did not start again.

Bulk carbonate  $\delta^{18}\text{O}_{\text{carb}}$  values reflect distinct differences in the amplitude of change. The general shift to lighter  $\delta^{18}\text{O}_{\text{carb}}$  at the onset of the YD reflecting colder temperatures is biased in JG by the occurrence of rhodochrosite. The return to more positive  $\delta^{18}\text{O}_{\text{carb}}$  at the onset of the Holocene is visible in all records whereas the JC shows a significant increase of 4‰, likely caused by evaporation processes. Despite local differences, our data shows that changes in the catchment area are consistently recorded in the all three bulk  $\delta^{13}\text{C}_{\text{org}}$  records. A significant shift of approximately 4‰ towards more positive values may reflect the regional vegetation change from forest to grassland at the YD onset.

This study is a contribution to the BaltRap project "WP2: Holocene annually laminated lake records", funded by the Leibniz Association.

P-4450

## **Abrupt climate changes during the early last glacial period recorded in French speleothems**

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The early last glacial period marks a transition interval from interglacial to glacial climate conditions and is accompanied by the onset of abrupt stadial-interstadial changes known as Dansgaard-Oeschger (DO) events. These early DO events are clearly represented in the NGRIP ice-core record, but their expression in many other terrestrial records remains more equivocal than later DO events. High-resolution and chronologically well-constrained records of the early last glacial are needed to improve our understanding of the geographical extent and timing of these first DO events. Here we present speleothem stable oxygen and carbon isotope records from two neighbouring caves in Ardèche, southern France; l'Aven d'Ornac and the cave of Saint-Marcel d'Ardeche. The speleothem records span the period 125 – 87 ka and are tied to a uranium-thorium based chronology. These records show millennial-scale variability that is structurally very similar to the NGRIP ice-core record and sea-surface temperature records from the Iberian margin, suggesting a strong climatic teleconnection between southern France and the North Atlantic during these early DO events. The Ardèche speleothems, with up to decadal resolution, also preserve evidence of shorter-lived, precursor or rebound type interstadials including GI 25a, 24.c and 23.2. This provides some of the first clear evidence of these events outside of Greenland and suggests that these features were widespread climate variations that also occurred in this region of Europe. Both isotope profiles record evidence of millennial-scale climate variations, interpreted to reflect wetter and more vegetated conditions above the cave, which is in contrast to some other stalagmites from France and the Iberian Peninsula where  $\delta^{18}\text{O}$  does not respond as strongly to such changes. The timing of interstadial events in the speleothems agrees within the uncertainty of the GICC05 and GICC05modelext chronologies, but provides much greater chronological control. Together, the Ardèche stalagmite records provide high-resolution and precisely constrained information on the expression of abrupt climate changes in southern France during the early last glacial.

P-4451

## Timing and abrupt oscillations during last deglaciation in stalagmites from Ostolo Cave, Western Pyrenees, Spain

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The last deglaciation (from  $\approx 19$  kyr BP to the onset of the Holocene) is an interesting time interval when all the components of the climate system underwent large-scale changes associated with global warming. This trend was punctuated by several warming and cooling events that took place abruptly. It is very important to know when precisely these events occurred and what their amplitude was in order to better understand their causes and impacts on the regional environment.

The northern Iberian Peninsula, due to its location with respect to the polar front at that time, is a sensitive place to determine climatic changes in Southern Europe during the last deglaciation. The climatic events mentioned above are recorded in lake and marine sediments denoting the importance of these records in the transitional zone between the Atlantic and the Mediterranean climatic realms. The glacial-interglacial transition was also identified in speleothems from northern Spain and southern France, where possible differences with the patterns identified in the Greenland record during GI-1 were analysed. In addition, a high-resolution analysis of a stalagmite suggests that the GS-1 response in the central Pyrenees was divided in two distinct phases.

In this new study, three stalagmites from Ostolo cave in the Western Pyrenees were analysed to identify and characterize the timing and climate variability along the abrupt changes that punctuated the last deglaciation. The samples were dated at high precision and cover almost continuously the same period (18-10 kyr BP) with a high degree of replication. The  $\delta^{18}\text{O}$  record follows closely the well-known changes from high latitudes showing more negative values during GS-1 and H1 ( $-8\text{‰}$ ), related to colder climates, while more positive values were reached during GI-1 and the Early Holocene ( $-2\text{‰}$ ), pointing towards warmer temperatures. The  $\delta^{13}\text{C}$  record is usually interpreted in this region as a proxy of vegetation cover density. However,  $\delta^{13}\text{C}$  variations in the Ostolo stalagmites suggest better hydrological conditions for vegetation development from 16 to 14 kyr BP, a period previously characterized by cold temperatures. Trace-element data together with monitoring are in progress to help clarifying this aspect.

**P-4452**

## **Is there a climatic imprint of the 8.2kyr event in Antarctica?**

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The 8.2kyr event is the most recent episode of abrupt cooling prominently recorded in the Greenland ice cores. It is widely believed that this climatic oscillation has been triggered by a freshwater pulse into the North Atlantic perturbing the Atlantic Meridional Overturning Circulation. By analogy to similarly forced glacial climate swings, we can thus expect a bipolar see-saw response in the Southern Hemisphere albeit under early Holocene interglacial conditions. This is supported by some (sub-) tropical speleothem and marine records implying a southward shift of the ITCZ during the event. However, the efforts to reliably test whether a climate response can be detected in Antarctica has so far been hampered by the short duration of the event, the relatively small expected amplitude of the climatic response (signal to noise), and timescale uncertainties.

Here we synchronize Greenland and Antarctic ice core timescales by means of cosmogenic radionuclides and volcanic tie-points, eliminating phasing uncertainties between climate records from both regions, and employ a suite of high-resolution water isotope and impurity records from Greenland and Antarctic ice cores to increase the signal to noise ratio of the climate records. We test whether an imprint of the 8.2kyr event can be detected in Antarctica and whether its timing is consistent with the proposed response time of the bipolar see-saw mechanism seen during the last glacial.

**P-4453**

## **Enhanced Bayesian statistical modelling of radiocarbon datasets obtained from three British sediment sequences spanning the Last Glacial-Interglacial Transition**

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We apply revised Bayesian statistical modelling to radiocarbon datasets obtained from three sediment sequences from the British Isles: Llanilid (SW Wales); Sluggan Bog (N. Ireland); and St. Bees (NW England); each spanning the Last Glacial-Interglacial Transition (LGIT). The existing chronologies for each of these sites is based upon radiocarbon (<sup>14</sup>C) dating of different material types, including both base-insoluble ('humin') and base-soluble ('humic') bulk sediment fractions. Previously, subjective choices were adopted when accepting or rejecting individual dates for inclusion in the finalised, published age-depth models, which is not ideal. Here, we account for the 'maximum' and 'minimum' ages that may be assumed to apply to the humin and humic sediment fractions through application of 'After' and 'Before' functions (more commonly employed for archaeological contexts) in the OxCal Bayesian statistical software (Bronk Ramsey, 2019). In this way, we seek to maximise the chronological information nevertheless attainable from such 'bulk' sediment samples, while minimising the need for the potentially subjective removal of data during age-depth model construction.

Bronk Ramsey, C. (2019) OxCal ver.4.3, <https://c14.arch.ox.ac.uk/oxcal/OxCal.html>.

P-4454

## Reconstructing abrupt climate changes of the last deglaciation & Holocene: Pollen and biomarker analyses from the Portuguese Margin

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In light of the current rate of anthropogenic climate change, it is becoming increasingly critical to enhance knowledge of past abrupt climate events and subsequent responses of the Earth system. One period that can provide such insight is the last ~30 kyr, with several abrupt changes occurring over the course of the deglaciation. The Portuguese Margin has been an ideal location to study the impacts of these abrupt climate events on marine and terrestrial environments. The combined effect of the narrow continental shelf and close proximity to the Tagus and Sado rivers, lead to the rapid delivery of a high quantity of sediment, including pollen and biomarker proxies, to the Tagus Abyssal Plain. Joint terrestrial and palaeoceanographic analyses from the same sediment samples enable an *in situ* assessment of the relative timing of changes in palaeoceanographic and terrestrial proxies.

Here we document the response of western Iberian vegetation to millennial and centennial-scale changes, particularly changes in moisture availability, over the deglaciation and Holocene, by combining (for the first time at a Portuguese Margin site) pollen and leaf-wax isotopic biomarker records ( $\delta^{13}\text{C}$  and  $\delta\text{D}$ ) from core SHAK06-5K. A high-resolution pollen record (every 2cm) and lower-resolution *n*-alkane  $\delta^{13}\text{C}$  and  $\delta\text{D}$  records spanning 28kya are compared with high-resolution XRF sediment and planktonic foraminiferal  $\delta^{18}\text{O}$  analyses from the same core. The sequence is supported by high-resolution age control, based on 38 Accelerator mass spectrometry (AMS)<sup>14</sup>C dates from monospecific samples of the planktonic foraminifera, *Globigerina bulloides*.

Our pollen record indicates the rapid response of regional vegetation to centennial changes and millennial-scale climate events, with forest expansion during the warm interglacial/ interstadial Bølling-Allerød and Holocene, and forest contraction and steppe expansion during cold glacial/ stadial conditions of the Last Glacial Maximum and Younger Dryas. Comparing our pollen and *n*-alkane biomarker data with the XRF Zr:Sr ratio and planktonic foraminiferal  $\delta^{18}\text{O}$  records, a clear synchronicity can be seen in the timing of millennial-scale changes in all records. The millennial-scale changes in our leaf wax *n*-alkane  $\delta\text{D}$  and  $\delta^{13}\text{C}$  records can be explained by both vegetation composition and growing season water availability.

**P-4455**

**A first annual-layer-counted chronology for the EastGRIP ice core and the search for a precise dating for the Thera eruption.**

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The development of paleoclimatic timescales is of vital importance for the understanding of climate. Ice cores are optimal tools for the construction of a timescale because they record the signal of multiple annually resolved proxies with well preserved stratigraphy. In 2018, the East Greenland Ice Coring Project (EastGRIP) reached a depth of 1760 m, corresponding to an age of approximately 21000 years BP. The newly drilled core has been matched to other Greenland ice cores to adapt the GICC05 ice-core timescale. This provides a chronological basis for the study of the core that is consistent with other Greenland cores.

The techniques adopted for matching of the ice cores rely on the assumed synchronicity of deposits from volcanic eruptions, biomass burning events, and solar events [1]. These time markers are essential for the synchronization of different time records as well as for the determination of regional leads and lags occurring at the onset of climatic transitions. The measurements used for volcanic matching are electrical conductivity measurements (ECM) and dielectric profiling (DEP), which were performed directly in the field and then processed to a high precision in depth assignment. Independent matching of DEP and ECM matching was performed to assess the precision of the synchronization before the two records were merged.

The strength of the volcanic matching between Greenland ice cores is increased by locating the same Northern Hemisphere volcanic ash deposits (tephra), which possess unique geochemical

'fingerprints'. This challenging search is conducted along the length of each core and is particularly useful in the Last Glacial Maximum, where the presence of acidic spikes is scarce both in ECM and DEP data. The transferred timescale is complemented by automated counting of annual layers between the observed tie-points, using annually resolved proxy data measured by chemical Continuous Flow Analysis (CFA). Ultimately, these new results will feed into the revision of the GICC05 time scale and hopefully reconcile the differences between GICC05 and the timescale proposed by Sigl et al [2].

In this framework, we are trying to narrow down the dating of the Thera eruption on Santorini (around 3500 BP). The timing of this event is still debated, because of an apparent discrepancy of about 100 years between carbon-14 dating and historical dating [3].

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P-4456

## Extending the INTIMATE tephra event stratigraphy into the Eastern Mediterranean, Levant and North Africa: potential, challenges and new correlations.

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The nature and expression of climate change in the Eastern Mediterranean, the Levant and North Africa is of considerable interest across a range of disciplines. This is, in part, due to the need to understand the potential for future climate forcing of environments in the region, but also as it is key locale for multiple phases of human dispersal out of Africa, with the potential for climate drivers to be implicated as a stimulus for these dispersals. The last glacial to interglacial period (c. 130-8 ka BP) is a critical window to examine such processes as a range of climatic signals are recorded. As with all such questions, however, absolute dating of abrupt climatic transitions with sufficient resolution to allow meaningful comparison is difficult, especially in the period where radiocarbon dating becomes challenging and other techniques are required.

To address such issues the INTegration of Ice core, MARine and TERrestrial (INTIMATE) community has proposed the INTIMATE event stratigraphy, which couples the stratigraphic framework of the Greenland Ice cores as a regional framework with a series of tephra horizons identifiable in the North Atlantic and Europe, to aid the process of independent correlation of records. The last INTIMATE event stratigraphy coupled the extended GICC05 timescale for Greenland back to 128 b2k with an allied tephra record (Blockley et al., 2014). This included a limited number of tephra known to originate or be located across the Eastern Mediterranean region, however, in many instances their distribution and origin was poorly understood. This work aims to improve and extend this provisional framework by integrating important Levantine archaeological records, and long marine and terrestrial palaeoclimate archives in the Eastern Mediterranean. These results are compared with data from known volcanic centres in Turkey and the Aegean Islands, as well as tephra from archaeological and palaeoclimate archives from the RESET project (Lowe et al., 2015) to assess the current potential and limitations for building a tephrostratigraphic framework for the correlation of archives in this region.

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**P-4457**

## **Cryogenic cave carbonates suggest changing winter conditions in the European Alps during the mid-Younger Dryas**

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Coarsely crystalline cryogenic cave carbonates (CCC<sub>coarse</sub>) are secondary carbonate deposits that form via slow freezing-induced supersaturation of small water bodies in cave ice at temperatures very close to 0°C. CCC<sub>coarse</sub> are also receiving increasing attention as a quantitative indicator of palaeo-permafrost thawing, because they can be precisely dated using U-series disequilibrium methods.

CCC<sub>coarse</sub> formed during the Younger Dryas (GS-1) cold period were found in two caves in the Eastern Alps that are located approximately 170 km apart from each other. The entrance of Cioccherloch cave is located at 2245 m a.s.l. in the Dolomites; the second cave (Großes Almbergloch) is situated in Totes Gebirge at an elevation of 1475 m a.s.l. Both caves act as cold traps, i.e. their microclimate is mainly governed by dense cold air incursions in winter, while being insulated from the outside atmosphere during summer. Modern cave air temperatures at the CCC<sub>coarse</sub> sites are 2.5°C and 1.9°C in Cioccherloch and Großes Almbergloch, respectively.

<sup>230</sup>Th dating of fourteen samples from Cioccherloch and four from Großes Almbergloch indicates a mid-Younger Dryas age for CCC<sub>coarse</sub> formation with a weighted mean of 12.20 ±0.09 and 12.32±0.09 ka BP, respectively. These data demonstrate that perennial (thawing) ice due was present in these caves during the mid-Younger Dryas, whereby cave temperatures were very close to the melting point.

As the thermal regime of these caves is controlled by the outside air temperature during winter only, the transient warming in these subsurface environments at 12.3 ±0.1 ka BP recorded a shift from very cold and dry to milder and more humid winter conditions in the Alps. The timing of this change agrees with proxy data from other terrestrial archives in Europe (e.g., Meerfelder Maar, El Soplao cave) and corroborates the hypothesis of a northward shift of the polar front during the mid-Younger Dryas in central and northern Europe.

P-4458

## First results from the Lateglacial and Early Holocene fill of Lac Retournemer (Vosges, France): another INTIMATE Example

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One of the current activities of the INTIMATE Network is the organization of bi-annual research training schools for Early Career Scientists. During these INTIMATE Example summer schools, fieldwork, lectures and lab-based activities are executed focusing on a central theme or specific site. The fourth INTIMATE Example Research Training school centered around the coring of Lac Retournemer in July 2018, and aimed at collecting a Lateglacial-Holocene record of past environmental change. Retournemer is located in the High Vosges mountains, and is a nice example of a cirque lake that was formed during the Weichselian. Lac Retournemer is located at 776m above sea level in the head-waters of the Vologne Valley and is currently a 11m deep lake behind a glacial threshold consisting of igneous rock. This area is one of the wettest areas in France with high precipitation values and might therefore be a good site to record Icelandic tephra. Previous investigations show that at least 15m of partially laminated sediments are present in this basin with also a possible occurrence of Laacher See Tephra.

During the summer school we obtained a 18m sediment record before we reached the basal glaciolacustrine sediments at 29 m below water level. In the top part of the sequence, clear sediment fluxes can be observed which might be linked to human impact or increased precipitation events in the catchment. The first results from the basal part of the sequence show a clear Lateglacial and Early Holocene record with Laacher See Tephra in a laminated sequence and a possible occurrence of Vedde Ash in the more siliciclastic Younger Dryas sediments. The Loss on Ignition profile shows multiple fluctuations in the Lateglacial Interstadial and Early Holocene which might be linked to the oscillations in the INTIMATE event stratigraphy for this time period. Preliminary palynological results support the Lateglacial and Early Holocene age of the sequence and will be further explored to investigate the differences in response with other proxies such as chironomids, geochemistry etc. The occurrence of Laacher See and Icelandic tephra in the core will add to the existing tephra lattice for the Lateglacial and Early Holocene in Central and NW Europe.

**P-4459**

## **Last glacial tephra markers recorded in the western North Atlantic and the Nordic Seas**

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Tephrochronology is an important geochronological tool for the synchronization of disparate paleoclimate archives. With the increased development of cryptotephra analysis, regional tephra frameworks are growing into important datasets. Marine tephra frameworks describe both distal and proximal tephra horizons and compile information on the spatial and temporal distribution of different volcanic eruptions. Furthermore, they provide an essential source to aid in the correlation of marine paleorecords across oceanic basins.

Here, we present new data from two well-known, distinct and broadly deposited tephra horizons: the basaltic Faroe Marine Ash Zone II (FMAZ II) and the rhyolitic component of the North Atlantic Ash Zone II (NAAZ II). A visible tephra layer (ca. 5 cm) recorded in a marine sediment core from the Nordic Seas (MD99-2284) stratigraphically fits the timing of the FMAZ II. The geochemical compositions of several tephra shards from different size fractions were analyzed using an electron microprobe. The major elements correlate graphically and statistically with previously published data. Thereby, it confirms a Hekla source and the identification of the FMAZ II. The visible layer is distinctly deposited, shows no signs of bioturbation and has a homogenous geochemistry, which all argues for a primary airfall deposition. Additionally, tephra horizons from two marine sediment cores from the Irminger Sea (GS16-204-18CC and GS16-204-22CC) stratigraphically also fit the timing of the FMAZ II. IRD records of both cores show no increased concentration coinciding with the observed tephra horizons. Within GS16-204-18CC, the tephra concentration profiles for different size fractions indicate a first appearance of increased tephra shards in the cryptotephra (25-80  $\mu\text{m}$ ) approximately 2-3 cm prior to the increased concentrations in the larger size fractions (80-125  $\mu\text{m}$  and >125  $\mu\text{m}$ ). Within GS16-204-22CC, a general background of tephra shards is recorded within the two largest size fractions (>125  $\mu\text{m}$  and 80-125  $\mu\text{m}$ ), while the cryptotephra shows one tephra concentration peak. For both cores, the major elements of the cryptotephra show a homogenous population, which graphically and statistically correlates well with previously published data and thus, confirms the identification of the FMAZ II. The more heterogenous geochemistry from the larger size fractions indicates multiple tephra populations. The different geochemistry of the three size fractions is likely due to diverse transport mechanisms. Further, the geochemical compositions of identified rhyolitic tephra horizons from the two Irminger Sea cores correspond to the NAAZ II horizon. The homogenous geochemistry and low IRD argues for a primary air-fall deposition, although deposition on seasonal/short-lived sea ice drifting past the site cannot be excluded.

Overall, the identified FMAZ II and NAAZ II horizons within different cores contribute to the North Atlantic marine tephra framework, which allows for a better marine-marine cross-correlation of paleorecords across the basin.

P-4460

## Tephra and abrupt climate changes in the North Atlantic: key achievements and future directions

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Without a full spatiotemporal synthesis of climate variability, the causal mechanisms of abrupt climate events during the last glacial period remain unknown. Unravelling the lead/lag responses (hence cause and effect) between the Earth's climate components is limited by the challenges of synchronising palaeoclimate records on a common timescale. Tephra deposits have long been hailed as powerful independent marker horizons for precisely correlating palaeorecords, but their full potential has yet to be realised. Here we present a summary of work undertaken during the TRACE project (Tephra constraints on RAPid Climate Events) whereby tephra deposits are targeted to precisely correlate the Greenland ice-cores with North Atlantic marine records. A series of new tephra deposits have been identified in both archives, including those originating from ultra-distal sources beyond the North Atlantic region. These discoveries increase the scope of identifying coeval isochrons, but also bring new challenges in the search for unique and robust geochemical fingerprints for unequivocal tephra correlations. As such, we categorize some tephra as being more valuable than others for underpinning key snapshots in time during the last glacial period. The North Atlantic Ash Zone II, for instance, represents the most widespread isochron and constrains the cooling of GI-15. NGRIP1895.24 m and NEEM 1669.25 m provide constraints for the GS-5-GI-4 interval and the FMAZ II offer a fix-point for GS-3. We present climatic snapshots related to these tie-points and explore possible future directions for optimising the application of tephrochronology to scrutinise abrupt climate changes.

P-4461

## Late Quaternary vegetation, climate and ocean dynamics in southeastern South America and the adjacent Atlantic inferred from marine sediment cores

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Southeastern South America harbours highly diverse ecosystems, such as the Atlantic rainforest, *Araucaria* forest and grasslands. These ecosystems are highly sensitive to changes in climate which in turn is influenced by a complex interaction between atmospheric and oceanographic features. In the study area, different climatic features, such as the South Atlantic Convergence Zone, cold polar fronts and El Niño Southern Oscillation can play a role.

Furthermore, the Brazil Current from the north as well as the Malvinas Current (MC) and Brazilian Coastal Current (BCC) from the south not only control the major hydrological patterns in the western South Atlantic, but also influence the climate on land.

To reconstruct vegetation, climate and ocean dynamics over long time periods, three marine sediment cores located on a 1400 km-long latitudinal transect (Figure 1) from ca. 27 to 38°S off southeastern South America have been studied for its pollen, spore, dinoflagellate cysts and freshwater algae content.

The northernmost core GeoB2107-3 (27.18°S) indicates cool but wet climatic conditions that probably produced an extensive coverage of *Araucaria* forest from 73.5 to 65 cal kyr BP. Colder and drier climatic conditions prevailed between 38.5 and 13.0 cal kyr BP, and were probably related to an enhanced transport of cold water masses from the south, evidenced by the occurrence of long distance transport of *Nothofagus* pollen. Multiple proxy records indicate that orbital obliquity is one of the most important factors controlling marine and continental environmental changes during the last 73.5 cal kyr BP.

Core GeoB6211-2 (32.50°S) recorded environmental changes since the Last Glacial Maximum (LGM). The results indicate cold and dry climate during the LGM when grasslands dominated the landscape over the studied area. Gallery forests expanded slightly during Heinrich Stadial 1. The Atlantic rainforest expansion to the south was only recorded after 5.5 cal kyr BP. The MC and BCC had a stronger influence to the coring site during the LGM and HS1.

The southernmost core GeoB13862-1 (38.01°S) provides ocean dynamics of the upper water column in the Brazil Malvinas Confluence region since 12.6 cal kyr BP. The palynological records suggest an increase in precipitation since 5.7 cal kyr BP, which probably related to higher frequency and stronger El Niño events. The highest eutrophication of the ocean surface occurred during the last ca. 100 years, which was most probably due to stronger human impact in the drainage basin of the Rio de la Plata.

Our transect records contributes to a better understanding of past vegetation and climate dynamics in southeastern South America, and ocean conditions in the western South Atlantic over long time periods. It also provides an insight into how long-term sea level changes affect coastal ecosystems in southeastern South America.

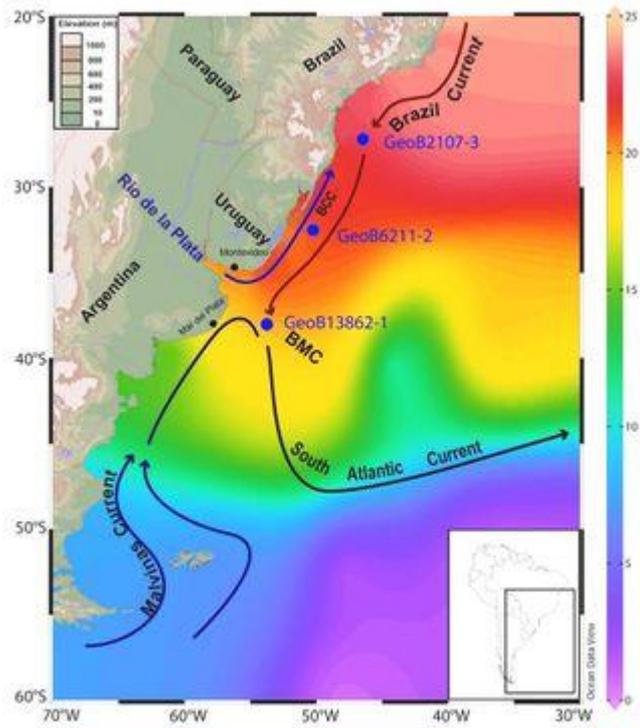


Figure 1: Coring sites and schematic surface oceanic currents in the study area. Colour shading shows mean annual sea-surface temperatures (°C). BCC: Brazilian Coastal Current, BMC: Brazil-Malvinas Confluence.

P-4462

## North-south gradients of $\delta^{18}\text{O}$ in precipitation between Greenland and Gibraltar during the Last Glacial

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We describe a methodology for reconstructing  $\delta^{18}\text{O}$  in palaeo-precipitation from speleothem records in Gibraltar and examine the implied north-south gradients of  $\delta^{18}\text{O}$  during the mid-Last Glacial.

A merged record obtained from flowstone and stalagmite (Gib10d/10e) from the same chamber of Ragged Staff Cave has a resolution of 5-20 years spanning 30 – 110 ka.  $\delta^{18}\text{O}$  variations between 40 and 62 ka align closely with NGRIP's GICC05modelext timescale but there is some divergence before and after this. We therefore restrict our reconstruction to 40-62 ka.

Three factors determine the  $\delta^{18}\text{O}$  of dripstone calcite: the seepage water's  $\delta^{18}\text{O}$ , the cave temperature (that determines the equilibrium fractionation factor between water and calcite), and non-equilibrium fractionation caused by  $\text{CO}_2$  degassing and/or surface reactions. Reconstructing the seepage's  $\delta^{18}\text{O}$  requires independent constraints on the second and third factors. It is also necessary that the relationship between  $\delta^{18}\text{O}$  in seepage and rainfall be well-constrained.

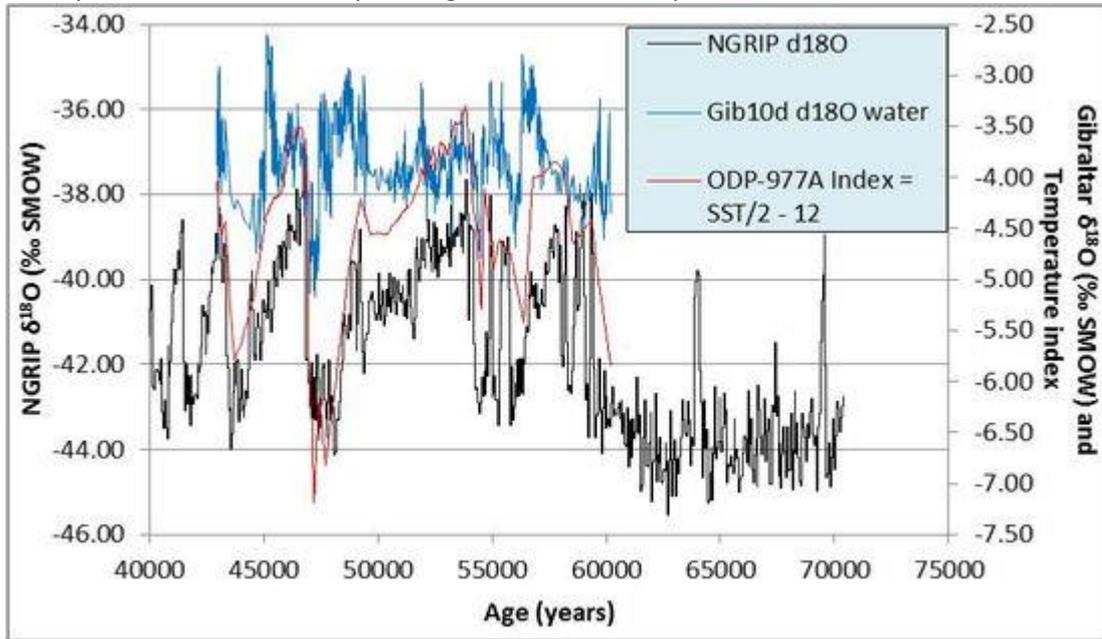
We constrain cave temperature using UK'37 data for annual average sea surface temperatures (SSTs) in core ODP-977A in the Alboran Sea, with its timescale converted to NGRIP from original tuning against the GRIP ice core. We assume that in coastal Gibraltar SSTs equalled Mean Annual Air Temperatures (MAATs). Cave temperatures would have tracked MAATs with a lag due to the thermal capacity of the bedrock. To deal with the uncertainty this imposes, we use two bounding scenarios for the evolution of cave temperatures. One computes the effects of heat storage and conduction using a 1-D model whereas in the other the lag is zero. The cave temperature scenarios are used to determine fractionation factors from which time-series of 'equilibrium' values for  $\delta^{18}\text{O}$  in water are calculated.

The effects of non-equilibrium factors are difficult to assess. The  $\delta^{18}\text{O}$  records for the two speleothems overlay almost exactly despite different morphologies. We take a similar approach to 'disequilibrium' as for cave temperature, defining one bounding scenario of 'no disequilibrium', and a second using the published 'Tremaine curve' that takes disequilibrium into account.

This approach gives rise to a 2 x 2 set of scenarios that define an 'envelope' for  $\delta^{18}\text{O}$  in palaeo-seepage. Cave monitoring shows that average seepage  $\delta^{18}\text{O}$  is currently 0.6 to 0.75 ‰ less than rainfall because of complete evaporation of summer rains. A similar loss probably occurred during interstadials but was less during stadials. We adjust the reconstructed envelope for seepage water by amounts related to prevailing SST, to obtain estimates and uncertainties for the average  $\delta^{18}\text{O}$  of palaeo-precipitation in Gibraltar that can be compared directly with NGRIP (see Figure).  $\delta^{18}\text{O}$  shows some similarities in the two records but the variation in Gibraltar is much smaller and partly



decoupled from NGRIP. Abrupt changes in Gibraltar may lead those in Greenland.



**P-4463**

## **Exploring the evidence for abrupt reorganisations in atmospheric circulation across NW Europe during the Last Glacial to Interglacial transition.**

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The Last Glacial to Interglacial transition (16 – 8 ka BP) is defined by a series of millennial-scale oscillations in climate where the transitions between warm (interstadial) and cold (stadial) states seemingly occurred abruptly. Shifts to stadial conditions appear to be forced by meltwater influx weakening in the Atlantic meridional overturning circulation (AMOC) amplified by feedbacks, while subsequent strengthening of AMOC leads to climatic amelioration. These changes are recorded across NW Europe in proxies for temperature, however, temperature change is unlikely to be the sole responding variable to this forcing. For instance, recent studies between 42 - 65°N have proposed variable timing and expression of the onset, progression, and termination of stadial conditions across the North Atlantic region. This research proposes that the offsets are likely to be driven by changes in sea ice and/or terrestrial glacier extent closely associated with abrupt shifts in the westerly wind patterns and consequently precipitation bearing weather systems. Therefore changes in hydroclimate may be as important to environmental change as temperature. These models also suggest that northerly and southerly latitudes are potentially less sensitive to these changes. However, testing these hypotheses is currently difficult as many of the available palaeoclimate records have one or more of the following challenges: (1) insufficient sampling density; (2) qualitative proxy data; (3) uneven spacing in time; (3) stratigraphic breaks in the records; (4) poorly constrained chronologies; and/or (4) poorly defined transitions.

This research identifies new and existing records which have sufficiently precise chronological control and quantitative proxy data to identify leads and lags in climatic variables and environmental responses. These records are then subjected to change-point analyses to constrain the timing of the onset, duration and termination and variability within each event. This presentation focuses on results from the onset of the Lateglacial interstadial (c. 14.7 ka BP) and the Younger Dryas period (c. 12.9-11.7 ka BP) and demonstrates that: (1) temperature and hydrological changes are asynchronous during periods of warming; (2) during cold intervals more variability occurs in hydroclimate than temperature; and (3) there are variable temperature and hydroclimatic responses across Europe.

**P-4464**

## **A lunar role in long-term climate variability**

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Essential characteristics of climate variability include cycles at various time scales, such as the ~209-yr Suess de Vries cycle of warm-cool temperatures and the Bond and Dansgaard-Oeschger quasi-periodicities of ice-rafted debris associated with abrupt climate change. Evidence also exists of a ~133-yr periodicity in precipitation, about which little is known, influencing water levels, sedimentation records, fire and drought cycles, and extreme weather events such as cyclones. A ~60-yr cycle has also been found in records of precipitation, atmospheric pressure, sea-level, global air temperature, and length of day. The global nature of these events suggests external forcing but these periodicities are poorly understood and have produced strong debates, particularly in relation to the Bond 'cycle'. Despite radioisotopic records suggesting a potential solar role at decadal, centennial and millennial scales, the longest known solar cycle is the ~11-yr variability in solar luminosity, with an inferred association with the sunspot cycle. Long-term solar cycles beyond the range of historical records are inferred from radioisotopic records, such as  $^{14}\text{C}$  and  $^{10}\text{Be}$ . The Moon's role in these events has only been partially considered. Keele (1910) linked a non-stationary 57-yr precipitation in Australia, Britain, and Egypt to southern lunar declinations. Keeling and Whorf (2000) linked lunar-forced tidal oceanic forcing to an 1800-yr cycle but were not able explain the mechanism that produced the Bond quasi-periodicity.

Based on 5.5 ky of astronomical data and dependent physical models, I provide evidence of a quasi-periodic, millennial-scale, lunar forcing associated with reduced Earth-Moon distance and maximum gravitation. A 133-yr cycle is a harmonic of the millennial-scale cycle, also resulting from variations in Earth-Sun and Earth-Moon distances. This 133-yr cycle consists of 57-yr and 76-yr components. The millennial-scale, quasi-periodic patterns in Earth-Moon distances and gravitation are strongly pronounced, with peak forcing coincident with the occurrence of Bond events during the term of the astronomical data. Patterns in insolation, total solar irradiance, and gravitation are not independent, influenced by distance. These results offer a mechanism for abrupt climate change, where concurrent tidal forcing of the atmosphere and ocean is accompanied by variations in radioisotopic records, thereby suggesting a solar influence. This mechanism has the capacity to produce regional variations through latitudinal variations that influence both oceanic tides and insolation.

P-4465

## New insights into vegetation disturbance and Māori agricultural practices on an active tectonic coastline, eastern North Island, New Zealand

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Recent radiocarbon dating suggests Polynesians likely settled on the New Zealand archipelago less than 750 years ago, making New Zealand the last major land mass colonized by humans. Two hundred and fifty years ago this year, Captain James Cook's ship, HMS Endeavour, arrived off the eastern coast of New Zealand. At that time, Māori gardening of introduced Polynesian cultivars was taking place in the north-eastern North Island (subtropical climate), while similar sites had been abandoned in the south-eastern North Island (temperate climate). Here, we present research on stone rows from a coastal site in the south-eastern North Island, in order to shed light on early Māori agricultural practices. Dating of these long stone mounds placed in shallow trenches is constrained to ~600 years ago. We have used an integrative approach incorporating analyses of microfossils, such as pollen and phytoliths, macrofossils and DNA from sediment samples taken at different depths to determine the plant remains present on and around the rows.

One of our aims is to determine whether crops were planted directly on the stone rows, which would have provided warmth and extended the growing season, or between the rows, with the stones providing shelter. Our data indicates the presence of both kumara (*Ipomoea batatas*) and gourd (*Lagenaria siceraria*) remains, making this site one of the most southerly records of gourd cultivation documented so far. Produce from this region may have been traded with South Island iwi across the ~25 km Cook Strait. A combination of dating and analysis of plant remains should provide insights into; a) the timing of when New Zealand's indigenous vegetation was initially and dramatically transformed by burning; b) the subsequent replacement by cultivars; and c) the cessation of Māori occupation at the site and continued degradation of New Zealand's indigenous flora upon European arrival. Hypotheses that have been proposed for the abandonment of stone row gardening from this region include tsunami inundation along this tectonically active coastline; and pronounced climate deterioration at this more southerly site. Both could have been devastating for the growth of these cultivars.

**P-4466**

## **When was the South Pacific colonised? A lake sediment approach to understanding palaeoecosystem change on remote Pacific islands**

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The islands of the South Pacific were amongst the last places on Earth to be colonised. However, the timing and associated impacts of colonisation are still much debated. The human colonisation of oceanic islands allows for the study of biological invasions of pristine environments. The isolation of these islands and their relative small size allow us to investigate processes and rates of invasions of exotic flora and fauna. The islands also act as microcosms in which we can observe the impacts of agriculture and altered burning regime. The relative recentness (late-Holocene) of the colonisation means that evidence (archaeological and palaeoecological) is well preserved. The aim of this poster is to summarise and describe the palaeoecological research project that we started in 2018. We will use sediment cores from locations across the South Pacific and will apply different methods to investigate palaeoecological changes and human impacts. These methods will include the analysis of pollen, non-pollen palynomorphs, charcoal, sediment DNA, biomarkers (coprostanol) and radiocarbon dating. These proxies will indicate the timing of colonisation and the drivers of landscape change (burning, agriculture and exotic species introductions). We will investigate the rate of change from pre-colonisation through to the establishment of settlements and post-European contact.

**P-4467**

## **Stress in paradise: Understanding and quantifying drought in South Pacific islands.**

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The South Pacific is the home of 13 island nations and 8 overseas territories that accommodates a population of over 10 million people across 1779 islands (Nunn et al, 2016). The small size and remoteness of these islands means that their natural resources are particularly susceptible to both natural and human hazards and are very limited. The availability of drinking water in Pacific Island Nations (PINs) is highly dependent upon rainfall but this region is also drought-prone. The risk to this vital resource is increasing due to human pressures, higher variability in rainfall, an increase in extreme El Niño events and stronger and more frequent storm events (IPCC, 2014).

The tropical Pacific Islands were the final frontier of the human colonisation of Earth and there is still uncertainty surrounding what drove migration across the region. It has been suggested that the climate – specifically drought - may have put pressure on the resources of certain islands and this may have forced the Polynesians to migrate eastwards (Nunn and Kumar, 2016). The Pacific region is a notoriously data poor region and there are still significant gaps in our knowledge around the past and present climate dynamics. It is important to understand the frequency, intensity and duration of droughts that have occurred and how they impacted these islands. Palaeoenvironmental records can provide key insights into the long-term variability of rainfall over millennial timescales so that it is potentially possible to understand the patterns of drought frequency, intensity and duration. From this we can infer whether the patterns we have observed in the past 50-100 years are typical or part of a larger scale of variability driven by Global Warming.

We hope to develop a better understanding of the role and definition of drought in this part of the world both past and present. This research intends to provide an applied palaeoenvironmental study using palaeodata to provide useful insights into the historical drought records and its impacts upon water security. The aim of this poster will be to provide a brief overview and review of the current water security issues in the Pacific and how we can use this to inform our understanding of the environmental pressures on historical Polynesian communities.

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P-4468

## New high-resolution Holocene ENSO records from tropical Pacific lakes: a varve-based chronology approach

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The South Pacific Convergence Zone (SPCZ) is the most extensive convective cloud band in the Southern Hemisphere, which generates a strong rainfall gradient in the South Pacific basin (SP). On inter-annual to inter-decadal timescales, Pacific climate phenomena, such as the El Niño-Southern Oscillation (ENSO) cause the SPCZ to shift position (Figure 1). Indeed, El Niño events cause the SPCZ to move north-eastwards and extreme El Niños, make the SPCZ join the Intertropical Convergence Zone (ITCZ). Polynesian islands experience severe droughts during such events, while SPCZ Zonal phenomenon is predicted to become more frequent under a warming world. Moreover, a major shift in the position of the SPCZ and ITCZ has occurred around the time of Polynesian migration (850-1150 BCE), resulting in a prolonged north-eastwards shift of the SPCZ that has strongly modified climate conditions on the islands. Nevertheless, the relationship between ENSO and the hydrological pattern of individual Pacific Islands is still poorly constrained. Thus, the SP is considered to be one of the most vulnerable areas to extreme climate events on Earth. However, only few instrumental data records are available from this critical region and these are often partial and short (<50 years). Therefore, high-resolution quantitative palaeoclimate data are a research priority to fully understand major SP climate dynamics (SPCZ, ENSO). This information is vital for the population of 13 million inhabiting the 1395 SP islands, who especially rely on rainfall for freshwater and food security. New high-resolution climate records from laminated lake sediment cores, collected at two key sites located across the SPCZ contraction axis (Atiu, Cook Islands and Efate, Vanuatu), will be presented. Thanks to a promising method based on varve chronology (thin section analysis), detailed intra-annual records covering main climatic transitions for the last 8000 years have been generated. These records allow to extend our understanding of hydroclimatological change in the SP, linked to SPCZ and ENSO dynamics and thus, to the colonisation of Eastern Polynesia.

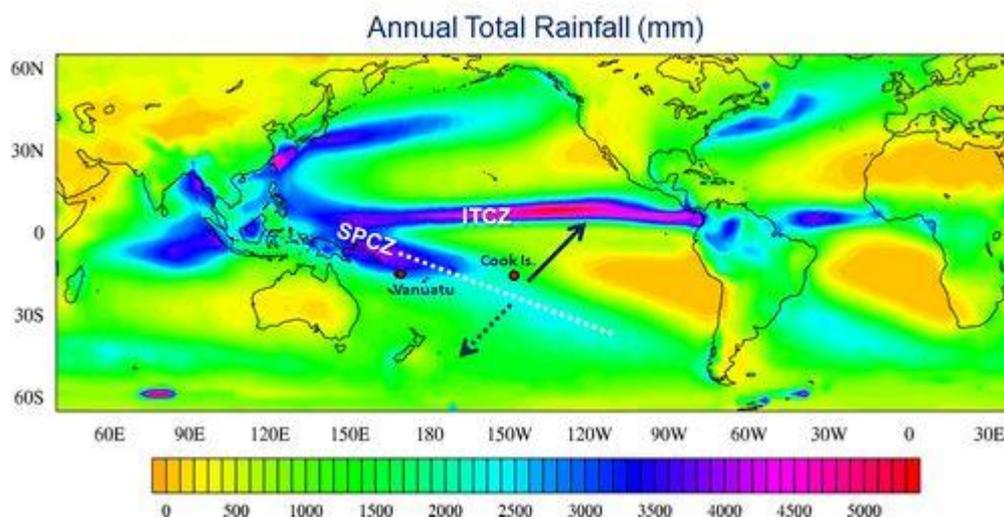


Figure 1: Position of the tropical sediment archives along the diagonal contraction axis of the SPCZ (dashed white line): sites mentioned are highlighted (red circles). El Niño phenomenon causes the SPCZ to move north-eastwards



toward the ITCZ (solid black arrow), whereas La Niña causes it to move south-westwards (dashed black arrow).  
Basemap generated from NOAA annual precipitation 1990-2015.

**P-4469**

## **Lake sediment hydroclimate proxies from the tropical South Pacific reveal large scale changes in the SPCZ over the Holocene**

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The South Pacific Convergence Zone (SPCZ) is one of the largest rain bands on our planet. Its interannual to decadal swings are largely governed by tropical Pacific sea surface temperature anomalies. The dynamics of this important climate feature and its response to external forcings have not been fully understood. Here we present the first continuous, Holocene record of SPCZ variability from Vanuatu, Samoa and the Cook Islands, southwest Pacific. Covering the past 9,500 years, this record reveals large scale shifts in the strength and / or position of the SPCZ and corresponding changes in hydroclimate across the South Pacific. The results document a large and rapid transition to pluvial conditions beginning at ca. 5,400 cal yr BP and lasting until 2,800 cal yr BP in Samoa, with a corresponding dry period in the Cook Islands. After 3000 BP, records from different lakes show how the SPCZ moved NE, creating drying in Vanuatu and Samoa, wetter conditions in the Society Islands and Cook Islands, before switching back around the Little Ice Age. Published records from Easter Island confirm existing conceptual models for the role that the SE Pacific High (Anticyclone) plays in strengthening moisture transport into the SPCZ. The Holocene hydroclimate proxies demonstrates how recent climate records provide only a partial understanding of the dynamics of the SPCZ.

**P-4470**

## **Reconstructing the geochronological context of the former Patagonian Ice Sheet in understudied northern Patagonian valleys (43°S) using cosmogenic radionuclides**

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The former Patagonian Ice Sheet (PIS) was the most extensive Quaternary ice sheet of the southern hemisphere outside of Antarctica, with a latitudinal extent of approximately 2000 km stretching along the Patagonian Andes (Davies *et al.*, 2018). Against the background of global, Northern Hemisphere-dominated ice volumes, it is essential to document how the PIS and its sensitive outlet glaciers fluctuated throughout the Quaternary. This information can help us investigate the climate forcing mechanisms responsible for ice sheet fluctuations and provide insight on the causes of Quaternary glacial cycles at the southern mid-latitudes. Although the PIS has been subject to an increasing number of geochronological glacial reconstructions, there is a general lack of published data for glacial deposits from the north-eastern part of the former PIS, between latitudes 41 and 46° S. Glacier reconstructions in this region are required to better understand the latitudinal variation in the timing of glacial advance and retreat throughout Patagonia, and the complex atmospheric and oceanic circulation systems responsible for millennial-scale interhemispheric coupling of climate change throughout the last glacial cycle. This study presents an effort to reconstruct the glacial geomorphology and geochronology in a valley of northern Patagonia previously occupied by the *Rio Huemul* and *Rio Corcovado* (43°S, 71°W) outlet glaciers. Several field-based techniques, with an emphasis on geomorphological mapping and cosmogenic radionuclide dating, will be used to establish a chronology from the oldest preserved deposits, to the Holocene. This geochronological reconstruction also aims at understanding the past evolution of the drainage system of those valleys throughout the last deglaciation, and to reconstruct the magnitude and timing of past local climate variations. By comparing our findings with results from other palaeoclimate studies, this research aims at improving our understanding of atmospheric systems and energy redistribution mechanisms responsible for climate variability in northern Patagonia. Such palaeoclimatic information is vital to parameterize climate models and better assess the significance of current and predicted global environmental change in the southern mid-latitudes.

**P-4471**

## **The Patagonian Ice Sheet from the last glacial cycle to the Present Day**

Bethan Davies<sup>1</sup>, Christopher Darvill<sup>2</sup>, Harold Lovell<sup>3</sup>, Varyl Thorndycraft<sup>1</sup>, Julian Martin<sup>1</sup>, Neil Glasser<sup>4</sup>, Andy Hein<sup>5</sup>  
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We present a new state-of-the art compilation of published Patagonian glacial and glaciolacustrine geomorphology and recalculated, recalibrated, compilation of published chronostratigraphy. These data are used to generate a new, updated reconstruction of the Patagonian Ice Sheet extent, volume and dynamics at the Last Glacial Maximum and at 5 ka timeslice to the present day, illustrating changes in the dynamics of the ice mass and the ice-dammed proglacial lakes through time. We compile published geomorphological mapping and combine this with our own new remotely sensed mapping to create a detailed GIS database of the geomorphological imprint of past Patagonian ice-sheet fluctuations. We also compiled published ages from the literature that give insights into the lateral and vertical extents of the Patagonian Ice Sheet and later ice fields. The literature was scoured for data pertaining to the geographical position of the ages, which was checked in ArcGIS using the maps and datasets provided in the published literature. The final ages were mapped in ArcGIS as ESRI point shapefiles (\*.shp). Each age contains attribute information including the publication reference, location (latitude, longitude, description), altitude (m asl), sample site, dating method, comments regarding sample characteristics, material dated, stratigraphical context or setting, reliability of the age and any other applicable information. Each sample has a unique ID in the table that can be cross-referenced to the maps in this paper. These data are used to generate isochrones of ice extent at 5 ka timeslices across the ice sheet. Using these isochrones, we generate palaeo ice-sheet reconstructions from 30 ka until the present day.

**P-4472**

## **Patagonian Ice Sheet deglaciation and palaeolake evolution in the Cisnes-Aysén basins, Chile**

Emma Cooper, Varyl Thorndycraft, Bethan Davies, Adrian Palmer  
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The structure, timing, and rate of Patagonian Ice Sheet (PIS) retreat since the Last Glacial Maximum are widely debated. Recently published geomorphological and chronological data (10Be, OSL, 14C) obtained from the Rio Cisnes Glacier catchment (44°S) suggests an earlier PIS deglaciation may have occurred in this region in comparison to more southerly latitudes. However, there is still scope for the development of more robust chronologies to test regional differences in the timing of deglaciation, for example through Bayesian age modelling underpinned by varve- and tephrochronologies. The formation of large proglacial lake systems as ice-lobes receded in the Cisnes-Aysén basins provides significant potential for the use of laminated lake sediments to improve our understanding of the timing, and processes associated with ice sheet retreat during the last glacial-interglacial transition (LGIT).

This project will apply a number of methods to constrain the rate and timing of PIS deglaciation and associated palaeolake formation in the Cisnes-Aysén basins (44- 45°S). This will be achieved by undertaking: (1) detailed geomorphological mapping using close and near range remote sensing methods (GIS, UAV mapping); (2) analysis of the timing of lake formation, duration and drainage by developing a deglacial varve chronology for the Rio Cisnes catchment, (3) dating the timing of glacial retreat using cosmogenic nuclide surface exposure ages (10Be) from Aysén Basin moraine crest boulders, and (4) examining visible tephra horizons found in glaciolacustrine sediments.

The aim of this poster is to present new geomorphological mapping, as well as a review of the regional geomorphology for the Cisnes-Aysén catchment, including dates on early-human occupation of the basin. We present data on topographic cross-sections to examine relationships between landforms and retrograde slopes at these sites. This research will have a number of broader scientific implications including insights into: (1) PIS deglaciation and wider late-Quaternary Ice Sheet responses to the LGIT, (2) regional palaeoclimate associated with the prevailing winds (southern hemisphere westerlies), and (3) early human occupation of Patagonia.

**P-4473**

## **Extending the speleothem record from Madre de Dios Archipelago, Patagonia, beyond the Holocene**

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Located at 50° S, Madre de Dios Archipelago is the southernmost karst region on Earth. Carved by Pleistocene glaciers, this exceptional maritime landscape has experienced extreme rates of karst denudation in a temperate oceanic climate characterized by extreme rainfall (up to 7-8 m/yr) and strong westerly winds. Little is known about how orbital- to millennial-scale climate change has affected this region. Speleothems in caves provide one of the best terrestrial environmental archives, with respect to chronology. Due to the remoteness of this area, however, very few speleothem records have been published so far (Schimpf et al., 2011) which span the Holocene only.

Here we present a set of speleothems from the islands of Madre de Dios and Guarello which for the first time extend into the Pleistocene. Dating these speleothems using U-Th is challenging given the abundance of non-carbonate constituents and the low Uranium concentrations. The resulting ages, however, provide robust chronological anchor points. The specimens comprise inactive flowstones and stalagmites which cover short growth intervals only, typically a few thousand years. The majority of the samples date from the Holocene, but some cover the Late Glacial, MIS 3, MIS 5e and MIS 7a. This demonstrates that subsurface environments on these islands at least locally preserve a record of climate and environmental conditions which survived the pervasive glacial and meltwater erosion during the Last Glacial Maximum, which obliterated coeval sediment archives on the surface.

Stable isotope data provide snapshots of local paleoclimate variability. Carbon isotopes show large excursions (up to 12‰ in the entire data set and up to 7‰ in a given sample) with values as low as -11‰ and as high as +1‰. In contrast, oxygen isotopes show a much smaller amplitude (less than 3‰) and most values are between -5‰ and -4‰. In several samples both isotopes co-vary, pointing towards kinetic isotope effects.

This new dataset highlights the potential of speleothems as recorders of environmental change even in an extreme setting such as the Madre de Dios Archipelago and opens the door to explore the impact of climate change on this unique landscape and vegetation beyond the Holocene.

**P-4474**

## **High-resolution glacial geomorphological mapping of the Cordillera Darwin Icefield, Tierra del Fuego, Chile**

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The Cordillera Darwin Icefield (CDI) is the third largest icefield in South America. Recent publications have focused on the extensive recession of its glaciers during the last termination as well as the marked frontal retreat of its outlet glaciers (e.g. Marinelli Glacier) since the Little Ice Age. Few studies have focused on Neoglacial advances of the CDI and the differences between the evolution of its marine-terminating and land-terminating glaciers.

In this poster, we present new mapping of the CDI. We combine high-resolution satellite imagery interpretation (mainly 3-5 m resolution PlanetScope/RapidEye and 1-m resolution DigitalGlobe/GeoEye-1 images available through the QGIS 'QuickMapServices' service) largely validated by fieldwork to improve the glacial geomorphological mapping of the CDI. The map is designed as a basis for future chronological campaigns and to enable a refined reconstruction of the glacial history of the icefield.

Our results emphasize the importance of local topographic and glaciological conditions, such as the presence or absence of marine-terminating or land-terminating glaciers, in determining glacier behaviour and response to climate change. We also consider the importance of these local topographic and glaciological conditions for a correct understanding of the glacier dynamics and glacial history reconstruction.

P-4475

## Dynamic shifts in the forest/steppe boundary, Southernmost South America (~53°S) during the Late-glacial and the Holocene: climatic inferences.

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The ecotones from forest to steppe are one of the most sensitive ecosystems of the world and where the impact of global climate changes becomes most evident. Therefore, the changes in the distribution and abundance of the vegetation in the ecotone can be linked to large-scale regional and global climate controls and can be used as indicators of climatic change. The Andes in Southernmost South America form a topographic obstacle to the Southern Westerlies Winds leading to an abrupt change of climate across short distances that produce a dramatic west-east precipitation gradient, which is reflected in the vegetation pattern in Fuego-Patagonia. Hunter-gatherer populations were the first inhabitants after the end of the last glaciation and persisted until the beginning of the twentieth century. They were nomads with a low population density and without agricultural development. These features permit the reconstruction of palaeoenvironments under low human impacts.

We present a synthesis of ten palynological records (peatlands) from Fuego-Patagonia. The synthesis was constructed using continuous well-dated records, new and previously published, which cover the Last Glacial-Interglacial Transition and the Holocene to produce an enhanced regional record of environmental changes. The records were taken from different locations along the west-east precipitation gradient. Tephrochronology was used to link palaeoenvironmental records from across the region and to view vegetation changes along the tephra isochrones. Comparison using methods for climate regime shift of the records of *Nothofagus* forest demonstrates that they differ in their response to regional climatic changes depending on the location along the west-east precipitation gradient. The palaeoenvironmental evidence provides a rare insight into the local site-specific environmental changes and more regional perspective of movements in the forest-steppe ecotone driven by longitudinal shifts in the west-east precipitation gradient across Fuego-Patagonia.

Our synthesis based on CONNIS cluster analysis suggests across the region a first pulse of establishment of *Nothofagus* forest between c.13.5-12.5 ka cal yr BP. An early Holocene dry period at c.10.5-9.5 ka cal yr BP and a major arid phase during the mid-Holocene at c.8.5-6.5 ka cal yr BP. Between c.6.5-2.0 ka cal yr BP, there was a gradual expansion of the forest which suggests an increase in the levels of effective moisture. From c.2.0 ka cal yr BP to present, the forest appears to have undergone repeated phases of wetting and drying probably in response to significant variability in the effective moisture levels. There were two marked contractions of the forest at c.2.0 and c.1.0 ka cal yr BP, likely due to short periods of reduced effective moisture.

This study provides a regional perspective of the movements in the forest-steppe ecotone and the lag in the response of vegetation to climate change. This shows that *Nothofagus* forest is highly vulnerable to future climate change.

**P-4476**

## **Glacial chronology of erratic boulders on Cerro Benitez, Patagonia, Chile : implications for opening and megafauna colonization of the Mylodon Cave**

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The Última Esperanza piedmont lobe is one of the outlet glaciers fed by the Patagonian Ice Sheet in the southern part of Chile in South America during the Last Glacial Maximum (LGM). The Andes Range in the study area reaches ca. 1500-2000 m a.s.l. of elevations and contains deeply dissected glacial valleys and extensive moraine ridges and glacial lakes developed further east of the present-day ice field. The objective of this study is to understand the deglaciation timing of Cerro Benitez area (51°33' S, 72°34' W; 120 m a.s.l.) to the north of Puerto Natales, where several caves and rock shelters, including the famous Mylodon Cave, are located. To that end, 16 erratic blocks were dated by cosmogenic <sup>10</sup>Be surface exposure method on top and around the caves. The age results clearly indicate that the maximum glacial advance was ca. 40.0 ± 6.0 ka ago during the local Last Glacial Maximum (lLGM). Indeed, several glacier records around the globe suggest that the southern and northern hemisphere ice sheets may have fluctuated out-of-phase during the last glacial period. The second maximum glacial advance is also clearly dated to ca. 20.0 ± 3.0 ka indicating that the global LGM (gLGM) was less extensive in Patagonia, as previously reported by other studies. We conclude that the Mylodon Cave and other caves and rockshelters of Cerro Benitez area were ice-free and opened up to be inhabited by the megafauna including, now extinct but well-preserved large mammals such Mylodon darwini, and then, later, by the first Palaeoindians. This work was supported by the French CNRS PICS GEOCEBE, the Chilean FONDECYT 1150845 and 1180272, and the İstanbul Technical University Research Funds (Project No: TGA-2017-40610).

**P-4477**

## **Late Holocene glacial chronology at Mount Tenerife, southern Patagonia Andes, using image analysis, geomorphologic mapping, tree rings, and lichens.**

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Glacier fluctuations have been used to reconstruct past climate variability to understand mechanisms underlying past climate changes at different time and spatial scales. For the Southern Andes, although important advances have been obtained refining glacier changes chronologies during the last glacial cycle, the timing, patterns and causes of glacial fluctuations, remain elusive. Besides, small mountain glaciers may be a useful approach to estimate glacier fluctuations during the Late Holocene, avoiding the complexities associated with large icefields and calving glacier fluctuations.

This work aims to reconstruct the history of glacial fluctuations for a small climate-sensitive mountain glacier in Mount Tenerife (51°20'S, 72°51'W, 1,600 m asl), during the Late Holocene, a period within recent earthy history for which there remain large discrepancies in our interpretation of the geological records.

We combined image analysis, glacial geomorphology mapping, dendrochronology, and lichenometry to document the spatial and temporal structure of Late Holocene glacial changes in Mount Tenerife, southern Patagonia. By combining these approaches, we expect to establish high-resolution glacial chronologies that allow us not only to decipher the timing and structure of fluctuations of the study glaciers, but also to test mechanisms involved in the initiation and modulation of the magnitude of glacial events in this study site during the Late Holocene.

Tree-ring series show significant positive correlation with summer temperature records from Punta Arenas and negative correlations with the SAM index. No significant correlations were found between tree-growth patterns and precipitation. Taking advantage of the correlation between tree-growth and climate variability, we compared the relationship between variations on the length of the Mount Tenerife glacier, a climate index mimicking glacier mass balance, and tree-growth trends. Our results show for the last few decades a constant negative mass balance, a marked decrease in glacier lengths and a decreasing trend in tree growth. Dating control for these processes was obtained from contemporaneous time series provided by tree-ring counting, lichen growth and image analyses.

Results exposed here contribute to our understanding of natural climate variability under interglacial conditions, providing a baseline to assess present-day glacier fluctuations, and to look for new insights regarding the mechanisms underlying glacial fluctuations.

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**P-4478**

## **Glacial geomorphic map of patagonian islands and peninsulas between the Gran Campo Nevado and Estrecho de Magallanes, Chile.**

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We present the first extensive glacial geomorphic map of peninsulas and islands located between the Gran Campo Nevado and the Estrecho de Magallanes, south-western Patagonia (52.8-53.1°S, 73.0-73.9°W). The map covers an area of 1.200 km<sup>2</sup> and is based on remote-sensing data analysis in a GIS environment and corroborated by field observations at Isla Tamar, Isla Zanelli and Peninsula Muñoz Gamero. High-resolution Planet satellite images (Imagery © 2019 Planet Labs Inc) from 2017 to 2018 and aerial photographs taken between 1978 and 1982 by the Servicio Aerofotogramétrico Chileno (SAF) were used to map at scales of 1:5000 and 1:8000. The ALOS PALSAR Digital Elevation Model was used as the topographic base data, while the 3D Google Earth viewer platform helped to improve landform limit determination. Selected remotely mapped sites were visited during the #ChileFjords18 science cruise in November 2018 to corroborate mapped features using direct field measurements, photography & drone footage. The research area is dominated by glacial erosional landforms that include horns, cirques, u-shaped valleys, roche moutonnees, whalebacks and truncated spurs. Glacial related depositional features principally correspond to fluvio-glacial terraces, outwash plains and erratic boulders on scoured bedrock. Frontal and lateral moraines were mapped on land, most of them are located close to cirques. This map is the first high-resolution geomorphic map in the area and one of the few at the western flank of the Andean Cordillera in south-western Chile. The methods developed here could be used as a guide to develop future studies that aim at understanding and comparing ice sheet behavior on both sides of the Andean massif during the last glacial period and subsequent deglaciation.

P-4479

## The local Last Glacial Maximum along the Patagonian Andes, southern South America: inferences from new $^{10}\text{Be}$ , Luminescence and $^{14}\text{C}$ chronologies

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The Patagonian ice sheet developed along the southern Andes between 38-55°S during the last glacial period. The ubiquitous imprint of this former glaciation is preserved in the landscape and is suitable for reconstructing how glaciers and climate fluctuated during this time, including Marine Isotope Stages 4-3-2. To present, most evidence has pointed out that Patagonian outlet glaciers reached their maximum extents during, or slightly earlier than, the global Last Glacial Maximum (gLGM) between ~26 and 18 ka (e.g., Kaplan et al., 2008). However, more recent evidence from southernmost Patagonia has unraveled that the local LGM (lLGM) occurred earlier during mid-MIS 3 at c. 48 ka (Darvill et al., 2015; García et al., 2018). The goal of this work is to unravel the lLGM along the Patagonian Andes and determine possible glacial asymmetries that may have punctuated the late Pleistocene glacial history in southern South America. Here, we discuss new paleoglacier  $^{10}\text{Be}$ ,  $^{14}\text{C}$  and single grain feldspar luminescence records obtained from the Chilean Lake District (40°S), Isla Grande de Chiloé (42°S), Río Cisnes Valley (44°S) and Seno Skyring (53°S). Our data shows that the timing of the local LGM varied depending on site/latitude. The geochronometers ( $^{10}\text{Be}$ ,  $^{14}\text{C}$  and luminescence) used to date outwash sediments in Chiloé indicate a pre-gLGM glacier maximum there, on the western Andes side. Here, a  $^{10}\text{Be}$  depth profile from the highest Cucao I terrace linked to the outer ice marginal position yielded a preliminary exposure age of  $70 \pm 15$  ka. At the same site, multiple luminescence ages indicate deposition at about ~50-70 ka. The lower Cucao II outwash terrace yielded preliminary luminescence ages in correspondence with the gLGM. Altogether, these ages indicate that maximum glaciation in Chiloé occurred during the MIS 4, which is consistent with MIS 3  $^{14}\text{C}$  dated wood overlying the Cucao I outwash sediments. A later ice advance reaching an inboard ice marginal position occurred during MIS 2 during the gLGM. In contrast, a gLGM timing has been dated at Río Cisnes, on the eastern side of the Andes, as based on  $>15$   $^{10}\text{Be}$  exposure dates from boulders resting on the outer CIS I and CIS II moraine ridges. CIS I moraine yielded a mean age of  $25.1 \pm 0.9$  ka and CIS II an age of  $22.3 \pm 1.6$  ka. Exposure  $^{10}\text{Be}$  samples collected from outer Laguna Blanca moraines at the Skyring site (eastern southern Andes) will be presented during the conference, with their paleoglacial and paleoclimatic significance discussed in relation to the causes underlying the lLGM in Patagonia.

P-4480

## Deglacial and postglacial forest history and climate changes on the eastern slopes of the central Patagonian Andes

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We report a high-resolution pollen and charcoal records from lake sediments obtained from Lago Mellizas to reconstruct the history of vegetation, fire and climate changes on the eastern slopes of the central Patagonian Andes over the last 17 ka (ka=1000 cal yr BP). These data allow examination of the timing and direction of arboreal colonization through the increasingly ice-free Patagonian landscapes and the timing and structure of the southern westerly winds (SWW) changes during and since the last glacial termination. Lago Mellizas (45°32' S; 71°48' W, 760 masl) is a small closed-basin lake located along the eastern slopes of the Andes near to the climate-modulated forest-steppe ecotone in central Patagonia. Central Patagonia (44°-49°S) is an area in which the SWW are the only source of precipitation, generating a strong west-east precipitation gradient across the Patagonian Andes that induces a zonation of the regional vegetation, which can be used for inferring past changes in precipitation regimes based on fossil pollen records. Furthermore, the Chilean-European colonization process in central west Patagonia started early in the 20th century, allowing characterization of natural vegetation and climate.

The pollen record shows an open landscape dominated by herbs (Poaceae, *Gunnera*, *Acaena*, Apiaceae) and shrubs (*Empetrum*) suggesting an open landscape under cold conditions between 17 and 16.7 ka. An increasing trend of *Nothofagus* started at 16.7 ka, along with hygrophilous and cold-tolerant conifers (*Pilgerodendron*, *Podocarpus*). The latter reached maximum abundance between 15-11.7 ka, indicating a rise of the precipitation, followed by the establishment of dense *Nothofagus* forests and declines in hygrophilous and cold-resistant trees, herbs, shrubs and increases of fire activity under warm and dry climate conditions until 9.5 ka. *Nothofagus* forests have persisted with little variation since 9.5 ka, despite of the occurrence of the increase of fire activity at multicentennial timescales and subtle increases of conifers. We detect a major change in the pollen stratigraphy at 0.06 ka when started a sustained decreasing trend in *Nothofagus*, along with increases of Poaceae and the aquatic Cyperaceae and *Myriophyllum*. We interpret these changes as a forest opening and centripetal expansion of littoral environments toward the lake center driven by lake-level lowering in response to lowered precipitation. *Rumex* and *Plantago*, which are indicative of human perturbation, increase at 1900 AD. Our results suggest an early expansion of cold-resistant hygrophilous conifers and rainforest trees sourced from the eastern flanks of the Andes in central Patagonia and the precipitation variations related to changes in the influence of the SWW during and since the last termination.

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P-4481

## Late glacial and Holocene mean annual temperature changes in the south-central Chile using a chironomid-based inference model

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The use of non-biting midges as a tool for inferring past environmental conditions in south America has grown in the recent years. However, the lack of modern ecological and taxonomic information at spatial scale difficult to state if the main forcing factor that control chironomid assemblages are the same across the continent. Here we present a chironomid training set from 24 lakes located in the south-central Chile between 37°S and 41°S. Multivariate analyses indicate that mean annual temperature (MAT) is the main driver that controls the chironomid distribution (12,8% of total variance and MAT gradient 7-13°C). Based on these results, a temperature inference model is developed using the weighted average partial least square technique, achieving a performance of  $R^2_{\text{jack}}=0.64$ ,  $\text{RMSEP}_{\text{jack}}=1.15^\circ\text{C}$ ,  $\text{Max.Bias}_{\text{jack}}=1.38^\circ\text{C}$ . A transfer function was applied to infer quantitative MAT changes in the fossil record from Laguna Las Ranas (39.2°S, 72.1°W, 389m asl, modern MAT=10.2°C) spanning the last 18,6 ka BP. The results suggest the major MAT increment occurred during the late glacial between 18,6 and 13,5 cal ka BP, from 7.6°C to 9.5°C, and then, the rising temperature trend stopped and fluctuated around 10.5°C until 10.8 cal ka BP. From the early to mid-Holocene (10.8 and 6.5 cal ka BP) an increase and high variability of MAT values are recorded (peak MAT=12.3°C around 9 cal ka BP), and associated to important changes in the chironomid assemblages suggest environmental instability around Laguna Las Ranas. Less extent MAT fluctuations are observed in the last 7 cal ka BP, however, comparing to modern values, relative cold periods are inferred around 7-4.2 cal ka BP and 0.25 cal ka BP (ca. 9.7°C), whereas warm periods occurred around 4.2-3.6 cal ka BP and 0.8-0.25 cal ka BP (10.6°C). Despite to relative low coefficient of determination of the inference model and the short environmental gradient of sampled lakes, the chironomid-based MAT reconstruction follows the main climatological patterns occurred in the southern South America during the late Quaternary.

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P-4482

## Neoglacial fluctuations of two contrasting Southern Patagonian Icefield glaciers (49°S)

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Direct constraints on the timing of Neoglacial glacier advances remain sparse in the South American mid-latitudes. Classical schemes – based on limiting <sup>14</sup>C ages – indicate several steps of Neoglaciation with the most extensive reached during the mid-Holocene, around 5 ka (Porter, 2000). Here we investigate the timing of Neoglacial extent of two contrasting east-flowing outlet glaciers of the Southern Patagonian Icefield (SPI) through <sup>10</sup>Be exposure dating of moraine boulders. The studied glaciers show different size, slope and tongue grounding environment. Viedma glacier is one of the largest SPI outlets (~900 km<sup>2</sup>) whose tongue calved into lake Viedma during most of the Holocene, whereas Marconi glacier (~50 km<sup>2</sup>) – whose tongue was grounded during the intervening period – merged with another major SPI outlet (Chico glacier; ~300 km<sup>2</sup>) during Holocene highstands. We show that the Viedma and Marconi glacier experienced their Neoglacial maxima around 7 ka and that at least two other advances quite similar in size occurred before 4 ka. Then, two other Neoglacial stadials of decreasing magnitude occurred around 2 ka and during the Little Ice Age, from 0.5 ka. Our chronology is consistent with growing evidence of a prominent change in the regime of the Southern Westerly Winds (SWW) at 7 ka, as indicated by proxy records (Moreno et al, 2018).

### References

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P-4483

## A 17,500-year record of environmental change based on pollen and charcoal in a lake sediment in northwestern Patagonia

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Patagonia is a key region to study the climate evolution of the southern mid-latitudes and the behavior of the Southern Westerly Winds (SWW) since the Last Glacial Maximum (LGM). Here we present results from sediment cores collected from Lago Fonk, a small closed-basin lake located in the Chilean Lake District sector of northwestern Patagonia (41°S). The record provides continuous information to reconstruct the vegetation, climate and fire disturbance history since Last Glacial Termination (LGT) to the present.

During LGT the record shows abundant presence of arboreal pollen, mainly elements characteristic of North Patagonian rainforests, such as *Nothofagus*, until 15,600 cal. yr BP, after that occur a rapid increase of Myrtaceae and *Podocarpus nubigena* until 12,300 cal. yr BP. And the end of LGT is coincident with the expansion of *Weinmannia trichosperma* between ~12,300–10,000 cal yr BP, and concurrent with the start of fire activity, suggesting the start of disturbance events. A total of 55 local fire events were detected in the record. The element characteristic of Valdivian forest, *Eucryphia/Caldcluvia*, show two pulses of increase at 10,000 cal yr BP and 6,700 cal yr BP, this results suggest warming condition during this epoch. After 6,700 cal yr BP vegetation alternate between *Nothofagus* and *Eucryphia/Caldcluvia*. We interpret this alternations in dominance between North Patagonian (e.g. *Nothofagus*) and Valdivian rainforests (e.g. *Eucryphia/Caldcluvia*) driven by changes in temperature and precipitation of westerly origin at millennial timescales.

Finally, we observed in the record that vegetation composition and heterogeneity declined in response to Chilean/European disturbance around 350 years cal. BP, with the rapid deforestation and increase of artificial grasslands and introduced species of the genus *Plantago* and *Rumex*.

P-4484

## Dysoxic conditions through the Holocene at the Churruca I site, Strait of Magellan, Chile (53°S)

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Multiproxy records from three overlapping sediment cores from the marginal site Churruca I (53° 03.460'S, 73° 55.543'W; ca. 75 m water depth), inner region of the Western/Pacific entrance of the Strait of Magellan, reveal two major changes in the marine environment and dysoxic conditions that prevailed throughout the Holocene.

The compound sequence span from deglaciation to fully marine conditions at present, with the transgression occurring by ca. 10400 a BP. Different opportunistic species dominated benthic foraminiferal records in small test sizes (mainly below 200µm), indicating the prevalence of stressed conditions.

During the early Holocene assemblages were strongly dominated by the infaunal genera *Buliminella* and *Stainforthia*, both associated with fine substrates, dysoxia, and denitrification capabilities. The earlier stages of foraminiferal colonization occurred in a probably tidally controlled proglacial environment.

Higher species diversity and the dominance of the genus *Stainforthia* changing to the detritivore *Epistominella* characterizes the mid-Holocene, a stage of known higher stand in relative sea levels in the region. The onset of this period was marked by a strong pulse of taxa from deeper and more open marine settings (genus *Uvigerina*, planktonic taxa), occurring between the date at ca. 9200 a BP and deposition of tephra linked to the Hudson volcano (H1 eruption previously dated at ca. 7700 a BP). This suggests the incursion of a strong tsunami-type of wave that broke apart the barrier restricting the site, allowing stronger exchange with outer waters while stagnation remained at the sea floor. This agrees well with the 8.2 ka BP event, common in the Holocene records around the world.

The late Holocene also started with a pulse in planktonic taxa followed by deposition of volcanic products arguably linked to the Reclus volcano. Regional relative sea levels dropped and organic flux increased, leading to a more restricted water exchange that limited species diversity. The genus *Buliminella* strongly dominates through this stage to present, conditions established by 3200 a BP.

This sequence records global and regional signals, including the southward migration of the Sub-Antarctic Front, which approaches the latitude of the Western entrance of the Strait of Magellan not earlier than the onset of the mid-Holocene.

Two major changes in the hydraulic regime are clearly identified, in agreement with the formal subdivisions of the Holocene series. Their occurrence at depths close to those of volcanic horizons, also highlights the need to explore the role of volcanic and seismic activity on deglaciation and their subsequent effect on the marine environment in this region.

Preliminary results of this work were presented at the Foraminifera and nannofossils groups joint meeting of The Micropaleontological Society in 2012.

**P-4485**

## **Palaeohydrology of lowland rivers in the Murray-Darling Basin, Australia**

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This study derives a new function describing the relationship of channel bankfull discharge ( $Q_{bf}$ ) to channel width in modern rivers of the Murray-Darling Basin (MDB) of southeastern Australia and applies this to dated palaeochannels of seven rivers to quantify late Quaternary discharge history in this important basin. All rivers show high MIS3 and MIS2  $Q_{bf}$ , declining in the Holocene. The  $Q_{bf}$  of modern MDB rivers is correlated with total catchment precipitation but comparison with palaeochannel  $Q_{bf}$  estimates shows that while enhanced runoff efficiency is necessary to account for much larger late Pleistocene palaeochannels, either lower or higher precipitation rates could have prevailed. A strong association between relative palaeo-  $Q_{bf}$  enhancement and temperature suggests a temperature-mediated mechanism controlling river discharge, such as the fraction of precipitation stored as snow and thawing in spring, the enhancement of orographic rainfall, or  $CO_2$  feedbacks with vegetation cover. Significantly enhanced MIS3  $Q_{bf}$  requires an additional mechanism, such as increased rainfall. These findings are consistent with others that increased moisture availability was associated with past colder climates, although this was not necessarily the result of enhanced precipitation.

**P-4486**

## **Speleothem records of Late Pleistocene abrupt climate change in the southern mid latitudes**

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Precise radiometric dating of palaeoclimate archives, such as speleothems, provides an avenue for deciphering interhemispheric teleconnections and understanding the mechanisms behind abrupt climate change. In this context, the terrestrial southern mid latitudes remain relatively unexplored in comparison to the Northern Hemisphere; radiometrically dated records from this region are even rarer. Tasmania, Australia, is situated between 40-43 degrees south and is one of just three major land masses intercepted by the Southern Westerly Winds. It has experienced extensive glaciation during cold stages of the Quaternary. As such it presents an ideal location in which to study both glacial terminations and millennial scale events in the southern mid latitudes. After an extensive U-Th reconnaissance survey to identify suitable materials using low-impact sampling protocols, a number of stalagmites were selected for the construction of detailed proxy records. Here we present preliminary speleothem records of abrupt climate change occurring between MIS 8 and 2 using high-resolution chronologies. This data will help to document the southern mid latitude expression of abrupt changes in climate throughout the Quaternary and allow comparison with their much more thoroughly studied counterparts in the Northern Hemisphere.

**P-4487**

## **Late Quaternary palaeoenvironmental records of tropical Australasia**

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The palaeoenvironments of tropical Australasia were extremely dynamic during the late Quaternary. Changing regional geology (e.g. ongoing subduction, uplift, and associated volcanism) and global climate interacted to create complex and localized environmental changes. For example, because the Sunda shelf includes large areas near sea level, changes in sea level dramatically affect the land area, the exchange between the Indian and Pacific Oceans, and the volume of the Indo Pacific Warm Pool. These dynamics are important for understanding the past and future of climate change in the region. The environment of the late Quaternary also paints the setting for the diversity of hominins in the area, including the intrepid ancestors of the first Australians.

This talk synthesizes a variety of data from published sediment records marine and terrestrial settings in tropical Australasia. Data drawn from stable isotopes, pollen, trace elements, and sedimentological features describe different aspects and different resolutions of the palaeoenvironmental story. It also provides an overview of current interpretations and highlights informational gaps. Finally, the talk describes preliminary results from new records from several tropical Australasian sites and incorporates them into the broader understanding of the region's past.

P-4488

## Comparison of $\delta^{18}\text{O}$ in groundwater and a cave flowstone: improving the interpretation of the speleothem $\delta^{18}\text{O}$ paleoclimate proxy

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Speleothems are high-resolution records that can be used for terrestrial paleoclimate reconstruction from their oxygen and carbon isotopes ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ), and whose deposition is directly related to the groundwater recharge process. Groundwater  $\delta^{18}\text{O}$  records have the potential to provide an important long-term record of past climate, but they are low-resolution records as the isotope signal can be altered during flow within the aquifer. In this study we compare measured  $\delta^{18}\text{O}$  values from both a groundwater record and speleothem record from a flowstone over the past 12,000 years for the first time from south west Western Australia.

Flowstones normally form from cave streams or fast dripping seepages and their oxygen isotope composition is sensitive to the extent of kinetic fractionation, determined by water flow rate, as well as, streams or seepages water  $\delta^{18}\text{O}$  composition. In this study comparison of  $\delta^{18}\text{O}$  values from a groundwater record and flowstone enables the source water oxygen isotopic composition to be constrained in order for a more complete interpretation of the higher resolution speleothem record, including the site specific kinetic processes and climatic changes.

The flowstone  $\delta^{18}\text{O}$  values appear consistent with millennial variability in recharge  $\delta^{18}\text{O}$  predicted using the groundwater values, although the flowstone oxygen isotopes are generally enriched in  $^{18}\text{O}$  compared to the regional groundwater record before  $\sim 7.4\text{ka}$ . This offset between the records indicates that flowstone calcite deposition was not in isotopic equilibrium with its source water likely due to low flow regimes and extensive degassing of  $\text{CO}_2$ . According to a model of isotopic disequilibrium that is driven by water supply, the Holocene portion of the flowstone record contains periods of relatively lower isotopic disequilibrium indicating possible higher water supply, and periods of relatively higher isotopic disequilibrium indicating possible lower water supply consistent with local and regional archives.

P-4489

## Reading the tea-tree leaves: *Melaleuca quinquenervia* leaves as a palaeoclimate proxy

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The analysis of organic material preserved in sedimentary records is a useful tool in reconstructing past climatic conditions. It has been suggested that the carbon isotope discrimination ( $\Delta$ ) calculated from the bulk leaf  $\delta^{13}\text{C}$  of the modern *Melaleuca quinquenervia* tree responds to local precipitation in south-east Queensland, Australia [1]. The preservation of these leaves in lake sediments on Minjerribah (North Stradbroke Island) dating to the mid-Holocene presents the opportunity to produce species-specific stable isotope-based records of precipitation.

Here, we test the potential for *M. quinquenervia* to be used as a palaeoclimate proxy by examining the preservation of the bulk leaf  $\delta^{13}\text{C}$  over time and the relationship of  $\Delta$  values to historical records of precipitation. Due to the varying rates of degradation of the different chemical constituents of plant matter, it is possible  $\delta^{13}\text{C}$  ratios to be altered by early diagenetic processes before, or during, the incorporation of leaves into the sediment. Therefore, modern studies are needed to establish what factors influence the discrimination derived precipitation record.

Focusing on the *M. quinquenervia* growing at Swallow Lagoon on Minjerribah, we studied the changes to the bulk leaf  $\delta^{13}\text{C}$  ratios of exposed leaves over an eighteen-month field study. We then applied our findings to the measured  $\delta^{13}\text{C}$  ratios of bulk leaf material retrieved from a core taken from the lagoon. The  $\Delta$  values calculated based on these measurements were then compared to instrumental rainfall data from the past century to test the established relationship with modern precipitation through time.

By bisecting each leaf used in this study, we were able to compare the experimentally degraded leaves directly to their corresponding control halves. We observed that decay causes an approximate decrease of 1 ‰ in  $\delta^{13}\text{C}$ , as the leaves become more  $^{13}\text{C}$  depleted relative to the control leaf halves that were dried immediately. Quantifying this offset enables adjustment of values to be comparable to the calibration equation established using natural fall leaves from modern *M. quinquenervia*. Comparing the adjusted  $\Delta$  values for lake core leaves from the last century to corresponding rainfall data the relationship to local precipitation seems to be preserved.

Understanding exactly how early diagenesis changes the stable isotope composition of *M. quinquenervia* leaf material over time allows us to adjust for the offset between modern and sub-fossil bulk leaf  $\delta^{13}\text{C}$  and advances the potential to use this species as a reliable climate proxy in the future.

1. Tibby, J., et al., *Carbon isotope discrimination in leaves of the broad-leaved paperbark tree, Melaleuca quinquenervia, as a tool for quantifying past tropical and subtropical rainfall*. *Global Change Biology*, 2016. **22**: p. 3474-3486.

P-4490

### **A 5.3-million-year history of monsoonal precipitation in northwestern Australia.**

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Australia is the driest inhabited continent on the planet, with its moisture mostly sourced from the tropical monsoon in the north and the southern westerlies in the south. The continent has experienced large climate fluctuations in the geologic past, but long continuous records of palaeo-environmental changes are lacking, particularly prior to ~0.55Ma. Here, we address this paucity by presenting a continuous record of continental aridity and monsoonal activity in northwestern Australia since the Pliocene (5.3 Ma). Our records are based on bulk-chemical XRF-scans and particle-size distributions of the terrigenous fraction, in two cores from the northwestern Australian continental shelf: MD002361 and ODP122-762B. In our records we distinguish between aeolian- and fluvial sediments that were deposited at sea. Support for the distinction between aeolian and fluvial sediment fractions in the two marine sediment cores is found in the bulk-chemical composition of aeolian- and fluvial material in the potential source areas in northern West Australia. Our records show a warm and dry early Pliocene (~5.3 Ma) on the northwestern Australian continent, which experienced a gradual increase in humidity peaking at about 3.8 Ma with higher than present-day rainfall. Between 3.8 and about 2.8 Ma, climate became progressively more arid with more rainfall variability. Coinciding with the onset of the northern hemisphere glaciations and the intensification of the northern-hemisphere monsoon, aridity continued to increase overall from 2.8 Ma until today, with greater variance in precipitation and an increased frequency of large rainfall events. We associate the observed large-scale fluctuations in Australian aridity with variations in Indian Ocean sea-surface temperatures, which largely control the monsoonal precipitation in northwestern Australia.

P-4491

## A U-Th-dated speleothem pollen record of environmental changes in southwest Western Australia, during the late glacial to early Holocene.

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The pre-Holocene palaeoenvironmental and palaeoclimatic history of southwest Western Australia remains almost completely unknown, so that this region constitutes a major gap in understanding of late Pleistocene environmental change in the Southern Hemisphere. Here we present a pollen record from a stalagmite collected in the Yanchep Cave system on the Northern Swan Coastal Plain (NSCP), ca. 60 km north of Perth, Western Australia. The pollen record, supported by a detailed U-Th age model, documents environmental changes from ca. 15.5 ka to ca. 6.5 ka, spanning the late glacial and the Pleistocene-Holocene boundary.

At the commencement of the record, the *Eucalyptus* open forests and woodlands that dominate the NSCP today were largely absent, and the pollen record was dominated by Asteraceae, *Banksia* (Proteaceae), Poaceae and Goodeniaceae. From ca. 14.2 ka, chenopods and Leptospermeae/Chamelaucieae (ca. 30 genera of sclerophyllous shrubs within the Myrtaceae; herein, "Myrtaceous shrubs") began to increase in importance, implying drying and/or cooling that coincided with the timing of onset of the Antarctic Cold Reversal (ACR), as observed in the West Antarctic ice sheet (WAIS) Divide  $d^{18}O$  record. At ca. 12.2 ka, within no more than ~two centuries, *Eucalyptus* values increased from trace values up to ca. 10% of the pollen sum, and Myrtaceous shrubs increased to high values, at the expense of chenopods. Thereafter, very little change in pollen proportions is observed across the Pleistocene-Holocene boundary, formally defined at 11.7 ka. However, at ca. 11 ka, within a few centuries, Myrtaceous shrubs and chenopods rapidly collapsed to low values, while *Eucalyptus* values increased to 20-40%, suggesting that a substantial *Eucalyptus*-dominated tree cover had been established.

The vegetation changes observed on the NSCP appear to correlate closely with some changes observed in the WAIS  $d^{18}O$  record. One intriguing link is the vegetation shift at 12.2 ka, which coincides with the abrupt termination of the ACR, several centuries prior to the Pleistocene-Holocene transition. On the other hand, the most important change in the record, at ca. 10.8 ka, the collapse of Myrtaceous shrublands and the rapid expansion of *Eucalyptus* canopy cover, does not correspond to any feature in the Antarctic record, and may therefore primarily reflect a moisture-, rather than temperature-related climatic response.

P-4492

## New Zealand climate and environmental change through the Holocene: a review

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The Southern Hemisphere Assessment of Paleoenvironments (SHAPE) international focus group within PALCOM has drawn together researchers from the Southern Hemisphere who are interested in climate variability and environmental change through the Quaternary. One focus for SHAPE has been the Holocene, with aims to test mechanisms of change, identify abrupt shifts, and characterise impacts from different modes of variability on terrestrial, ocean and cryosphere environments.

As part of our contribution to the hemisphere-wide SHAPE integrations, we have drawn together a comprehensive range of Holocene palaeoenvironmental and palaeoclimate evidence from the New Zealand region. This area is located in the middle latitudes of the Southern Hemisphere and it has teleconnections to a range of tropical and polar climate processes. We have gathered only published records that cover part or all of the Holocene, including tree rings, speleothems, lacustrine and peat cores, and discontinuous stratigraphic records of glaciation, alluvial sedimentation and fire occurrence. Our team has applied consistent protocols for dating and developing age models for records that are temporally constrained using cosmogenic dating, tephrostratigraphy, Uranium-Thorium, and radiocarbon chronologies.

From the New Zealand data collection, we evaluate the austral applicability of the recent formal Greenland-centric Holocene subdivision, including the inter-regional consistency for timing of the main transitions, the duration of climate excursions, and several anomalous climatic intervals at millennial to multi-decadal scales. In this presentation, we highlight the onset of the Holocene, whether an early optimum occurred, and whether there was an obvious mid-Holocene shift in the climate state on land and at sea. We interrogated a subset of our records covering the Common Era to examine what intervals temporally aligned to the Medieval Climate Anomaly and the Little Ice Age in Europe were like, and contextualise our data interpretations in an atmospheric circulation regime context.

The identified gaps in the national data network indicate more quantitative records of hydroclimate (particularly from lakes and speleothems) are required from northern and eastern regions. Expanded chronologies of glacier activity, droughts, floods and pre-human fires would be helpful for contextualising long-term alpine changes and extremes. Updates for many tree ring records will improve calibrations with instrumental climate records and reanalysis data, and will also help to refine reconstruction uncertainties. The expanded tool box of proxy techniques that are readily available now will also allow former study sites to be revisited to expand on the basic evidence that has been developed so far for the Holocene.

P-4493

## Glacial chronology and Holocene environmental history of Lake Tennyson, North Canterbury, New Zealand

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Lake Tennyson is located in the northern South Island of New Zealand. The site is critically positioned at the boundary between regional climate districts with very different precipitation regimes and is highly sensitive to atmospheric circulation changes. Evidence from this location can provide a backdrop for testing hypotheses about what drives New Zealand glacier responses to climate variability and change. However, few detailed studies on the late glacial and post glacial history exist on the northeast fringe of the main divide outside of the central Southern Alps.

We addressed this aforementioned knowledge gap by establishing the timing of the glacial sequence emplacement at Lake Tennyson. At this site, there are well-defined end moraines marking the southern margin of the lake basin, and the catchment has a simple geometry. Our work employed geophysical, stratigraphic and geomorphic approaches that included pedology, tephrostratigraphy, cosmogenic analysis, radiocarbon dating, and modelling.

The most recent maximum ice extent was achieved close to ~18.6ka at Lake Tennyson. However, an older advance of similar extent, limited by local accommodation space, is likely for MIS4 at ~64ka. Kawakawa Oruanui Tephra is also inferred as a cryptotephra within a well-developed podzolised soil capping the moraine that marks maximum local ice extent at Lake Tennyson. Inboard recessional moraines mark glacier (and presumably climate) variations during the early part of the last termination through to ~17.1ka. Replicated cosmogenic ages on the cirque sill of Princess Bath, which fed into the main glacier that filled Lake Tennyson, suggest ice had mostly evacuated the catchment by 11.2ka.

Sediment cores change from inorganic to organic sedimentation following small tree and shrub expansion at the expense of herbs prior to 10.5ka cal BP. Beech (*Fuscopora*) pollen has been present since prior to 10.5ka, and has been elevated for at least the last 1000 years. Additional dates on moraines located inboard of the LGM sequence are forthcoming.

P-4494

## What happened at the end of the mid-Pleistocene transition in the Southern Hemisphere? Insights from western Tasmania, Australia

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The current southward shift in the southern westerlies that is stripping southern Australia of rainfall is unprecedented over the past 12 kyr years at least, and is due to the effects of both the anthropogenic hole in the ozone layer and greenhouse gas-driven global warming. Predictions of future climate suggest the Earth is moving in to a "super-interglacial" (peak warming) because of anthropogenic greenhouse gas release. "Super-interglacials", which are warmer than today, are uncommon in the geological record. A recent increase in the frequency of these peak warming events since ca. 450 ka (the end of the mid-Pleistocene transition; MPT) is associated with a 7° latitude southward shift of the southern westerlies and an increase in atmospheric CO<sub>2</sub> that warmed the atmosphere - a stark similarity to current trends.

Here, we present multi-proxy analyses of two closely spaced (<50 km) sediment cores that comprise a complete sequence from the mid-Pleistocene to the present from western Tasmania, Australia - in the mid-latitudes of the Southern Hemisphere. Lake Selina is a modern-day lake with a continuous ca. 230 kyr sediment sequence, while Darwin Crater is a palaeo-lake within a meteorite impact crater that formed at ca. 816 ka and which completely in-filled during MIS5 (ca. 120 ka). We report on petrophysical whole core logging, lithological core description, spectrophotometry, grain size, natural gamma ray, paleo- and rock-magnetism, loss-on-ignition, pollen analyses and micro-XRF geochemistry. The composite record is unique in the Australian sector of the Southern Hemisphere and we discuss the data in the context of the global and regional changes that occurred at the end of MPT, paying particular attention to impact of the shift toward warmer super-interglacials, the large-scale southward shift of the southern westerlies and higher atmospheric CO<sub>2</sub> content that occurred at ca. 450 ka (MIS11 to present).

P-4495

## From stormtracks to savannah: modeling the climate and environment of early humans in Southern Africa during the last glacial-interglacial period

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The Centre for Early Sapiens Behaviour (SapienCE) at the University of Bergen (Norway) aims to understand where, when and why early humans in southern Africa started to think and behave as we do today. Current archaeological evidence, though limited, suggests that the period 100-50kya was a watershed for human cognitive, technological and social development. The climate reconstruction team at SapienCE seeks to elucidate the regional to hemispheric environmental conditions and the role these may have played in shaping early human development and movements. Key questions are: What were the regional climate characteristics over southern Africa during periods of early human habitation? Can shifts in climate and circulation patterns/regimes help explain early human 'disappearances'/ 'reappearances' in the region? The present work focuses on one of these 'disappearances'. Most of the period 100-50kya falls within the later part of the MIS5 interglacial, which may have had a climate conducive to early human cultural and cognitive development. However, shortly after 70kya the southern hemisphere entered what has been described as a nearly glacial state in MIS4. Evidence from caves along the southern African coastline show a thick dune layer that closed off the caves to human occupation, while sea levels may have dropped 80m or more, shifting the coastline many tens of kilometers from the caves. The present work focuses on this MIS5-MIS4 (~63-76kya) period straddling the transition. Coupled AOGCM simulations show robust changes in sea level pressure (higher) and temperature (cooler) both locally and remotely as the climate transitioned. The poleward flank of the southern hemisphere jet is weakened (strengthened) in DJF(JJA) and the DJF(JJA) Hadley circulation (weakens)strengthens. These have implications for weather variability and extremes, especially in the midlatitudes. However, many of these changes are modest and changes in the hydrological cycle such as precipitation rates and moisture flux divergence/convergence are even less robust. Results are compared with speleothem data from the region and sediment cores from the Agulhas plateau gathered by SapienCE colleagues. While there is general agreement on direction of change there are some areas of disagreement. In particular, the hydrological cycle response remains uncertain. Some studies/records indicate cooler wetter conditions, others cooler drier. Our simulations suggest the latter over southern Africa, but needs further investigation to improve confidence. Towards this end we perform sensitivity studies on the effects of changes to the Antarctic sea-ice extent, which is hypothesized to have extended into the present day polar front during MIS4. We also statistically assess the robustness of the climate simulations by comparing the simulated climate signals against the natural variability simulated in baseline control simulations. The potential implications of these climatic changes for the population of early humans in southern Africa are discussed.

P-4496

## A multi-proxy record of climatic changes and Southern Westerlies dynamics in the subtropical Andes of South America since 12ka

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The subtropical Andes of South America are a key area to study the interaction of tropical and extra-tropical climatic systems. The climate is characterized by wet winters and dry summers related to its position at the northern edge of the Southern Westerlies Wind Belt (SWWB) which migrate seasonally so that during the austral winter they expand equatorward to about 30°S. The SWWB is modulated by the presence of the Southern Eastern Pacific Subtropical Anticyclone (SEPSA) which migrates in conjunction with the SWWB determining the strong precipitation seasonality of Subtropical Andes. Thus, the interplay of the SWWB modulated by the SEPSA at millennial-centennial scale superimposed to the interannual scale variability related to the Southern Oscillation is reflected in precipitation patterns over the Andes allowing to trace the winter activity of SWWB at millennial-to-interannual time scales.

This paper presents the dynamics of the northern edge of the SWWB since 12ka based on a multi-proxy record of Laguna El Cepo located at 30°S (2900masl).

The pollen record is dominated of Poaceae with maximum values between 12-11ka, 9.6-8ka and since 5.8ka which suggest moderate humid conditions peaking since 2.2ka given the increase of Portulacaceae and Apiaceae. Dry phases characterized by increases of *Ephedra* occurred between 11-9.6ka and particularly 8-5.8ka. Pollen accumulation rates recorded the driest conditions between 11-5.8ka. The charcoal record shows that fire occurrence increased from 7ka onwards with maximum values between 7-6ka, during the driest period for the whole record.

The diatom record reflects cold temperature of the water given the high values of *Eunotia spp* at 12-10.5ka and 4.8-3.8ka alternating with warm conditions between 10-8.5 and 8-6ka pointed out by *Chamaeopinnularia sp* which together with *Chamaeopinnularia hassiatica* reveal the warmest conditions around 6.4ka. High percentages of *Kobayasiella micropundata* between 8.5-8ka and at 5.5ka indicate the occurrence of exogenous input into the lake. High values of *Eunotia spp* during the late Holocene reflect cooler conditions during the last 5ka, compared to the early-mid Holocene conditions.

The chironomid record show high percentages of *Cricotopus* suggesting littoral environment dominance at 12ka. Cold conditions associated to discrete increases of *Smitia* between 8.5-8ka and 5ka. The presence of *Chironomus* between 8-4.8ka and its highest percentages at 7.3-6.4ka suggest warm conditions. Sedimentological proxies suggest a recurrence of storms around 8.5-8ka and 5.8-4ka and a decrease productivity of the lake between 7.7-5.4ka.

The joint interpretation of different proxy records suggests cold and humid conditions during the end of Pleistocene while the basin was still becoming a lake. During the early and mid-Holocene up to 5.8ka, dry and warm conditions dominated, with increased occurrence of storms around 8.5-8ka. The last 5.8ka appeared to be relatively more humid and colder conditions than the early and mid-Holocene. FONDECYT#1180413;1170408

P-4497

## Early spread of rainforest trees during the Last Glacial Termination along the eastern slopes of the Central Patagonian Andes (45°S)

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Few studies have examined in detail the structure of vegetation and climate changes during the Last Glacial Termination (T1, ~11-18 ka, ka= 1000 cal yr BP) in central Patagonia (45°- 48°S). This region is adjacent to the zone of maximum southern westerly wind (SWW) influence in South America, and features strong climatic gradients along and across the Andes. These gradients influence vegetation composition and structure, resulting in zonation of evergreen and deciduous rainforests from the pacific coast upslope into the high-Andean meadows. Deciduous forests dominate the eastern slopes of the Andes and transition into the Patagonian Steppe toward the east. Here we present palynological results from Lago Unco (45°34'29.4''S; 71°43'7.6''W, 756 masl), a small closed-basin lake located in the modern forest-steppe ecotone, in direct association with moraines deposited during the Last Glacial Maximum (LGM). Our aim is to document the composition, tempo and mode of vegetation changes during T1 to infer the climate evolution through this interval and the spatial/temporal patterns of afforestation.

The pollen record features predominance of herbs and shrubs characteristic of cold high Andean environments and the Patagonian steppe between 17.8-11 ka, with dominance of Poaceae, Asteraceae, Fabaceae, and Apiaceae between ~17.8-17.3 ka. The record then shows dominance of Poaceae, Ericaceae and Asteraceae, along with *Acaena* and *Gunnera* until 15 ka. A sustained rise in *Nothofagus* is evident starting at 16.5 ka accompanied by the hygrophilous cold-tolerant conifers *Fitzroya/Pilgerodendron* and *Podocarpus nubigena*, the rainforest tree *Drimys winteri*, and the hygrophilous pteridophytes *Blechnum* and *Lycopodium magellanicum*.

These data suggest an increasing trend in humidity and SWW influence starting at 16.5 ka until it reaches its maximum at 15 ka. Our findings constitute the earliest occurrence of cold-resistant hygrophilous taxa at the east of the Andes during T1, suggesting that they thrived near the eastern margin of the PIS during the LGM and may have been a source for the postglacial dispersal and colonization of trees currently dominant in rainforests along the pacific coast of central Patagonia. *Nothofagus* forests established between 11-10 ka near Lago Unco, concomitant with a decline in hygrophilous taxa and increased fire activity. We interpret these changes as a warm pulse and decline in precipitation brought by diminished influence of the SWW at ~11 ka.

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P-4498

## New Zealand paleoclimate reconstruction from speleothem fluid inclusion measurements

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New Zealand's location makes it a particularly advantageous place to study past Southern Hemisphere climate dynamics and their impact on terrestrial hydroclimate. Few New Zealand speleothem-based studies exist beyond a handful of stable isotope records. It is increasingly understood that multi-proxy speleothem records are needed to unravel the various drivers embedded in complex carbonate stable isotope signals. Here, we present preliminary speleothem fluid inclusion (FI)  $\delta^{18}\text{O}$  and  $\delta\text{D}$  measurements, and carbonate  $\delta^{18}\text{O}$  measurements from Waipuna Cave (Waitomo, New Zealand; 30°S), dating back 16,000 years, as part of an on-going New Zealand paleoclimate reconstruction project. Speleothem FI measurements have the potential to directly measure fossil dripwater composition, but are still underutilized due to analytical barriers, particularly with respect to  $\delta^{18}\text{O}$  measurements.

We present data from a new fluid inclusion extraction system at the Godwin Lab for Paleoclimate Research, Cambridge University. In addition to measurements from Waipuna Cave, we measured an in-house water standard ( $n=40$ ) at varying sample sizes via an injection port in the crusher system, upstream from the crushing block. Further, we measured two different types of speleothem samples from three climatologically distinct regions, India (stalagmite;  $n=4$ ), Siberia (stalagmite;  $n=3$ ), and New Zealand (2 flowstone sites;  $n=25$ ). The water standard average measurements were  $\delta^{18}\text{O} = -7.4 \pm 0.3$  and  $\delta\text{D} = -51.0 \pm 3.1$ , including all samples sizes from 0.05 – 0.5  $\mu\text{L}$ . Average water standard values of each sample size are within error of known values, suggesting sample size does not influence measured values for injected water standards. Cubes of varying mass were cut from each speleothem sample for FI measurements. We found water concentration ( $\mu\text{L/g}$ ) varied among cubes, even among cubes from the same speleothem, with a range of 0.1 – 6.8  $\mu\text{L/g}$  across all samples. Further, there exists inverse relationship between water concentration and  $D_{\text{excess}}$  suggesting samples with lower concentrations report inaccurate values of fossil dripwater, and notably the stalagmite samples reported lower water concentrations than the flowstones. Whether this issue is analytical or due to in-cave processes is unclear and necessitates further experiments. Down-core FI  $\delta\text{D}$  and  $\delta^{18}\text{O}$  values from Waipuna cave are stable from ~16 – 10 ka, and exhibit variability during the Holocene. This shift from a stable deglacial to variable Holocene is also exhibited in the carbonate  $\delta^{18}\text{O}$  values from of the same flowstone, which exhibit an excursion to lower values during from the deglacial to the Holocene.

P-4499

## Vegetation and climate reconstruction from marine cores east and west of South Island, New Zealand, during past interglacials

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Previous terrestrial palynological records of mid-latitude Southern Hemisphere interglacial periods are often fragmentary and poorly dated. Here, these problems are circumvented by extracting terrestrial palynomorphs from marine sediment cores collected from the levee banks of submarine canyons to the west (MD06 2990/2991) and east (DSDP 594) of southern New Zealand. These cores have been dated by  $\delta^{18}\text{O}$  stratigraphy,  $^{14}\text{C}$  chronology, and the identification of two widespread silicic tephra horizons at 25.6 ka and ~345 ka, sourced from the central North Island. The cores cover the last 500 kyrs and have an average sedimentation rate of ~7-20 cm/kyr. The continuity and chronology of these records provides an opportunity to examine changes in vegetation between interglacials of different warmth.

The records show that 'super-warm' interglacials of MIS 1, 5e and 11 each side of the South Island are characterised by more pollen of conifer and thermophilous taxa than cooler interglacials of MIS 7 and 9 by ~50%. MIS 7 and 9 are characterised by increased southern beech pollen and suggests that the beech forest 'Biotic Gap', which characterises both flanks of the central South Island today, developed after MIS 7.

The characteristics of each interglacial can be further illuminated by comparing west and east NZ, across which there is a major rainfall gradient of 12,000 and 3,000 mm/yr over the Southern Alps. During peak warmth, MIS 11 sea surface temperatures were up to 3°C warmer than present west of NZ in the Tasman Sea. In southwestern NZ, this corresponds with a notable expansion and dominance of the thermophilous shrub *Ascarina lucida* at the expense of the currently dominant tall tree conifer *Dacrydium cupressinum*. The MIS 11 forest composition in this highly humid region also contrasts markedly with reconstructions of forest conditions during periods inferred to be up to 1.5°C warmer than present in early MIS 1 and 5e, when *D. cupressinum* remained dominant in the region. In contrast in southeastern NZ, the tall tree conifer pollen reaches the highest values in MIS 11, which is consistent with warm and wet conditions, which is possibly related to more southerly incursions of sub-tropical air masses. For each interglacial period the prominent expansion of tall tree conifers in southeastern NZ lags that in the west. The longest lag (~10 kyr) occurred during the MIS 12/11 transition. The delayed afforestation between west and east likely resulted from harsher local climate conditions (cooler and drier) east of the Southern Alps, forest disturbances, changing seasonality and competition. This suggests climate processes in Southern Hemisphere mid-latitudes during MIS 11 is fundamentally different to other Late Quaternary interglacials.

P-4500

## Stable isotopes as tracers for elucidating the origin of siderite in the volcanogenic Lake Inawashiro-ko, Japan

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Lake Inawashiro-ko, Fukushima Prefecture, Japan, is the largest volcanogenic freshwater lake in Japan. A 29-m-long core from the lake was studied in order to understand the eruptive impacts onto the lake system which hosts active Adataro and Bandai volcanoes in the upstream of their catchment. The core has 71 subaqueous flow event deposits intercalated in the background hemipelagic sediments mostly associated with volcanic activity of two volcanoes in the past 50,000 years. The present study focuses on event deposits bearing siderite mineral grains in lacustrine environments concerning with volcanic and hydrothermal sediment supply and early diagenesis.

The brown event deposits (Bm/Bs) are concentrated in the stratigraphic interval older than 15 ka. The clay-rich brown deposits are centimeters thick and are characterized by the common presence of organic material and fresh glass shards derived from Bandai volcano, suggesting volcanic density flows generated by subaerial eruptions. The Bm/Bs deposits appear in two colors: 1) brown to brown gray color or 2) olive gray to dark brown gray. Micro-XRF analysis reveals that the dark colored Bm/Bs deposits has high Fe<sub>2</sub>O<sub>3</sub>(total iron) and MnO contents. Microscopic observation and XRD analysis show the presence of siderite in the deposits. SEM images clarified that some siderite grains overgrow fresh glass shards indicating post-depositional precipitation of siderite *in situ*. The yellow event deposits (Ys) occur in the lower part of the core sequence, i.e. >29 ka in age. The thinly layered deposits, appearing in a few millimeters to 2 cm thick, are massive and semi-consolidated by cementation. The deposit has very high content of Fe<sub>2</sub>O<sub>3</sub>(mean value ~32 wt%) and high MnO contents as well (2.9%). XRD results and SEM images indicate the preponderance of highly crystalline siderite grains and coherent crystal growth, implying a post-depositional formation of siderite. Incidentally, sulfur-rich gray event deposits (Gm/Gs) derived from Adataro volcano do not contain siderite.

Carbon and oxygen isotopes of siderite were analyzed for the siderite-bearing layers and the results show distinct difference between the siderite in the Bm/Bs deposits and Ys deposits. The Ys siderite has a positive  $\delta^{13}\text{C}_{\text{PDB}}$  values (up to 10 ‰), whereas Bm/Bs deposits have a lower values of between -1 and +7 ‰. The  $\delta^{18}\text{O}_{\text{PDB}}$  values are also different between the two deposits with Bm/Bs siderites showing negative  $\delta^{18}\text{O}_{\text{PDB}}$  values when compared to Ys samples. We interpret these differences in carbon and oxygen isotopes due to a difference in primary source of carbon such as entrainment of terrestrial organic materials, volcanic gas, and hydrothermal fluids, and the interplay of siderite formative process of sulfate reduction and methanogenesis. A detailed evaluation of siderite genesis in a volcanogenic lacustrine environment of Lake Inawashiro-ko will be presented.

**P-4501**

## **Multi proxy records of dynamic climate changes during the Last Interglacial in Central and Eastern Europe basing on speleothems studies.**

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During quaternary period, the Earth's climate has been dominated by ice age cyclicality. Long cold periods (glacials) have been interrupted by shorter and warmer intervals, known as interglacials. The duration of the last interglacial (LIG) has conventionally been set at 129 - 116 ka. Recent research shows, that the LIG climate was more unstable in comparison to Holocene; this instability has been caused by changes in the dynamic of the North Atlantic Meridional Overturning Circulation. However the full understanding of the LIG climate mechanisms is still difficult.

The lack of suitable dating techniques and precisely defined absolute age benchmarks like: dated tephra layers or magnetic excursions, is one of the problems for present LIG studies. Therefore many of LIG chronologies base on indirect dating techniques like record alignment strategies. In this context, speleothems are valuable paleoclimate archives because of their capability to be dated by U-series method. In Europe LIG speleothem records are known mostly from western part of the continent. We present four new stable isotopic records of LIG age, from speleothems located in central and south-eastern Europe. This region is especially interesting for LIG climate studies because of the possible influences of Atlantic circulation, the Mediterranean Sea and the monsoonal system over the East Mediterranean and Levant regions.

Three from presented stalagmites come from Tatra Mountains (Poland), one from Low Tatra Mountains (Slovakia) and one from Ruse region (Bulgaria). The stalagmites from Tatra Mountains and Low Tatra Mountains represents the period of time between ca. 180 and 90 ka. Stalagmite from Bulgaria records the period of time ca. 129 –112ka.

All stalagmites were analyzed petrographically in terms of their micro fabric. The geochemical analyses include the stable isotopic composition of calcite and trace elements content. All stalagmites (except the part of Bulgarian stalagmite not included in research) are built from clean calcite with low porosity. The time scales were constructed by MOD-AGE software basing on obtained U-series ages. All analyzed geochemical proxies point to dynamic changes in the environment during the at the time of interglacial development (129-126.5 ka), the beginning of last interglacial optimum is connected with a rapid change to more humid and warm conditions. During interglacial demise local climate become more dependent on regional settings.

As a result of our studies, we are going to present the synthetic comparison of speleothem stable isotopic records from different regions of Europe and Middle East in a terms of local differences and their changes during the whole LIG period. Finally we will compare the speleothem proxies with other regional and global proxies.

P-4502

## Variations in carbon isotope ratios of plants across a temperature gradient and their relevance to paleovegetation reconstruction

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Carbon isotope values ( $\delta^{13}\text{C}$ ) of plants reflect the balance between photosynthesis and stomatal conductance and vary with environmental conditions. Temperature is an important influential factor for plant  $\delta^{13}\text{C}$ ; however, variations of plant  $\delta^{13}\text{C}$  across temperature gradients have yet to be quantified. This impedes interpretation of variability of  $\delta^{13}\text{C}$  in ancient terrestrial organic matter and reconstructions of paleoclimate and paleoecology. In this study, the effect of temperature on  $\delta^{13}\text{C}$  of C3 and C4 plants was assessed by comprehensive investigation of a large number of species (118 C3 plants and 17 C4 plants) from 29 sites across a temperature gradient along the 400mm mean annual precipitation isoline in north China. After deducting the effects of precipitation on plant  $\delta^{13}\text{C}$ , a strong positive relationship is found between  $\delta^{13}\text{C}$  values of C3 plants averaged for each site and mean annual temperature, with a coefficient of 0.104‰/°C; however, no significant correlation is found for C4 plants. Based on this results, we conduct a sample reconstruction of paleovegetation of the central Chinese Loess Plateau and demonstrate that, to a certain extent, our paleovegetation reconstruction is affected by temperature corrections.

P-4503

## Spatial change of precipitation during the Paleocene-Eocene Thermal Maximum in East Asia

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The Paleocene-Eocene Thermal Maximum (PETM) was a transient greenhouse climate interval associated with a huge release of carbon to the ocean-atmosphere system ~56 million years ago. The estimated input amount of carbon during the PETM is comparable in magnitude to that which could occur over the coming centuries, it thus provides a geological case study for the effect of rapid global warming on regional hydroclimate. Here we calculated carbon isotope fractionations ( $\Delta$ ) of C<sub>3</sub> plants across the PETM in the Fushun and Nanyang Basin of China. The  $\Delta$  values show significant increase at both basins (Nanyang Basin: 1.5‰; Fushun Basin: 3‰) but with greater magnitude in the Fushun Basin during the PETM. The general increase and marked spatial difference in  $\Delta$  values are explained as a response to regional precipitation. Using the relation between mean annual precipitation and the  $\Delta$  values of living C<sub>3</sub> plants, the mean annual precipitation at both sites was quantitatively estimated. The result suggested that East Asian continent generally became more humid with relatively more precipitation occurring at higher latitudes in response to the PETM warming. Our results support the prediction that continuous anthropogenic warming will lead to a wetter climate in East Asia with relatively more precipitation in higher-latitude lands.

P-4504

## Spatiotemporal changes in C<sub>4</sub> plant abundance in China since the Last Glacial Maximum and their driving factors

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Knowledge of changes in the distribution of C<sub>3</sub> and C<sub>4</sub> plants in relation to climate change is the key to predicting the biosphere's response to future climatic warming. There are significant differences in the spatiotemporal evolution of C<sub>4</sub> plant abundance at different latitudes since the Last Glacial Maximum (LGM), and the factors responsible remain debated. In this study, we reconstructed the spatiotemporal pattern of C<sub>4</sub> plants in China since the LGM, based on a synthesis of  $\delta^{13}\text{C}$  records of soil organic matter from paleosol sequences and  $\delta^{13}\text{C}$  records of individual n-alkanes from lake and marine sediments. The results indicate that, spatially, maximum C<sub>4</sub> abundance during the LGM was in South China; while maximum C<sub>4</sub> abundance occurred in the Chinese Loess Plateau in North China during the early and mid-Holocene. Temporally, in North China, C<sub>4</sub> plant abundance initially increased since the LGM, reached a maximum during the early and mid-Holocene and then decreased; however, the opposite trend occurred in South China. Combined with a physiological-process model used to study the sensitivity of C<sub>3</sub> and C<sub>4</sub> plants to changes in climate and atmospheric  $p\text{CO}_2$  in different regions, our results reveal that temperature was the dominant factor driving C<sub>4</sub> plant expansion in North China, whereas atmospheric  $p\text{CO}_2$  and precipitation were the main factors controlling C<sub>4</sub> plant abundance in South China.

P-4505

## Revisiting Lake Garba Guracha in the Bale Mountains, Ethiopia – rationale, chronology, geochemistry, and paleoclimate implications

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Our knowledge about East African paleoclimate history is largely based on marine cores and paleolimnological studies. Accordingly, more humid climatic conditions such as the African Humid Period (AHP) are usually associated with summer insolation-driven increased monsoonal precipitation.

In order to contribute to the paleoclimate reconstruction of the Bale Mountains, Ethiopia, within the DFG Research Unit 2358 'The Mountain Exile Hypothesis: How humans benefited from and re-shaped African high-altitude ecosystems during Quaternary climate changes' we revisited Lake Garba Guracha, a continuous and high altitude (3950 m asl) lacustrine archive (e.g. Umer et al., 2007; Tiercelin et al., 2008). Basal calibrated radiocarbon bulk sediment ages of around 16 cal. ka BP from the bottom-most sediments are in contradiction to cosmogenic nuclide dating results of moraine boulders at lower altitude in the research area and especially in the same valley (around 14 ka) documenting landscape stabilization following glacial retreat. We therefore propose that old carbon accumulated in the basal sediments during glacial retreat. By contrast, a robust chronology could be established for the Late Glacial and Holocene sediment cores based on radiocarbon dating of bulk sedimentary organic matter, charcoal, and *n*-alkane biomarkers.

Results from organic geochemical and XRF analyses document that minerogenic input dominated during the Late Glacial and organic matter input increased considerably only from 11 cal. ka BP on. We also investigated sugar and lipid biomarkers as well as their compound-specific stable oxygen and hydrogen isotopic composition ( $\delta^{18}\text{O}_{\text{sugar}}$  and  $\delta^2\text{H}_{n\text{-alkane}}$ ) to infer past hydrological patterns. Most negative  $\delta^{18}\text{O}_{\text{sugar}}$  and  $\delta^2\text{H}_{n\text{-alkane}}$  values characterize a maximum moisture availability concurring with the African Humid Period during the Early Holocene. The  $\delta^2\text{H}_{n\text{-alkane}}$  record is interpreted to reflect paleo leaf water, whereas the  $\delta^{18}\text{O}_{\text{sugar}}$  record is interpreted to reflect paleo lake water. The coupling of  $\delta^2\text{H}_{\text{alkane}}$  with  $\delta^{18}\text{O}_{\text{sugar}}$  allows the establishment of a deuterium excess record (cf. Zech et al., 2013) that can be interpreted in terms of lake water evaporation. We thus have evidence that a perennial lake overflow occurred from about 10 to 8 cal. ka BP, whereas during the period before and afterwards (from about 8 to 5 cal. ka BP) the lake experienced at least seasonal evaporation.

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P-4506

## Ice cores and isotopic climate emulation to reconstruct the Last Interglacial Greenland Ice Sheet

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The Greenland Ice Sheet (GIS) contribution to the Last Interglacial (LIG) sea level high stand is uncertain. Published studies show wide range of LIG ice loss estimates, varying from 0.3 to 5.5 meters of sea level equivalent. Here we propose to combine, for the first time, a compilation of stable water isotopic ( $\delta^{18}\text{O}$ ) information from Greenland deep ice cores with isotopic climate emulation to provide new constraints on GIS ice volume and configuration changes during the LIG. Greenland ice records show that between present-day and the LIG climatic optimum, there was a rise in  $\delta^{18}\text{O}$  of at least 2.5‰.

Isotopic LIG climate simulations are performed with a wide range of GIS morphologies. The outputs from the isotope-enabled climate model (HadCM3) are used to build an emulator of the response of  $\delta^{18}\text{O}$  to all possible changes in the shape and extent of the GIS at 125ka. By applying this rather novel emulation technique, we show that strong ice loss occurred over southern Greenland, possibly resulting in a two dome structure, with a small remnant dome covering the south of Greenland and a larger one in the north. We also demonstrate the sensitivity of the solution to DYE3 ice core data. This shows where the most valuable ice core data lies in order to reduce uncertainties on GIS ice volume change estimates during the LIG.

**P-4507**

## **Speleothem record from the Swiss Alps highlights Last Interglacial climate variability**

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The Last Interglacial (LIG), ~130,000 to 115,000 yr BP, is an important time period in recent Earth history, when temperatures were warmer and sea level was higher than present. Examining the climate and vegetation during the LIG in the Alps will provide invaluable feedback on the current warming trend in this region which is twice as large as the mean of the Northern Hemisphere. However, only a handful of studies have been published on the LIG so far, with discrepancies in the fine-scale structure, highlighting the need for replication. A new speleothem from Neotectonic Cave in Melchsee-Frutt (Switzerland), which opens at 1727 m a.s.l., covers almost the entire LIG at high resolution (~9 yr resolution). The  $\delta^{18}\text{O}$  record shows an initial warming at 130,150 yr BP. This warming trend is interrupted by a hiatus between 129,200 and 127,000 yr BP, possibly suggesting flooding of the cave passage. After the hiatus, an early optimum is identified between 126,700 and 125,700 yr BP. Significant isotopic variability exists at the end of the optimum at 125,700 yr BP, suggesting abrupt swings in climate and vegetation. Slight cooling occurs at 124,500 yr BP, followed by stable conditions until 118,100 yr BP. Deteriorating climate is observed after 118,100 yr BP, with a sharp increase in  $\delta^{13}\text{C}$  suggesting a decrease in soil bioproductivity; however, the  $\delta^{18}\text{O}$  decrease (suggesting cooler temperatures) is more subdued.

P-4508

## The early Marine Isotope Stage 5 record of IODP Site U1390, Gulf of Cadiz (NE Atlantic)

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During Integrated Ocean Drilling Program (IODP) Expedition 339 – Mediterranean Outflow IODP Site U1390 (36°19.11'N, 7°43.08'W, 992 m water depth) was drilled into sediments of the central middle slope of the Gulf of Cadiz. While its open water location allows to monitor changes in the subtropical surface waters advected into the Gulf of Cadiz by the Azores Current, bottom conditions are dominated by the presence –as nowadays– or absence of the Mediterranean Outflow Water (MOW). IODP Site U1390 exhibits extremely high sedimentation rates of 75 cm/ky during the late Pleistocene and we made use of this to generate centennial-scale climate records for surface and intermediate-depth water conditions during Marine Isotope Stage (MIS) 4 to MIS 6. Here we focus on the interval covering the glacial/interglacial transition from MIS 6 into MIS 5e (Eemian) and subsequently the interglacial demise and onset of glacial conditions during MIS 5d. Surface-water conditions are reconstructed using the stable isotope records of planktonic foraminifer species *G. ruber* white and *G. bulloides*, whereas conditions in the intermediate depth water column, i.e. in the MOW level, are reflected in the benthic foraminifer stable isotope data. In addition, the mean grain size of the bulk fraction <63µm, the weight percent of the sand fraction >63µm and the XRF-derived ln(Zr/Al) data reveal variations in bottom current strength with maxima in all three proxy records indicating a stronger current, namely the MOW, and the formation of a contourite layer.

The planktonic foraminifer stable isotope records show high-frequency oscillations throughout the whole interval, including the interglacial interval. In addition, the *G. bulloides* oxygen isotope record clearly reflects marine impressions of Greenland interstadials 25 and 24. During the interglacial period, the current strength related proxy records indicate a sluggish bottom flow – a phenomenon that is linked to the formation of sapropel 5 in the Mediterranean Sea and subsequent changes in the outflow. The very negative benthic carbon isotope values, contemporary with the low current speed, point to Antarctic Intermediate Water replacing MOW during this period in the intermediate depth of the central Gulf of Cadiz. On the other hand, maxima in bottom flow strength, together with relative high benthic carbon isotope values, during the terminal cold event of the glacial/interglacial transition, during the glacial inception and during stadial MIS 5d indicate the presence of the MOW. The Site U1390 records therefore reflect millennial-to-centennial scale hydrographic changes in the surface to intermediate depth waters in the Gulf of Cadiz.

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P-4509

## Implications of mid-Holocene and Last Interglacial changes in insolation seasonality on high and mid-latitude climate

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The mid-Holocene (MH), 6000 years BP, and the Last Interglacial (LIG), 127,000 years BP, are key reference periods for the 4<sup>th</sup> phase of the Paleoclimate Modeling intercomparison Project (PMIP4, Kageyama et al., 2018; Otto-Bliesner et al., 2017), and will contribute to the overall understanding of the response of the climate system to external forcing as part of CMIP6. These two interglacial periods are characterized by enhanced (reduced) seasonality of the incoming solar radiation at the top of the atmosphere in the northern hemisphere (southern hemisphere). In the annual mean, larger obliquity also increases solar radiation in high latitudes and decreases it in the tropics. Trace gas atmospheric concentrations are similar to pre-industrial values.

We will present the new sets of available simulations with the aim to characterize the differences in snow and ice feedbacks in high latitudes resulting from differences in the magnitude of the changes in seasonality between the two periods. The impact of this feedback on polar amplification will be investigated. Also both periods are characterized by enhanced monsoons in the tropical regions. These first analyses will investigate how monsoon seasonality is related to the characteristics of the solar forcing and to feedbacks from ocean circulation and land surface properties. For both periods, model results can be analyzed in the light of available paleoclimate reconstructions. In addition, the mid-Holocene is considered as an entry card for the paleoclimate simulations in CMIP6, because it has been a reference period for PMIP since the first PMIP phase (Joussaume and Taylor, 1995). A comparison with previous MH PMIP simulations will highlight the evolution of model performances in simulating a climate state different from the modern one.

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P-4510

## A study of Late Quaternary benthic foraminiferal assemblages from Kongsfjordhallet, (North-West Svalbard)

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The Quaternary environment of the Arctic varied profoundly due to glacial-interglacial cycles in the last 200 ky and this variation created a large impact on the arrangement of hydrographic and biological systems of that region. Though there are uncertainties in older glaciations, the Late Quaternary glacial extent and deglaciation record of the North West Svalbard (High Arctic) sector of the Svalbard-Barents Sea ice sheet has been well documented (e.g. Alexanderson *et al.* 2018). The Kongsfjorden area contains key locations for the present understanding of the two last glacial cycles (MIS 6 to present); such as Kongsfjordhallet where five major glacial advances during the last 200 ky have been identified (Alexanderson *et al.* 2018). These glacial advances are separated by interglacial or interstadial intervals characterized mainly by glaciomarine mud and littoral sands containing abundant microfossils and molluscan shells. The application of benthic foraminifera can be a key proxy for assessment of the past hydrological conditions that prevailed during those interglacial or interstadial events and can be correlated with other proxy records, e.g. sedimentological data, and with radiocarbon and OSL dating.

Three fine grained units (Unit-1, Unit-4 and Unit-8b) from the upper part of sedimentary succession at Kongsfjordhallet (Alexanderson *et al.* 2018) have been investigated. These units, being deposited in high relative sea level during deglaciations, are significant in the stratigraphy of Kongsfjordhallet; They are indicative of preceding large scale glaciations and their fossil content makes them suitable for paleoceanographic reconstructions. Sediments from these three units have been collected, processed and sorted in the laboratory for identification, abundance, diversity and facies interpretation from benthic foraminiferal assemblages. The uppermost Unit 8b correlated with post Last Glacial Maximum (17 ky) shows low to moderate number of total calcareous benthic foraminifera specimens; Unit 4, representing the last Interglacial (MIS 5e-Eemian), shows well where as Unit 1, indicative of Early Saalian Glaciation (Early MIS 6), shows abundant total number of benthic foraminifera specimens with dominance of *Cassidulina reniforme*, *Islandiella norcrossi*, *Elphidium excavatum*, *Haynesina orbiculare* and *Nonionella labradorica*. The assemblages of Unit 8b and Unit 4 from Kongsfjordhallet represent glacial intermediate, inner shelf environment where as Unit 1 represent glacial proximal inner shelf environment with a seasonally open connection to the ocean.

The study of foraminiferal assemblages from Kongsfjordhallet together with lithostratigraphy and OSL dates will help to delineate past environment change within and between interglacials and interstadials.

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P-4511

## Refining Last Interglacial biostratigraphies: A novel palynological record from the Swiss North Alpine Foreland Basin

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The Last Interglacial (Eemian, c. 130 ka) has been a major focus of recent research efforts because its warmer-than-today conditions offer unique possibilities to assess vegetational responses to a warmer climate in the future. Nevertheless, the biostratigraphic position and the plant succession during the Eemian have not been fully deciphered and characterized yet. In fact, the numerous palynological records from the Swiss North Alpine Foreland Basin (Welten 1982, 1988; Wegmüller 1992) are all lacking well-constrained independent internal chronologies. It is the major scope of this project to improve the characterization and the temporal calibration of Eemian biostratigraphic records. To address this scope, we plan to perform a high-resolution investigation of a novel palynological record from Spiezberg, Switzerland, coupled with independent dating techniques (<sup>230</sup>Th/U and luminescence dating). The planned analyses would represent a major scientific advance in Quaternary biostratigraphy, as they would, for the first time, generate independent internal chronologies of Eemian pollen records from the North Alpine Foreland Basin. In addition, refining and chronologically constraining the Eemian biostratigraphies with state-of-the-art approaches will allow better foundations for biostratigraphic comparisons of European pollen archives.

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**P-4512**

## **Transient simulations of the last and penultimate deglaciations using MIROC AOGCM**

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The last deglaciation (~21-9 thousand years before present) is the transition from the last glacial maximum to the present interglacial, as well as the penultimate deglaciation (~138-128 ka) is from the penultimate glacial maximum to the Last Interglacial (LIG, ~129-116 ka). The Last Interglacial was characterized with warmer surface temperature of high-latitude and higher sea level compared to the present interglacial. There were some significant differences in magnitude and temporal evolution of climates between the last two deglaciations. As the response times of climate systems such as ice sheets and deep-ocean circulations are long, the climate states and ice sheets might have been influenced by the gradual changes that occurred during the preceding deglaciations. A working group has been set up as part of the Paleoclimate Modelling Intercomparison Project (PMIP) phase 4 to investigate the responses of the climate systems during deglaciations. The protocols have been proposed to perform transient simulations of the last deglaciation and penultimate deglaciation (Ivanovic et al. 2016; Menviel et al. 2018).

We are conducting transient deglaciation experiments using an atmosphere-ocean coupled general circulation model MIROC4m. The experiments are both realistic simulations following above protocols, and idealized simulations investigating the roles of respective boundary conditions. We will present preliminary results and discuss influences from respective boundary conditions on climate evolution.

**P-4513**

## **The UK contribution to paleoclimate modelling for CMIP6/PMIP4: Results from the mid-Holocene & Last Interglacial, and comparison to the preindustrial era**

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The use of physically-based tools, such as Global Climate Models (GCMs) or Earth System Models (ESMs), to better understand environmental and climate changes during the geological past (such as the late Quaternary) is a well-established technique. Moreover, the modelling of paleoclimate is regarded as an excellent way to test the GCMs/ESMs currently being used for future climate change projections, by providing an out-of-sample test for the models. By simulating past climates, and comparing these simulations to existing proxy data, the models' ability to reproduce climates that were radically different from our own can be assessed. Due to this, the Paleoclimate Modelling Intercomparison Project (PMIP, now at phase 4) spearheads the paleoclimate contribution to the current phase of the Coupled Model Intercomparison Project (CMIP6).

In preparation for the forthcoming IPCC Assessment Report (AR6), PMIP4 is coordinating the modelling of 5 separate time periods: the Last Millennium (past1000), the Last Glacial Maximum (LGM), the mid-Pliocene Warm Period (midPliocene), the mid-Holocene (MH) and the Last Interglacial (LIG). Concerning the UK contribution to these 5 experiments, using the UK Met Office's most recent GCM (HadGEM3.1), the MH and LIG have now been completed, and the others are currently underway or imminently about to start. Some of these will be repeated in the near future using the UK Met Office's most recent ESM (UKESM1).

Here, we will present preliminary results from the MH and LIG simulations (~6kya and ~127kya, respectively), grouped together as they both represent, in very general terms, a warmer world with greater seasonal temperature variations in the Northern Hemisphere, primarily due to changes in the Earth's orbital configuration. Both of these will be compared to the preindustrial control simulation (piControl), concerning firstly their spin-up runs (to test whether the simulations have reached acceptable equilibrium) and secondly their production runs (to test, via model-data comparisons, whether the simulations are correctly reproducing the expected climate during these periods).

P-4514

## **An Antarctic ice core as a potential global boundary stratotype section and point (GSSP) for the Upper Pleistocene Subseries**

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The Upper/Late Pleistocene Subseries/Subepoch has yet to be defined formally. The term was in use during the Second International Conference of the Association pour l'étude du Quaternaire européen (a precursor of the International Quaternary Association [INQUA] and its congresses) in Leningrad in 1932, and later employed in a formal sense in English in 1935. The Upper Neopleistocene in the Russian scheme is an exact equivalent. During the Leningrad Conference in 1932, it was decided that the base of the Upper Pleistocene should coincide with that of the last interglacial (the Eemian regional Stage in Europe), and at the 12th INQUA Congress in Ottawa in 1987, a proposal was approved to use the base of MIS 5 (termination II) to define the boundary. Two sections have been suggested as possible candidates for a Global Boundary Stratotype Section and Point (GSSP): the Fronte section, Taranto, Italy and an Antarctic ice core. The Fronte Section has yielded an excellent last interglacial marine record, although Termination II marking the base of MIS 5 is apparently not preserved. A proposal submitted in 2008 based on a non-marine to marginal marine succession in the Amsterdam Terminal borehole failed to achieve ratification. Although the pollen record in this borehole clearly marks the base of the Eemian Stage, it is now known that the base of MIS 5 is about 6 kyr older than the base of the Eemian pollen stage. Leads and lags in the climate-ocean system challenge efforts to define the base of the Upper Pleistocene, with isotope stratigraphy giving Atlantic over Pacific leads of several thousand years for the past six terminations, and North Atlantic high-latitude temperatures lagging southern hemisphere records likewise by several thousand years. Given these limitations, an Antarctic ice core should be considered for the GSSP, with the abrupt methane rise seen in ice cores at Termination II potentially serving as the primary guide to the boundary. This methane rise is a distinctive global event closely related to rising temperatures in the higher northern latitudes. To provide a more recent comparison, methane lagged temperature rise by less than 30–70 years for the last glacial interval in Greenland, and its abrupt increase during Termination II in Antarctica is thought to reflect essentially synchronous abrupt warming of the air above Greenland. Termination II has a gas orbital age of 132.4 ka at its midpoint, with a subsequent steep methane increase at  $128.51 \pm 1.72$  ka in the EPICA Dome C core that leads the onset of the Eemian in southern Europe by ~2 kyr. Although an ice core is an unconventional choice for a GSSP, the Lower and Middle Holocene subseries GSSPs are both defined in Greenland ice cores.

**P-4515**

## **Last Interglacial temperature changes from the North Atlantic to the Southern Ocean based on a coherent and precise chronological framework**

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The Last Interglacial (LIG, ~129-116 ka) is a key period to decipher the interactions between the different components of the climate system under warmer-than- preindustrial conditions. Modelling the LIG climate is now part of the CMIP6/PMIP4 targeted simulations. As a result, recent efforts have been made to propose surface temperature compilations focusing on the spatio-temporal evolution of the LIG climate, and not only on its peak warmth as previously proposed. However, the major limitation of these compilations remains in the climatic alignment of records (e.g. temperature, foraminiferal  $\delta^{18}\text{O}$ ) that is performed to define the sites' chronologies. Such methods prevent the proper discussion of phase relationship between the different sites.

Thanks to recent developments we propose for the first time a global compilation of LIG temperature changes based on a coherent and precise chronological framework using key absolutely dated tephra layers from the Mediterranean region and the alignment of independently dated paleomagnetic variations of reference sites within the different ocean basins.

Based on this chronological framework, we discuss the sequence of events of surface temperature changes during the LIG that will serve as reference for future model- data comparison of the up-coming CMIP6/PMIP4 LIG simulations.

P-4516

## Speleothem record from western Germany suggests a relatively late timing (124-114 ka) of the Last Interglacial in Central Europe

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We present high-resolution  $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$  and trace element profiles for three stalagmites from western Germany, which grew during Marine Isotope Stage (MIS) 5. All stalagmites were precisely dated by MC-ICPMS  $^{230}\text{Th}/\text{U}$ -dating. Stalagmite HBSH-1 from Hüttenbläuserschachthöhle grew between 130 and 80 ka and provides a climate record with decadal to centennial resolution. The other two stalagmites grew faster than HBSH 1, but their growth phases are shorter. Stalagmite HBSH 5 grew between 129 and 122 ka, whereas stalagmite BR 5 grew between 126 and 122 ka.

The record of HBSH 1 shows four growth interruptions coinciding with Greenland Stadials (GS) 21, 22, 24, 25, and 26. This shows that growth of this stalagmite is a very sensitive proxy for cool and dry conditions in the North Atlantic realm and enables us to precisely determine the timing and duration of the GS.

We interpret stalagmite  $\delta^{18}\text{O}$  values as a proxy for supra-regional temperature changes in the North Atlantic realm, which is particularly evident from their close resemblance with the  $\delta^{18}\text{O}$  values of the NGRIP and NEEM ice core records. Stalagmite  $\delta^{13}\text{C}$  values primarily reflect changes in hydrological balance and vegetation density and are, thus, interpreted as a proxy for terrestrial climate in central Europe. The  $\delta^{13}\text{C}$  record shows three pronounced negative peaks during MIS 5, and their timing is in agreement with MIS 5e, 5c and 5a. This suggests generally warm and humid climate in central Europe during these phases.

Interestingly, the evolution of the  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values during the Last Interglacial (MIS 5e) is not parallel. The  $\delta^{18}\text{O}$  values progressively increase from 130 ka, peak at 125 ka and subsequently show a gradual decrease. The  $\delta^{13}\text{C}$  values, in contrast, start to decrease at 124 ka, show a negative peak at 120 ka and an abrupt increase at 114 ka. This suggests a decoupled evolution of temperature, precipitation and vegetation density in Central Europe and that the Eemian sensu strictu lasted from 124 to 114 ka. This is in agreement with a marine record from the Norwegian Sea and indicates a strong influence on central European climate from high northern latitudes.

Climate modelling simulations performed with the general circulation model HadCM3 confirm the decoupled evolution of temperature and precipitation in Europe during the Last Interglacial and suggest a strong influence of atmospheric circulation.

**P-4517**

## **The Past and Future of Antarctic Sea Ice: The Last Interglacial**

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According to the most recent IPCC report, sea ice is expected to decline in both the Southern and Northern Hemispheres in the future. In particular, current climate models predict a reduction of the Antarctic sea ice of about 50–60% by the next two centuries.

Recent modelling and paleoclimate reconstruction studies indicate a substantial (up to 50-60%) retreat of the Southern Hemisphere (SH) sea ice during the Last Interglacial (LIG) period, between 130 000 and 116 000 years Before Present (BP).

Because there has not been a recent retreat event in the Southern Hemisphere to constrain climate models, the analogy between the Last Interglacial and the projected sea ice retreat events offers a unique opportunity to improve our understanding of what drives a (major) sea ice retreat.

We propose to test a set of hypotheses on the causes of the LIG sea ice retreat. To do so, we set up a CMIP6-PMIP4 last interglacial experiment (lig127k) using the global coupled HadGEM3-GC3.1 model. This experiment has now run for 200 model-years.

The lig127k experiment is designed to address how the Earth system responds to the stronger orbital forcing that occurred 127 ka, compared to today. Here we present our preliminary results on the climate response to the last interglacial orbital forcing. We investigate the role of the radiative forcing in causing a reduction of SH sea ice by analysing Sea Ice Concentration, SST, Surface Air Temperature and other climate variables. We compare the LIG both against reference CMIP6 preindustrial and historical simulations, and against observations.

We find that time series of annual mean sea ice area during the LIG shows a negative trend. However, the decline is small. We suggest that radiative forcing alone is unlikely to explain the major LIG sea ice retreat event. Additional sensitivity tests to test the effects of a weakened AMOC (because of the concomitant melting of the Greenland Ice Sheet) and the consequences of a collapse of the West Antarctic Ice Sheet on the atmospheric and oceanic circulation are thus in the process of being set up. The lig127k experiment will be the reference simulation against which these additional sensitivity experiments will be examined.

**P-4518**

## **Grain size and magnetic properties of Loess in the southeastern margin of the Chinese Loess Plateau and their paleoclimate implications**

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The mechanism of magnetic susceptibility enhancement of loess deposits has long been debated. Though pedogenetic enhancement model was regarded to be dominant, in the fringe areas of the Chinese loess plateau it was indicated that the relationship between pedogenetic intensity and susceptibility were more complicated. Detailed studies in the fringe areas can help shed insight on paleoclimatic evolutions and eolian deposition. Systematic grain size and rock magnetism measurements were made on loess samples from two typical sections in the Southeastern margin of the Chinese Loess Plateau. The results show that: [1] the  $<5 \mu\text{m}$  fraction and  $30\text{-}50 \mu\text{m}$  fraction of loess samples from the southeastern margin of the Loess Plateau increased from bottom to top of the sections, while the magnetic susceptibility exhibited a reverse upwards weakening trend, which was in line with the Quaternary globe change. In contrast, for loess deposits which are distributed in the northwestern margin of the loess plateau and close to arid source areas, the susceptibility demonstrates an up-section increasing trend. It was indicated that original eolian input did not play a significant role in magnetic enhancement in the southeast margin as in the northwest margin of the loess plateau. [2] The paleoclimatic evolution since the last interglacial recorded by the studied sections are consistent with previous reports in east Asia monsoon areas and Greenland Ice Core records. Paleoclimatic variations in MIS5 and MIS4 could be traced and correlated to other geological records. Compared to other proxies, frequency-dependent susceptibility was more sensitive to paleoclimatic changes. For MIS3, the frequency-dependent susceptibility variations in one of the studied sections can be correlated to the grain size variations of the Huining Section in the northwest of the Chinese loess Plateau. [3] Holocene paleoclimate constructed using rock magnetic proxies and grain size demonstrated a step-like cooling trend and can be correlated to the grain size variations in the loess from the northwest of the Chinese loess Plateau. [4] On the whole, pedogenetic enhancement dominated in the loess-paleosol sequences. Significant magnetic enhancement could be frequently observed, which could be attributed to local eolian input and was probably relative to the watercourse changes of Yellow river. Low magnetic intensity corresponding to fine grain size might result from waterlogging or excessive moistening conditions. It is suggested that the southeastern margin of the Chinese loess plateau experienced a generally cooling Quaternary paleoclimate. The mechanism of magnetic variation was more complicated and therefore the magnetic signals have to be studied carefully before they are used to trace paleoclimatic changes.

**P-4519**

## **Upper ocean temperatures and productivity in the Ross Sea from MIS 5 to the Holocene: Biomarker results from IODP-Site-U1524**

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Marine based ice sheets are very vulnerable to warming. Understanding the past dynamics of sea ice and ocean temperature in the Antarctic continental margin, particularly during the last interglacial, a period considered as an analog of the coming warmer global climate, will help elucidate the near future evolution of the vulnerable West Antarctic Ice Sheet.

Long sediment sequences from five sites were retrieved during the International Ocean Discovery Program (IODP) Expedition 374 on the Ross Sea continental shelf and slope with a targeted aim of investigating past warm climates.

This work focusses on biomarker analyses of sediments collected at IODP Site U1524 (74°13.05'S, 173°37.98'W, 2394 m water depth) covering the last interglacial to the present. Located on the continental slope of the Ross Sea, Site U1524 is sensitive to advances and retreats of the sea ice edge and changes in the Antarctic Slope Current and Antarctic Bottom Water formation. We present preliminary highly branched isoprenoid (HBI), phytosterol and glycerol dialkyl glycerol tetraether (GDGT) data that will provide for estimates of past (ice algae) productivity and ocean temperature changes. These records will contribute to the understanding of mechanisms related to ocean-atmosphere heat and gas exchange, bottom water formation and polar amplification.

P-4520

## Last Interglacial marine molluscan assemblages from Uruguay: palaeoenvironmental reconstruction in mid latitudes of the southwestern Atlantic

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Quaternary marine fossiliferous beds from Uruguay preserve relevant information for the reconstruction of the biotic, palaeoecological and palaeoenvironmental conditions of the Southwestern Atlantic Ocean during the last thousands of years. Three molluscan assemblages originated in the Late Pleistocene are recorded in emerged deposits in Puerto de Nueva Palmira, Zagarzazú (boundary between the Río Uruguay and the Río de la Plata estuary) and La Coronilla (northeastern Atlantic coast) localities. A recent systematic sampling effort of these deposits allowed to increase their molluscan species diversity and to make new palaeoenvironmental inferences through the palaeoecological analysis of the recorded taxa. We identified 132 molluscan species (4 polyplacophorans, 65 bivalves and 63 gastropods), increasing by 40% the previously known richness of the Late Pleistocene deposits. The three assemblages included a majority of marine molluscan species, so an intense influence of marine waters from the southwestern Atlantic reached the nowadays Río de la Plata estuary and even the current Río Uruguay mouth. However, in the western assemblages, the high abundance of typical euryhaline species and the record of two estuarine taxa, may indicate fluctuating salinity conditions on this coastal sector today dominated by freshwater. Soft substrate taxa were the most abundant in the Late Pleistocene assemblages. Dead shells are inferred to have provided the bottom for the settlement of hard substrate taxa in the La Coronilla assemblage. Regarding the biogeographic origin of the molluscan species of the deposits, it is noticeable the almost absence of cold water species that today reach the Uruguayan coast due to the cold Malvinas (Falkland) Current and the high representation of tropical-subtropical species influenced by the warm Brazilian Current. More than 40 species were warm-water extralimitals, with current southern Atlantic endpoints of distribution located on the Brazilian coast. These pieces of evidence indicate that the recorded molluscan assemblages had settled in the Uruguayan coast during a time interval of higher sea level and warmer temperatures than today, such as the Last Interglacial or MIS 5e (about 130 ky BP), a time lapse when similar faunal migrations occurred around the world. However, the palaeoenvironmental signal contrasts with the numerical dating obtained for the fossiliferous beds. The minimum radiocarbon ages for the three assemblages (about 30-35 ky BP) and the OSL ages (about 80-88 ky BP) yielded by the Puerto de Nueva Palmira and Zagarzazú deposits provide conflicting results with the environmental evidence yielded by the molluscs. Besides considering the molluscan deposits as corresponding to the Last Interglacial, it should be further evaluated if the western assemblages may have been deposited during a younger MIS 5 substage as suggested by the OSL results. This is a contribution to PEDECIBA-Biología, PEDECIBA-Geociencias, CSIC and ANII.

**P-4521**

## **A comparison of interglacial episodes from Crevice Cave, Missouri in the North American midcontinent**

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The well-dated speleothem record from Crevice Cave, Missouri (37°45'N, 89°50'W) now covers nearly 400,000 years and provides critical paleoclimate information for a highly underrepresented area throughout much of this time. The record captures paleoclimate information through various proxies, including stable isotopes, flood laminae, growth onset and cessation, and breakage (possibly by earthquakes). A brief consideration of the entire MIS 5 through MIS 1 sequence in the speleothem record helps put the interglacial episodes in perspective. Speleothem deposition was abundant during most of the last interglacial/glacial cycle from MIS 5 through MIS 2, even somewhat during the last glacial maximum, but slowed and ceased during the late glacial, from approximately 17-12 ka, suggesting uniquely cold/dry conditions during that time. Growth resumed during the early Holocene. The record documents a large transition in climate around 55 ka, from overall warmer to cooler conditions and including all the millennial-scale frequency variation seen in the Greenland ice core record superimposed on the larger trends. One of the most unique periods is early MIS 4, from 74 to 72 ka, a time when global ice buildup was occurring rapidly, yet conditions at Crevice Cave were distinctly non-cold; and according to proposed correlations with nearby lake sediments containing insightful paleoecological evidence, were distinctly "interglacial" in character.

A comparison between MIS 5e and the Holocene reveals some distinct differences between these two classic interglacial periods. Whereas widespread paleoecological sites from the Upper Midwest shows ubiquitous evidence for a distinct "prairie period" between forested intervals during the Holocene, the Lower Midwest, as represented by Crevice Cave, indicates nearly unchanging, savanna-like vegetation during the last 8,000 years. In contrast, the MIS 5e record contains a distinct prairie period between forested intervals, precisely occurring between 128 and 125 ka, and plausibly related to a peak in summer insolation. Finally, the flood laminae record reveals that the Holocene is unique in the last 400,000 years in its frequency of large flood events. The most active period of flooding in the last 400,000 years was from 900 to 600 years ago.

P-4522

## Magnetostratigraphic dating of the Shixia red sediments and implications for formation of Nihewan paleo-lake, North China

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The sedimentary sequence in Nihewan Basin, northern China, is rich in mammalian fossils and Paleolithic sites. Extensive magnetostratigraphic investigations have been carried out in the Nihewan sediments, but precise age control on the earliest Nihewan red sediments, which have a fluvio-lacustrine origin in the upper part and an eolian origin in the lower part, has remained unavailable. The formation process of Nihewan paleo-lake, therefore, remains unclear. Here we contribute to understanding the age of the early Nihewan reworked and eolian red clays by presenting detailed magnetostratigraphic and rock magnetic results from the Shixia section coupled with geochemical and petrographic analyses. Magnetite and hematite are the main carriers of characteristic remanent magnetizations documented in the Shixia section, eastern Nihewan Basin. Our new magnetostratigraphic results indicate that the underlying eolian red clay in the Shixia section is slightly younger than the Cochiti subchron, that is 4.19 Ma. The main bulk minerals in the studied sediments are quartz, calcite, albite and ferrosilite, with smaller concentrations of albite and clay minerals. REE patterns are characterized by LREE enrichments with relatively flat HREE distributions. A slight negative Eu anomaly also occurs in most of the studied samples. The reworked red clay formation in the Shixia section is one of the sources of the earliest fluvio-lacustrine Nihewan Formation sediments. These results indicate that prior to initiation of Nihewan paleo-lake, the Shixia red clay had an eolian origin in the Nihewan Basin during the Pliocene and was then redeposited as the Nihewan Formation. With tectonic development of a graben basin, early red clay was deposited first in Nihewan Basin during the Early Pliocene before giving way to lacustrine environments in Nihewan paleo-lake. Geochemical and petrographic results indicate a wind-blown origin for the lower red clay deposits, which have been reworked and mixed with conglomerates produced by local tectonic activity to produce the basal Nihewan sediments. Later formation of carbonate nodules has given rise to the sediments that are now exposed in Nihewan Basin.

**P-4523**

## **The paleoclimate of Pliocene-Pleistocene transition based on stable isotopes analysis from flowstones profiles in the Javoříčské jeskyně Caves (Czech Republic)**

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Along the corridors of the Javoříčské jeskyně Caves (Central Moravia, Czech Republic) a number of profiles composed of clastic sediments interbedded with speleothems have been observed. Two profiles were selected for the study. The first (JV) is located around 10 m from the cave entrance. The second one (JC) is located in the central part of the cave (around 600 m from cave entry). The thickness of the speleothem profiles is about 150 cm and 230 cm, respectively. Paleomagnetic results combined with zoopaleontology (small mammals) indicate the age of sediment deposition from ca 3.6 to 1.77 Ma ago.

Isotopic records of oxygen and carbon preserved in speleothems allow reconstructing the isotopic composition of the water from which speleothem crystallized, i.e. climatic conditions incl. the amount of the rainfall or temperature in the area of the cave.

Stable isotopic composition analyses of flowstones were performed in the Institute of Geology PAS (Warsaw, Poland). The value of  $\delta^{18}\text{O}$  changes within the range of ca 3 ‰ (from  $-3.96$  to  $-7.06$  ‰) for JV profile. The range of the carbon isotopic changes is wider and reaches ca 4 ‰ (the  $\delta^{13}\text{C}$  changes from  $-4.11$  to  $-8.04$  ‰). In JC profile the value of  $\delta^{18}\text{O}$  changes within the range of ca 2.5 ‰ (from  $-5.86$  to  $-8.36$  ‰). Again, the extent of the carbon isotopic composition changes is wider and reaches ca 5 ‰ (the  $\delta^{13}\text{C}$  changes from  $-5.88$  to  $-10.94$  ‰). Obtained isotopic records were correlated with global and regional paleoclimatic data. The analysis resulted in first data concerning Pliocene/Pleistocene transition climatic conditions in the studied area.

P-4524

## Climatic changes during the Plio-Pleistocene transition as recorded by the isotopic composition of pedogenic carbonates.

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Plio-Pleistocene continental deposits in south-eastern Buenos Aires province (Argentina), correspond to fluvio-alluvial deposits interbedded with palaeosols. The Pliocene units show little participation of carbonatic features in their palaeosols, which are classified as Argillisols. The late Pliocene-Pleistocene palaeosols show a much higher participation of pedogenic carbonates and are classified as Calcisols. Could this change from Argillisols to Calcisols be related to the global-scale climatic change during the Plio-Pleistocene boundary?

For the pedogenic carbonates here-by studied, the  $\delta^{13}\text{C}$  values range between  $-9.92$  and  $-5.62\text{‰}$  and the  $\delta^{18}\text{O}$  values range between  $-4.19$  and  $-2.80\text{‰}$ . These values are typical for calcretes, and particularly the  $\delta^{18}\text{O}$  values indicate formation under the influence of meteoric water. If we consider that soil carbonate  $\delta^{13}\text{C}$  values higher than  $-8\text{‰}$  are indicative of the presence of  $\text{C}_4$  plants, then the obtained  $\delta^{13}\text{C}$  curve can be divided into a lower and an upper section, the boundary between both of them suggestively coinciding with the Plio-Pleistocene boundary (Fig. 1). Most of the average  $\delta^{13}\text{C}$  values of the lower section are lower than the  $-8.00\text{‰}$   $\delta^{13}\text{C}$  threshold, ( $-9.72$ ,  $-9.67$  and  $-8.32\text{‰}$  PDB), which could be related to a plant community dominated by  $\text{C}_3$  vegetation. In contrast, the average  $\delta^{13}\text{C}$  values of the upper section are higher than the  $-8.00\text{‰}$   $\delta^{13}\text{C}$  threshold ( $-6.80$ ,  $-6.65$ ,  $-7.20$ ,  $-6.02$ ,  $-6.86$ ,  $-7.87\text{‰}$  PDB), which could be related to a plant community dominated by  $\text{C}_4$  vegetation.

$\delta^{18}\text{O}$  values can be related to climate, especially to mean annual temperature. For the studied palaeosols,  $\delta^{18}\text{O}$  values show little variation (Fig. 1), except for a negative excursion during the late Pliocene, interpreted as a cold event. Although MAT and MAP values for the middle and late Pleistocene are still being analysed, the values for the late Pliocene and lower Pleistocene show a cooling and drying trend, and the abundance of Calcisols suggest the continuance of this trend up to the late Pleistocene. When comparing the  $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ , MAT and MAP curves, positive and negative excursions of all 4 values coincide among them (Fig. 1) and also with well-known climatic events in the region: till deposits in Patagonia of  $\sim 3,5$  Ma and  $\sim 1,8$  Ma and the Middle Pliocene Climatic Optimum between 3,3 - 3 Ma.

In summary, for the Pampean Region, climatic conditions changed since the Pliocene from warm and humid to more cold, dry and seasonal. This change is reflected in the transition from Pliocene Argillisols to Pleistocene Calcisols and in the plant community, which changed from  $\text{C}_3$ -dominated to  $\text{C}_4$ -dominated, in accordance to worldwide records.

Figure 1. Schematic sedimentological profile of the studied units.  $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ , MAT and MAP curves and their suggested correlation with regional climatic events.

P-4525

## Palynological implication for paleoenvironments of the Eastern South Korea Plateau (ESKP), East Sea during the Plio-Pleistocene climate transition

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A terrestrial and marine palynomorph analysis from the IODP Exp. 346 Site U1430 was carried out to reconstruct the paleoenvironments during the late Pliocene to early Pleistocene climate transition period. East Sea is controlled by climatic and oceanographic conditions, especially East Asian monsoon (EAM) and Tsushima Warm Current (TWC), respectively. Site U1430 provides a good opportunity to monitor paleoclimate and oceanographic changes caused by intensity of EAM and TWC. According to results of the palynofloral analysis, two pollen and dinocyst zones are established with a boundary at ca. 3.0 Ma. Prior to ca. 3.0 Ma (P-I, D-I), long-term oscillation of the East-Asian winter monsoon (EAWM) is suggested by fluctuations in the abundance of pollen taxa, representing cold-dry and cool-wet climates. After ca. 3.0 Ma (P-II, D-II), an increase in cold-dry conifer pollen indicates an enhanced and stable EAWM. In addition, the xerophytic herb, *Artemisia* dramatically increases markedly in P-II, suggesting open grassland on the exposed South Yellow Sea shelf during the sea level lowstand in cold-dry climate conditions. *Artemisia* pollen are interpreted to have been delivered to the coast through paleo-channels in this grassland environment, and subsequently transported to the East Sea inflow of a weak Tsushima Warm Current (TWC) through the narrow Korea Strait. The TWC intrusion signal is represented by an influx of *Tuberculodinium vancampoeae*, a warm-water dinoflagellate species, in the western Pacific region. The High abundances of cold-dry conifer pollen and cold-water dinocyst elements after ca. 2.8 Ma suggest an intensified EAWM. Meanwhile, a short-term increase in moisture-loving *Tsuga* pollen after ca. 2.5 Ma was likely due to soil moisture derived from snowfall caused by evaporation of heated seawater from the weak TWC in the East Sea under cold climate conditions.

P-4526

## Evidence of the middle Pliocene climate changes on the southeastern Tibetan Plateau caused by the development of Northern Hemisphere glaciation

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Late Miocene to Pliocene was a period that the global environmental pattern has been greatly changed, including the development and spread of C<sub>4</sub> grasses, the aridification of the interiors of continents and the development and evolution of the Asian monsoon climate. Intensive studies have been carried out to reconstruct the history of the Asian Monsoon system. However, the evolution of the Asian Monsoon system, especially, the South Asian monsoon, on geological time has been highly debated. The records of the South Asian monsoon evolution during the late Miocene to Pliocene are mainly from marine sediments of Arabian Sea and fluvial sediments of Siwalik Group in the South part of Himalaya, which resulted in that the South Asian monsoon intensity variation characteristics and driving factors remain controversial.

To obtain a better understanding of the South Asian monsoon evolution history during the late Miocene to Pliocene, we present sedimentary, mineralogy, geochemical and palynological proxies from a late Miocene-Pleistocene sedimentary sequence (~6.0-1.0 Ma) from the Dasongping section in Dali Basin on the southeast margin of the Tibetan Plateau. Multiple proxies indicate changes of sedimentary facies from swamp/shore lake facies to fluvial and alluvial facies with a clear two-stage climate change. During ~6.0-3.3 Ma (Unit I), the enrichment of quartz, illite, kaolinite content, stronger degree of chemical weathering and warm mixed forest (WAMF) or temperate deciduous forest (TEDE) suggest relatively warm and humid climate conditions. During ~3.3-1.0 Ma (Unit II), the increase of smectite, vermiculite, calcite and dolomite content, weaker degree of chemical weathering than Unit I, and cool mixed forest (COMX) or cool coniferous forest (COCO) suggest relatively cool and dry climate conditions. Comprehensive comparisons among records from marine and continental records demonstrate that the ongoing global cooling with the development of Northern Hemisphere glaciation (NHG) have played a dominant role in the climate changes from warm and humid to cool and dry conditions in Dali Basin since the mid-Pliocene, as well as the progressive aridification during the late Pliocene in East and interior Asia.

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P-4527

## Sedimentological and palynological assessment of three wells in eastern Dahomey Basin, southwestern Nigeria. West Africa

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Integrated studies have been carried out on one hundred and eleven (111) ditch samples retrieved from Lagos coastal area of Nigeria. The study aim at determining the provenance, heavy mineral assemblages, establishing the lowstand-highstand Quaternary episodes, deducing the palaeoenvironment and age estimation of the sediments. The lithofacies constitute sandstones and siltstones with thin beds of lignite. The sandstone range from medium to fine grained with the lignite consisting of plant fragment remains. The petrographic results show abundant detrital minerals with average modal composition of quartz (90%), feldspar (2%) and rock fragments (4%). The Quartz-Feldspar-Rock fragments (QFR) ternary plots revealed that the sands are super-matured quartz arenites derived from the continental block under humid climatic setting which have experienced medium transportation history and have been subjected to mechanical and chemical weathering. Heavy mineral assemblages suggest matured sediments. The Zircon-Tourmaline-Rutile (ZTR) index indicates the super maturity of the sediments. The Apatite: Tourmaline (ATi) ratio showed variations within the wells indicating differences in the rate of weathering and period of residence on the flood plain despite similar provenance and fluctuation in ratios suggesting sea level changes. Fifty two (52) species of palynomorphs recovered include *Rhizophora* sp., *Avicennia africana*, *Acrostichum auruem*, *Laevigatosporites* sp., *Combretaceae* sp., *Mitrogynaciliata*, *Sapotaceae* sp., *Disopyros* sp., *Elaeis guineensis* and *Alchronea* sp. The palaeoenvironment of deposition suggest graduation from mangrove to fresh water swamp due to occurrence of *Zonocostites ramonae*, *Acrostichum aureum* and *Avicennia africana*. The abundance of *Podocarpus milianjanus* and *Retitricolporites hians* and the absence of Miocene diagnostic forms suggest Pleistocene age (Tarantian 0.126Ma).

Keywords: Dahomey Basin, palynomorph, Sea level, palaeoenvironment, provenance, assemblages

**P-4528**

## **Human settlement and past environmental change on the Comoros, far western Indian Ocean**

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As humans have colonized new places, they often initiate dramatic environmental change, even in the distant past. On remote islands, where levels of endemism are high, species and environments are often particularly vulnerable to the effects of introduced species like humans, and the plants and animals they deliberately or accidentally bring with them. The first study of the environmental history of the Comoros, a volcanic archipelago in the far western Indian Ocean, was conducted in 2016 in order to test the hypothesis that the Comoros were stepping stones for prehistoric human migration from east Africa to Madagascar. This research will contribute to our understanding of patterns and chronologies of human colonisation, as well as the environmental impacts that humans have had. The pollen and charcoal records show dramatic changes in vegetation and fire regimes in the last 1500 years that are best explained through the influence of human settlement. Such studies of the past are extremely useful for better understanding and mitigating the effects of human-induced environmental change today.

P-4529

## Fossil antelope teeth to reconstruct Plio-Pleistocene environments in eastern and South Africa (3.5 - 0.5 Ma)

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Antelope remains are abundant in the African fossil record, and have often been used to facilitate palaeoenvironmental reconstructions. The springbok (genus *Antidorcas*) is one of the most abundant, herbivorous, mixed-feeding antelopes, in the South African Plio-Pleistocene fossil record, and is represented in the east African fossil record, where the mixed-feeding impala (genus *Aepyceros*) is also very abundant. Present-day springbok and impala are known to adapt their diets according to the prevailing vegetation conditions. Such a high dietary adaptability can provide interesting data regarding changes in paleovegetation and paleoclimate through time, not least because variations in food intake might reflect potential shifts in vegetation conditions at regional/local scales.

Fossil teeth of impalas (*Aepyceros*) and springboks (*Antidorcas*) from the Turkana Depression (Kenya and Ethiopia) and from the Cradle of Humankind (South Africa) are studied to investigate past changes of vegetal resources and climate conditions between 3.5 Ma and 0.5 Ma. Dental use-wear analysis provides the lifetime (mesowear) and end of life (microwear) dietary signals, supplemented by the early years signal from stable isotope analysis (carbon and oxygen). Further paleoenvironmental conditions, such as precipitation levels (oxygen isotopes) and possibly exogenous grit/dust particles (use-wear) are inferred from use-wear and isotope analysis.

In both regions, there is a great dietary variability among fossil impalas and springboks, reflecting various degrees of mixed-feeding, as expected when considering their modern relatives. Such dietary variability could reflect the presence of a wide range of resources, but could also be due to seasonal differences in food and other habitat resources. An underlying paleoenvironmental trend of increased aridity and open grasslands is apparent with a marked shift around c. 1.7 Ma from the analysis of *Antidorcas* species from the Cradle of Humankind. Around 1.7 Ma, *Antidorcas* dietary changes display high inter- and intraspecific variation, implying increased paleoenvironmental instability and habitat heterogeneity. These behavioural adaptations coincide with climatic changes around 1.7 Ma, such as the onset of the Walker Circulation. However, no significant differences in dietary signals through time were observed among the *Aepyceros* and *Antidorcas* specimens from the Turkana Depression.

The dietary adaptability of these antelope species can help us to understand the habitat structure and seasonality experienced by faunal communities in the Turkana Depression and the Cradle of Humankind between 3.5 Ma and 0.5 Ma, and gain greater insight into how local environments might differ in these two regions due to differential factors such as latitudinal range, as well as climatic and tectonic processes.

P-4530

## A 8.5 kyr high-resolution multi-proxy paleoclimate record from lake Voëlvlei, Southern Cape, South Africa

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South Africa is a key region for paleoclimatic studies, because it is affected by both, the Southern Hemisphere temperate Westerlies and the tropical Easterlies. However, due to the scarcity of natural archives, the climatic and environmental evolution of South Africa during the late Quaternary is highly debated. Today, Voëlvlei is an episodic lake that is situated at the junction/interplay of both climate systems near the Southern Cape coast, and thus an ideal archive to investigate past regional environmental changes. A 13 m long sediment core was retrieved from this site and analysed using a multi-proxy approach, including granulometric and elemental analyses, as well as leaf wax *n*-alkanes and their compound-specific  $\delta^{13}\text{C}$  isotopic signature. The chronology is based on 16 radiocarbon ages and reveals a basal age of 8,480  $^{+150}_{-240}$  cal BP. Elemental analyses, e.g., Ca/Mg ratios indicate marine influence between 8,480  $^{+150}_{-240}$  and 4,140  $^{+510}_{-490}$  cal BP related to sea levels higher than today. Ever since, Voëlvlei has evolved to a purely lacustrine system without marine influence due to sea level lowering. Between 8,480  $^{+150}_{-240}$  and 8,140  $^{+210}_{-240}$  cal BP enhanced terrestrial input (e.g., high Al, Fe, Si, Ti) suggest enhanced runoff in the catchment of Voëlvlei. Contemporaneously depleted leaf wax  $\delta^{13}\text{C}$  values point to overall moist conditions in the area. Afterwards, drier conditions persisted between 8,140  $^{+210}_{-240}$  and 6,900  $^{+220}_{-160}$  cal BP, which are indicated by lower terrestrial input and enriched leaf wax  $\delta^{13}\text{C}$  values. From 6,900  $^{+220}_{-160}$  to 4,140  $^{+510}_{-490}$  cal BP, highly variable climatic conditions with several marine and/or terrestrial flooding events occurred at the southern Cape coast.

From 4,140  $^{+510}_{-490}$  cal BP until today, Voëlvlei is a purely lacustrine system without marine influence. Between 4,140  $^{+510}_{-490}$  and 2,580  $^{+360}_{-450}$  cal BP enriched leaf wax  $\delta^{13}\text{C}$  values indicate dry climatic conditions at the southern Cape coast. The aridity led to an opening of the landscape becoming highly vulnerable to soil erosion, which resulted in increased input of terrestrial sediments into the lake (elevated Al, Fe, Si, Ti). Since 2,580  $^{+360}_{-450}$  cal BP, depleted leaf wax  $\delta^{13}\text{C}$  values point to moister conditions at the southern Cape coast leading to a more stable vegetation cover resulting in lower sedimentation rates and reduced input of terrestrial input. Granulometric parameter indicate two large fluvial flooding events (at 700  $^{+440}_{-480}$  and 10  $^{+50}_{-60}$  cal BP), which deposited large amounts of sediment (~15 cm and ~30 cm).

These findings contribute to a more detailed understanding of paleoenvironmental and –climatic conditions at the southern Cape coast of South Africa. Future leaf wax  $\delta^2\text{H}$  analyses will give insights to past changes of moisture sources and atmospheric circulation.

**P-4531**

## **Quaternary Sea Level record in Maio Island (Cape Verde): Preliminary results**

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Quaternary geology of Maio Island (Cape Verde) has revealed a quite complete sequence of marine terraces that allows us to reconstruct the history of sea level changes in this island. Geomorphological, isotopic and sedimentological analyses have been carried out supported by paleomagnetic analyses and Th/U - 14C dating.

The whole sequence is composed of at least 18 marine terraces, developed from +80m to 0m in a staircase or offlap disposition.

Palaeomagnetic measurements have been carried out in order to identify the Early to Middle Pleistocene transition in a sequence located between +80-85 and +32 m asl.

Within the Middle Pleistocene the most widely developed terrace around the island is located at around +6m asl attributed to MIS 11, and a younger terrace located at +4-5m, has yielded ages correlatable to MIS9.

MIS5 on its turn is located at low tide sea level or up to few decimeters asl and bsl. This low altitude of sea level for MIS5 is however compatible to the GIA models of Creveling et al. (2017) for low latitude settings.

MIS1 coastal units are widely represented by beachrocks around almost the whole the island, and spit barrier – lagoon systems in the southwestern part of the island, evidencing a higher input of longshore drift in this part.

Macropalaeontological content has been also analyzed as well as the isotopic oxygen signal from calcite shells of *Ostrea*, showing a close relationship between lighter signal and higher biodiversity in those marine terraces related to warmer climate.

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P-4532

## The Palaeoecology of the springbok (*Antidorcas*)

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The rich biodiversity of Plio-Pleistocene South Africa offers a wealth of information on the palaeoenvironmental status and changes therein of the landscape and of smaller scale habitats. The majority of research may select a select group within a given assemblage to inform on aspects of the climate, environment or other landscape dynamics. This research takes an in-depth focus on one of the most abundant fossil taxa in Plio-Pleistocene African faunal assemblages: The springbok (genus *Antidorcas*). This approach hopes to eradicate the generalised picture that can be gained from averaging diverse faunal communities and offer the finer scale detail that can be obtained regarding aspects such as likely habitat presence and subtle environmental changes that may be intangible from larger scale studies.

A multi-method approach was used to establish the palaeoecology of this abundant, believed mixed-feeding bovid. Multiple complementary methods establish the dietary breadth and complexity of the genus and of each of the fossil (and extant) species. The method used to identify dental remains taxonomically is presented. Dental measurements were taken to support taxonomic identification of specimens. Further linear measurements were used to establish evolutionary advances within the genus through the Plio-Pleistocene. Dental use-wear (mesowear and dental microwear texture analysis (DMTA)) was conducted to establish the lifetime (mesowear) and last few days-weeks diet of the individuals and species. This information was combined with stable isotope (carbon and oxygen) analysis to establish the early years dietary signal and hydrological (oxygen isotopes) aspects of habitat and dietary preference.

This research established that the extant *Antidorcas marsupialis* is a seasonal, mixed-feeding species, with individuals falling anywhere along the broad dietary spectrum from grazing to browsing. The ancestral *Antidorcas recki* was a predominantly browsing species but interestingly also showed some individuals to have practiced obligate grazing. Fossil species *Antidorcas bondi*, the believed grazing springbok, appears to have practiced seasonal mixed-feeding, with the species displaying only browsing inclinations via DMTA evidence from the early Pleistocene onwards.

This research found little support for the presence of a potential fourth species at the Cradle of Humankind sites, from the assemblages used (primarily, Sterkfontein, Swartkrans and Kromdraai).

Here, the ecology of each of the fossil *Antidorcas* species and of the extant species (and sub-species) is presented, as established via dental evidence from modern and palaeontological South African specimens. *Antidorcas* is found in many important African hominin deposits throughout the Pliocene, Pleistocene and into the Holocene. The detail gained here can help to establish robust palaeoenvironmental indicators for shared landscapes.

P-4533

## Radiocarbon dated oak tree-ring sequence from a submerged 6,000-year-old archaeological site in the Northern Adriatic

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In this paper, authors will try to use a new oak tree-ring sequence set in time with radiocarbon dates, from a submerged archaeological site in Zambratija Bay, Croatia, as dendroarchaeological evidence for links between environmental and cultural changes that were happening around the Alpine Adriatic during the 6<sup>th</sup> and 5<sup>th</sup> millennium BP. Underwater archaeological investigations revealed that the Zambratija site is a pile-dwelling, originally placed over a freshwater environment, and positioned today three metres under the Adriatic Sea. A combination of archaeological evidence and one preliminary radiocarbon date range between 4,230–3,980 calBC implied that human activity occurred there sometime between the Late Neolithic and the Early Bronze Age. The settlement was built on the outer edges of a karstic sinkhole filled with muddy lake and peat sediments, with preserved wooden piles protruding from the seabed, indicating a connection to the then contemporary building tradition around the Alpine glacier lakes. The 20<sup>th</sup> century discovery of dendrochronological analysis and its accuracy revolutionised not only the research of paleoclimate, but also the absolute chronology of Central European prehistory. As a result, the occupation of pile-dwellings of the Northern Alpine range can be followed back to the Neolithic on a calendrical time scale. Long tree-ring databases in combination with archaeological research can answer further questions, determining the relationships between past environmental changes and the human adaptations to climate events. In 2017, as a part of an archaeological PhD research, a series of interdisciplinary fieldwork activities were performed in Zambratija resulting in 7 seabed sediment cores and 20 waterlogged wood samples, with the aim to test the submerged Late Neolithic/Early Bronze Age pile-dwelling hypothesis. The wooden samples were then analysed in the dendrochronological laboratory at Aix-Marseille University, with results revealing a 62-year-old oak (*Quercus* sp.) tree-ring sequence. Several samples present irregular growth rhythms, with sets of narrow rings. Two wood samples, one from the beginning of the dendrochronological sequence and the other from the end, were then sent for AMS radiocarbon dating. This made it possible to set the sequence in time, where the new dates aligned with the preliminary one. The differences in the chronologies of pile-dwellings in the Northern as opposed to the Southern Alps are due to specific environmental variables in the tree-ring data. This is why the Northern Alpine sequence is continuous, while the Southern one is still developing. With the submerged settlement being positioned on the southern edges of the Alpine Adriatic, the new radiocarbon dated oak tree-ring sequence from Zambratija represents a valuable addition to the growing Southern Alpine dendrochronological database, as well as to the discussion on the intense social networks and material culture exchange of the Central European Middle Holocene.

P-4534

## Growth behavior of fir and pine in response to climate and glacial variability along the altitude in Kashmir Himalaya

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Continuous rise in the global average temperature puts concern on the future growth trend of the treeline tree species in the mountain regions. Himalayas though highly vulnerable to climate change and characterized with variety of treeline structures has remained poorly investigated in terms of treeline response to climate change. Few studies from central and western Himalaya however show complexity in the treeline response, either due to variations in the climate-species interaction or other biotic factors. To understand the impact of climate on the growth behavior of Himalayan conifers we analysed tree ring data of two subalpine conifers, *Abies spectabilis* (Silver fir) and *Pinus wallichiana* (Blue pine) growing at different elevations in the westerly dominant Kashmir region of western Himalaya. Noticeable variability has been observed amongst the lower (~2400 masl) and treeline elevation (3200 to 3500 masl) silver fir and middle elevation (~3200 masl) blue pine in response to climatic and glacier mass balance data. Growth of silver fir though show positive and negative relationships respectively with mean temperatures of winter (JFM) and summer (MJJA) months, but for lower elevation fir, strong negative relation is observed from May to August, compared to July and August for higher elevation fir. For precipitation, summer (AMJJA) months show positive relationship, with lower elevation fir strongly related compared to higher elevation fir. Palmer drought severity index (PDSI), another climate factor, also show strong positive relation with growth of lower elevation fir for summer months (AMJJ). Relatively higher temperature and early melting of snow at the lower elevation could lead to early growth and hence more demand of moisture in summer months. Blue pine, growing on drier south facing slopes, show contrasting positive relationship with mean temperature of summer months (AMJJA). Also strong negative relation with PDSI of both winter and summer months could explain low moisture demand and warm winter and summer months for the growth of pine at the region. With the glacier mass balance data, both fir and pine show negative correlation. More prominent relationship is recorded for higher elevation fir ( $r=-0.54$ ) compared to lower elevation fir trees ( $r=-0.33$ ). Katabatic winds blowing through glaciers significantly regulate the growth of trees at treeline, thus providing sensitive tree-ring sequences comparable to the changing glacial mass balance. Pine is moderately correlated ( $r=-0.394$ ) here. Fir growing at treeline are reported more sensitive compared to pine in responding the climatic changes and glacier dynamics at Kashmir region. Growth of silver fir shows increased trend at treeline but decline at lower elevation. Whereas, pine show increased growth during recent years. More analyses are required to understand the tree growth – climate relationship on spatial and temporal scale from Himalayas.

P-4535

## Tree-ring based seven century long snowfall reconstruction from semi-arid Lahaul-Spiti, Himachal Pradesh, India

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Over high-altitude semi-arid to arid western Himalaya snowfall variation is incredibly momentous as snowmelt is the only source of water for agrarian economy and its variation severely affects the socioeconomic activities related to hydroelectric projects and tourism. The vegetation in Lahaul-Spiti, Himachal Pradesh is mainly isolated and bushy, but forest of Himalayan cedar is found in pure scattered patches occasionally associated with other conifer species. The tree-ring data of Himalayan cedar generated from network of twelve well replicated moisture-stressed sites, where winter precipitation is the main source for tree-growth. Ring-width chronologies of Himalayan cedar from Lahaul-Spiti, Himachal Pradesh were used to reconstruct snowfall records back to AD 1290 and extend earlier reconstruction around two centuries. The snowfall reconstruction showed annual to decadal scale variations. The reconstruction revealed severe droughts in 18<sup>th</sup> century and comparable with the low river discharge in the Indus and Satluj, flowing in the winter monsoon dominated areas of the western Himalaya. The reconstructed snowfall showed significant correlation with the precipitation and gridded PDSI data available for the region. The reconstruction is also comparable with winter river flow of Chenab, flowing from semi-arid regions of Lahaul-Spiti. The findings endorse that extended snowfall reconstruction developed from well replicated tree-rings should provide a baseline data for socioeconomic activities in Lahaul-Spiti, Himachal Pradesh in long-term perspective.

**P-4536**

## **Tree-ring based drought reconstruction for the western Qilian Mountains of China over the past 1775 years**

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Moisture conditions, especially decadal droughts, have profound impacts on society, especially in arid and semi-arid areas. However, the lack of a high-resolution climatic proxy series for the past two thousand years greatly limits our understanding of the variations of droughts and their impacts. Here, we present an 1882 year (181–2015 CE) tree ring width chronology based on Qilian Juniper trees (*Juniperus przewalskii* Kom.) from the western Qilian Mountains, China. The tree-ring index significantly correlated with the May-June self-calibrating Palmer Drought Severity Index (scPDSI) and thus was employed to reconstruct moisture variations in May-June since 241 CE. The reconstruction demonstrated obvious decadal variations of moisture over the past two millennia. The wet periods were 241-259, 286-311, 527-540, 634-640, 797-801, 842-851, 890-895, 966-999, 1091-1094, 1187-1192, 1204-1214, 1233-1244, 1357-1393, 1570-1584, 1612-1622, 1735-1743, 1767-1785, 1801-1813, and 1862-1871 CE; the dry periods were 364-379, 457-497, 508-511, 693-714, 739-764, 902-909, 1007-1011, 1110-1114, 1124-1132, 1146-1155, 1256-1264, 1271-1275, 1455-1465, 1468-1472, 1476-1512, 1670-1681, 1685-1698, 1706-1724, 1823-1829, 1925-1932, and 1952-1971 CE. The driest and wettest periods are the late 5th century and the 3rd century, respectively, while the drought duration in the 17th century is the longest. Comparing tree-ring data and other proxy data across neighbouring records, decadal droughts often have large spatial extents with compound impacts on social activities in ancient times.

**P-4537**

## **Oxygen isotopes from Ethiopian tree-rings demonstrate the seasonal migration of the ITCZ**

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Reconstructing Ethiopian hydroclimate is complex as precipitation is largely controlled by the seasonal migration of the Intertropical Convergence Zone (ITCZ) with precipitation originating from both the Indian and Atlantic Oceans. Although there is a general scarcity of high-resolution proxy records at these lower latitudes, absolutely-dated tree ring records offer the potential to extend our understanding of hydroclimate into the pre-instrumental era. However, dendrochronology is generally acknowledged as a challenge as aseasonal climate causes the formation of indistinct tree-rings. The adoption of a re-iterative approach supported by radiocarbon dating confirms that *Juniperus procera* growing in the Ethiopian Highlands forms annual rings that can be used as an indirect measure of past climate. The determination of oxygen isotopes from these samples has also enabled inferences to be made about wider atmospheric circulation patterns in the region.

**P-4538**

## **Precipitation reconstruction based on tree-ring width over the past 279 years in the northeastern Xiao Hinggan Mountains, northeast China**

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Quantitative Reconstructions can provide a necessary framework to evaluate the realism of high-resolution climate simulations, increasingly used for predictions and impact studies. Precipitation has an important effect on the forest and agriculture in the northeast China. It has a critical significance for forestry management and agriculture production to understand the long-term precipitation regime in this region. This study presents a 279-year precipitation reconstruction for the Xiao Hinggan Mountains, northeast China based on tree-ring width data from 99 tree-ring cores of *Pinus koraiensis* Sieb. et Zucc. from two sample sites. The reconstruction explained 43.9% of the variance in precipitation from the previous October to current June during the calibration period (1956-2017). On the decadal scale, we identified two prominent drought periods during AD 1739-1788 and 1867-1985 and two prominent moist periods during AD 1789-1866 and 1986-2017, and the AD 1986-2017 was a wettest period in the past 279 years. Inter-annual (2-7 year) cycle was detected in our reconstruction, which may be correlated with El Nino-Southern Oscillation.

**P-4539**

## **Links between orbital forcing and interannual rainfall variability from a South African speleothem**

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Our understanding of the interannual variability of African rainfall is limited by short instrumental records and a lack of high-resolution palaeoclimate proxy records. Here we present an annually-resolved 91,000 year Early Pleistocene record of hydroclimate from the early hominin-bearing Makapansgat Valley, South Africa. Novel confocal microscopy methods were used to image and measure annual laminae in the Buffalo Cave Flowstone and the chronology was established via annual-lamina counting, oxygen isotope tie-points and magnetostratigraphy. Changes in annual band thickness are dominated by precession over four consecutive orbital cycles with strong millennial-scale periodicity. The frequency of interannual variability (2.0-6.5 year oscillations) does not change systematically, yet its amplitude is modulated by the orbital forcing. These long-term characteristics of interannual variability are reproduced with transient climate model simulations of water balance for South Africa from the Late Pleistocene to Recent. Based on these results, we suggest that the frequency of interannual variations in tropical net rainfall is likely to be stable under anthropogenic warming, but that the size of year-to-year variations may increase. In addition to the lamina-thickness hydroclimate record, we present a carbon and oxygen isotope record at approximately 20-year sample resolution. Rapid carbon isotope transitions over intervals of approximately 50 years indicate threshold behaviour in the vegetation response to half-precession cycles in hydroclimate. Attempts to model these vegetation responses are underway.

**P-4601**

## **Improving chronological control for environmental sequences from the last glacial period**

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Recognition of palaeoclimatic instability in the Greenland ice cores has spurred researchers to identify corresponding evidence in other terrestrial records from the last glacial stage. Such evidence is critical for establishing how much environmental stress precipitated Neanderthal and Late Pleistocene megafaunal extinctions, although a need for improved chronology has been consistently highlighted. In formerly glaciated and periglaciated areas of northern Europe, palaeoenvironmental sequences are frequently discontinuous. These often yield high-resolution proxy-based quantitative palaeotemperature estimates but can be hard to date, due to difficulties in removing contamination from biological samples at the limits of the radiocarbon technique (c.30-50kya). Here we demonstrate, for the first time using samples with independent age control, that different radiocarbon pretreatments can generate different age data and that gentler, less effective treatments applied to avoid sample loss may not yield reliable age-estimates. We advocate alternative harsher pretreatment using a strong acid-base-acid protocol. This provides an acceptable balance between contamination removal and excessive sample loss and generates more accurate ages, significantly enhancing our ability to detect and understand the impacts of palaeoclimatic instability in the terrestrial record of the last glacial.

P-4602

## **Infrared-Radiofluorescence (IR-RF) Dating of loess samples with independent age control from central Alaska**

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Infrared Radiofluorescence (IR RF) dating is a method to determine the last sunlight exposure of feldspar-grains and is suitable to date back several 100 ka. Hence, the dating method is an important alternative to luminescence dating and it is especially relevant to establish chronological frameworks for Middle Pleistocene sediments. Until now, there are still several methodological issues related to IR RF, that need to be solved and only few dating laboratories apply IR RF. To obtain a higher acceptance of the method among dating specialists and Quaternary scientists further investigations are mandatory and it has to be outlined that IR-RF yields resilient chronological results. We here present first results from an ongoing research project testing IR RF on fine-grain samples with independent age control mainly taken from northern American loess-palaeosol sequences (Gold Hill and Halfway House sections, central Alaska). The age of the samples ranges from the Holocene to the Middle Pleistocene. We will present results from dose recovery tests, bleachability- and saturation experiments.

Additionally, the reliability of equivalent dose measurements and age determinations will be discussed.

P-4603

## Simultaneous analysis of radiogenic ( $^{228}\text{Th}/^{228}\text{Ra}$ ) and stable isotopes ( $\delta^{18}\text{O}$ ) to validate reliability of the $^{228}\text{Th}/^{228}\text{Ra}$ dating method in coral skeleton

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Isotopes provide significant tools in coral chronology, which play a fundamental role in coral reefs as archives to reconstruct climate change and environmental pollution. In the present study, we exhibited a novel approach of the  $^{228}\text{Th}/^{228}\text{Ra}$  dating method in coral chronology. The  $^{228}\text{Th}/^{228}\text{Ra}$  disequilibrium was widely observed in modern coral genera with distinct morphologies from the fringing reefs in the coastal ocean to the atoll reefs in the open South China Sea (SCS) using High Purity Germanium (HPGe)  $\gamma$  spectrometry in the ground laboratory and China Jinping Underground Laboratory (CJPL) with the deepest rock overburden in the world. The  $^{228}\text{Th}/^{228}\text{Ra}$  dating method was used to estimate the  $^{228}\text{Th}/^{228}\text{Ra}$  disequilibrium-derived age based on the assumption of the ingrowth of  $^{228}\text{Th}$  from  $^{228}\text{Ra}$  in coral skeleton. To validate the  $^{228}\text{Th}/^{228}\text{Ra}$  dating method, the radiogenic ( $^{228}\text{Th}/^{228}\text{Ra}$ ) and stable isotopes ( $\delta^{18}\text{O}$ ) were simultaneously measured for the calculation and comparison of the absolute age and relative age in *Porites* coral skeleton. The  $^{228}\text{Th}/^{228}\text{Ra}$  disequilibrium-derived absolute age was in agreement with the relative age based on the  $\delta^{18}\text{O}$  curve. Additionally, the uncertainty of age was demonstrated to constrain the dating limits of the  $^{228}\text{Th}/^{228}\text{Ra}$  dating method in addition to the radionuclide's half-life. Therefore, the  $^{228}\text{Th}/^{228}\text{Ra}$  dating method is proposed as a novel approach to obtain absolute age in distinct coral genera with variable morphologies at the time scale of 0-10 a and provides a supplementary to the existing coral chronological toolbox of  $^{210}\text{Pb}/^{226}\text{Ra}$ ,  $^{14}\text{C}$ ,  $^{231}\text{Pa}/^{235}\text{U}$ , and  $^{230}\text{Th}/^{238}\text{U}$  at the time scale from decades, hundreds to thousands of years.

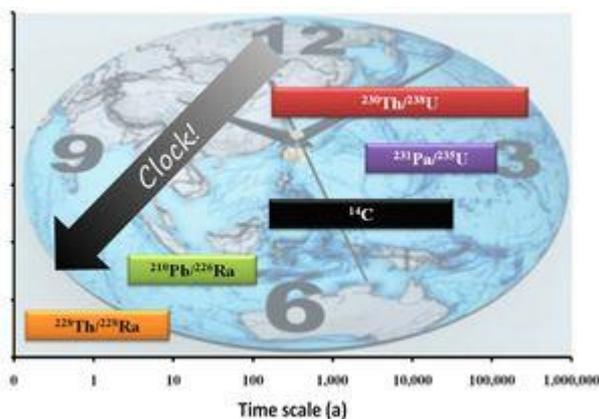


Fig. 1. Typical time scales of several dating methods based on the radionuclide pairs including  $^{228}\text{Th}/^{228}\text{Ra}$ ,  $^{210}\text{Pb}/^{226}\text{Ra}$ ,  $^{14}\text{C}$ ,  $^{230}\text{Th}/^{238}\text{U}$ , and  $^{231}\text{Pa}/^{235}\text{U}$  in coral chronology. The length of color rectangles represents the time scales of specific dating methods, which depends on the half-life of the radionuclide as well as the performance of instruments.

P-4604

## Isochron-informed Bayesian age modelling for tephtras and cryptotephtras, and application to mid-Holocene Tūhua tephra, New Zealand

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Tūhua tephra is a distinctive peralkaline rhyolitic eruptive derived from Mayor Island (Tūhua) in the Bay of Plenty ~30 km east of North Island. The tephra, containing common aegirine and compositionally distinctive glass ( $\text{SiO}_2$  ~73 wt%,  $\text{Al}_2\text{O}_3$  ~10 wt%,  $\text{Na}_2\text{O}$  ~6 wt%,  $\text{K}_2\text{O}$  ~4 wt%,  $\text{FeO}_t$  ~6 wt%), forms a unique chronostratigraphic marker bed for the Holocene of North Island and adjacent marine deposits. Its deposition coincided with the Holocene relative sea-level high-stand ~8100–7200 cal BP when present sea-level was first attained. Deriving an accurate age for Tūhua tephra is a priority for palaeoenvironmental applications as well as volcanology and palaeopedology. Ten dates were obtained previously for the tephra, only one from Mayor Island itself on ‘charcoal logs’ in the base of the pyroclastic flow associated with the Tūhua eruption ( $7172 \pm 393$  cal BP) (95.4% probability-range, PR). Bayesian age-modelling of the Kaipō bog sequence in eastern North Island using Bacon ( $6577 \pm 547$  cal BP) and OxCal (*P<sub>sequence</sub>*,  $6947 \pm 150$  cal BP; *Tau<sub>boundary</sub>*,  $7027 \pm 170$  cal BP,  $n=10$ ) (all 95.4%-PR) generated contradictory, imprecise ages on Tūhua from ~6600–7100 cal BP. Hence we use a new approach to dating Tūhua by applying explicitly a key principle of tephrochronology to Bayesian age modelling: tephtras are erupted and deposited effectively instantaneously forming isochrons so that a primary tephtra or cryptotephtra is identical in age everywhere it occurs. We modelled 54 <sup>14</sup>C-dates, together with ages on nine interbedded tephtras or cryptotephtras in three peat cores from each of Kopouatai and Moanatuatua bogs in the Waikato region, North Island, to attain a new age for Tūhua tephtra, which occurs in all six cores. In applying the Bayesian *P<sub>sequence</sub>* routine of OxCal, Tūhua tephtra was ‘cross-referenced’ (i.e., set as the same event) in each of the cores, and thus the modelling was ‘isochron informed’. Using SHCal13, the isochron-informed modelling yielded a new age for Tūhua tephtra of  $7637 \pm 100$  cal BP (95.4%-PR), older and more precise than previous estimates. A similar age (~7630 cal BP) was obtained using *P<sub>sequence</sub>* modelling whereby independent ages on Tūhua were estimated for each core without cross-referencing and then amalgamated using *Combine*. Finally, using independently-modelled age distributions, we defined Tūhua deposition as a ‘Phase’ set between start and end ‘Boundaries’, and then used OxCal’s *Difference* function to estimate the ‘Phase’ duration across cores (it should be zero years based on tephrochronology): it ranged from 0–730 years (95.4% confidence interval), mean 277 years but, reassuringly, was markedly skewed towards zero (i.e., instantaneous). This isochron-informed Bayesian age modelling approach could be readily applied in settings where one or more tephtra or cryptotephtra deposits occur in common with sequences of dates in peats or lake sediments in the same cores.

P-4605

## OSL dating of the Late Pleistocene marine deposits in the Bengal Fan

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It is of significance to understand the marine sedimentation and the source-to-sink process in the entire terrestrial-marine sedimentary system under the various climate conditions. Approximately 80% of the material eroded from the Himalaya was deposited in the Bay of Bengal, which therefore hosts the most complete record. These sediments thus allow us to investigate the erosion of Himalaya and to reconstruct the accumulation history in the Bengal Fan to trace the paleomonsoon changes. Reliable chronology is required prior to the paleoenvironmental studies for different timescales.

The objective of this study is two-fold; first, we assess the applicability of the OSL dating for the marine deposits in the Bengal Fan. Secondly, we aim to reconstructing the sediments erosion, transportation and the accumulation processes in the Bengal Fan since the Late Pleistocene based on a reliable OSL chronology. The quartz OSL and polymineral post-infrared (IR) IRSL (pIRIR) dating approaches have been used to investigate the luminescence characteristics of the applied signals and to constrain the timing of the marine deposition in the Bengal Fan using thirteen fine-grained (FG; 4-11mm) samples collected from the cores U1454C and U1455D, which were obtained during the International Ocean Discovery Program (IODP) Expedition 354. Prior to the quartz OSL dating, dose recovery test and preheat plateau measurement were firstly conducted to determine the appropriate preheat temperature. The quartz OSL dating was then carried out using the single-aliquot regenerative dose (SAR) protocol. The FG polymineral fraction was measured using the pIRIR protocols with different thermal treatments. The degree of luminescence signal bleaching was assessed by comparing the ages determined by the quartz OSL and polymineral pIRIR dating. The reliability of the luminescence ages was then evaluated by age comparison with the AMS<sup>14</sup>C ages in core U1454B after stratigraphic correlation using magnetic susceptibility and sediment reflectance spectrum.

P-4606

## How can we date loess older than MIS 3?

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Loess palaeosol sequences (LPS) are important terrestrial archives for environmental changes. Thus, they require accurate chronologies of their formation to take full advantage of the palaeoclimatic information contained and to facilitate interregional and land-sea correlations. During the past decades, optically stimulated luminescence (OSL) dating has evolved as the method of choice for establishing direct chronologies of loess deposition. However, despite reliable ages for loess <50–60 ka, age underestimation has been reported beyond that threshold using the quartz OSL single-aliquot regeneration (SAR) protocol. Recently, it has been claimed that the post-infrared infrared stimulated luminescence (pIRIR) signal from potassium-rich feldspar at elevated measurement temperature (e.g., 290 °C, pIRIR<sub>290</sub>) has sufficient long-term stability to accurately date loess up to MIS 6 or even older. Furthermore, infrared radiofluorescence (IR-RF) of potassium-rich feldspar was also suggested to be devoid of signal loss over time with saturation doses corresponding to an upper dating limit of ~200–400 ka in loess environments. Given the crucial importance of reliable dating tools for Upper and Middle Pleistocene loess records, the question arises as to which of these luminescence methods actually are capable of providing accurate ages for loess >60 ka. In an attempt to obtain age information for a palaeosol supposed to have formed during MIS 5 (based on stratigraphic and pedological considerations) and bracketing loess deposits at three locations in the lower Danube area (Dobrogea, Romania), we compare different dating efforts using a range of measurement protocols. In total, 15 samples from LPS at Vama Veche, Mircea Voda and Urluia were analysed with four different protocols (quartz: OSL-SAR; polyminerals: pIRIR<sub>290</sub> multiple-aliquot, pIRIR<sub>290</sub>-SAR, IR-RF-SAR).

OSL-SAR ages obtained for silt-sized quartz samples taken from the supposed MIS 5 palaeosol range from 49 to 240 ka and are stratigraphically not always consistent. While the older ages seem to be overestimated, samples from below the palaeosol from Mircea Voda and Vama Veche yield much younger ages than expected (~85 ka). Giving additive laboratory doses on top of the natural dose of polymineral samples does not result in higher pIRIR<sub>290</sub> signals, so that no meaningful multiple-aliquot additive-dose ages could be calculated. Likewise, the level of the natural pIRIR<sub>290</sub> signal cannot be reached by multiple-aliquot laboratory regeneration. The more surprising is that the pIRIR<sub>290</sub>-SAR protocol results in finite ages that largely comply with stratigraphic expectations at Mircea Voda and Vama Veche but which are highly scattered and possibly overestimated at Urluia. IR-RF tests on some polymineral silt-sized samples are not entirely conclusive.

We discuss our findings from a methodological viewpoint, and given the difficulties inherent to each of the applied methods, it still appears challenging to routinely date loess older than MIS 3 at our study sites with luminescence methods.

P-4607

## Orbital tuning of palaeoclimate chronologies based on the transformation of heat flux to temperature

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Today there are a lot of methods for reconstructing past climate changes. Palaeoclimate is evaluated by the analysis of proxies such as tree rings, ice cores, deep-sea cores, pollen data and the others, as well as the direct sources of palaeoclimate information (long-term meteorological records and borehole temperature data). Therein whatever the method of palaeoclimate inversion the improving of timing accuracy of reconstructed palaeoclimate records is of crucial importance.

An accurate time scale is the basis for the correct interpretation of palaeoclimate records. All the existed dating methods have advantages and drawbacks. Orbital tuning is one of the most widely used method for correction of palaeoclimate chronologies (Bender, 2002; Martinson et al., 1987; Shackleton, 2000; Dreyfus et al., 2007). The principle of orbital tuning method is to adjust the time scale of palaeoclimate record to the chronology of insolation changes caused by the variations of Earth's orbital parameters. The main shortcoming of the orbital tuning is the hypothesis of a constant phasing between the external radiation and induced temperature reaction (Peixóto, Oort, 1984; Parrenin et al., 2007; Douglass, Knox, 2012). When comparing the insolation variations with reconstructed palaeotemperature records the existence of time lag between radiation forcing and induced temperature reaction must be taken into account. Current modifications of orbital tuning implement different ways to account for this time lag, however these approaches are predominantly not universal. Corrections are commonly applied only to a given frequencies of a signal or are completely ignored.

We proposed a new approach to orbital tuning based on the synchronization of palaeotemperature chronologies with the quasi-temperature curves obtained using the data on insolation changes. These quasi-temperature curves are calculated based on a simple physical model describing the relationship between the incoming radiation and subsequent ground surface temperature change. Such quasi-temperature curves are represented past temperature variations except for constant factor determined by the climate sensitivity value. The orbital quasi-temperature curves are calculated for a number of latitudes, covering the entire globe, for a period of the last million years. The use of calibration quasi-temperature curves will eliminate the problem of the determining of delay in temperature response to external radiative forcing changes. It will make the procedure of timing of palaeoclimate reconstructions more valid and formalized versus traditional dating methods.

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P-4608

## Chronology of Paleolithic sites in the north Hunan Province of China based on luminescence dating

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Recently, several Paleolithic sites have been found and excavated in the north Hunan Province, China, where lots of stone artifacts have been discovered, indicating occupation on the region by hominins. To evaluate the potential archaeological significance of the artifacts from the sites, their accurate ages and the regional chronology of the sites are essential. These sites are located on fluvial terraces, and the archaeological deposits are characterized by the fact that they have been strongly chemically weathered due to temperate climate, resulting in the removal of dateable materials such as organics for radiocarbon dating. It appears that optically stimulated luminescence (OSL) dating method is the only one that can be used for dating these sites since this method utilizes quartz grains as natural dosimeter. This is because quartz grains are resistant to chemical weathering and are almost ubiquitous. In this study, the sediment samples from the Paleolithic sites of Shiligang, Wuyashan and Tiaotougang were investigated and optically dated. The grain-size analyses show that the deposits are mainly composed of fine silt, and the results of X-ray diffraction analysis indicate that feldspar grains almost disappeared due to chemical weathering. Various luminescence techniques were employed on fine-grained quartz and polyminerals. The preliminary results show that the quartz samples have excellent luminescence properties such as fast component and high sensitivity for the single-aliquot regeneration dose (SAR) method. The SAR-OSL  $D_e$  values obtained vary from about  $90.5 \pm 2.2$  to  $694 \pm 54$  Gy, and the dose rate from  $3.44 \pm 0.31$  to  $4.06 \pm 0.36$  Gy/ka. Correspondingly, the quartz OSL ages obtained range from about  $23.8 \pm 2.0$  to  $202 \pm 24.2$  ka. The dose-response curves and large  $D_e$  values obtained indicates that quartz SAR-OSL signals from samples are close to saturation. It is noted that  $D_e$  values in the high dose range of OSL quartz is generally problematic, resulting in underestimation of the true burial ages. In this case, pIRIR and TT-OSL methods and other tests will be carried out on fine quartz and polyminerals to evaluate the reliability of the quartz SAR-OSL ages obtained for these sites, and to attempt to establish the chronology of the sites in this region.

P-4609

## OSL dating in agrarian settings: dealing with post-deposition mixing of sediments

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Humans triggered or accelerated erosion and deposition processes since prehistoric times through agricultural practices. Optically Stimulated Luminescence (OSL) dating is often used to quantify the phases and rates of these deposition processes, by measuring the last moment grains were exposed to daylight. However, natural and anthropogenic mixing processes, such as bioturbation and tillage, complicate the use of OSL as grains of different ages become mixed, and grains may be exposed to daylight even long after the depositional event of interest. The youngest ages carried by the grains thus represent the stabilization age, indicating when sediments were buried below the active mixing zone, rather than the deposition age.

We present a novel methodology to include tillage effects in OSL dating of colluvial sediments. We took 32 samples from five locations in the colluvial infilling of an agrarian kettle hole in northeastern Germany. We used a Minimum Age Model to select the grains that represent the stabilization ages of the samples. The uncertainty of the stabilization ages was constrained using a Bayesian approach which utilized the stratigraphic order of the samples. These stabilization ages were combined with an archeological reconstruction of historical ploughing regimes to correct for the post-depositional mixing by reconstructing the former soil surface as a function of time of deposition.

Consideration of post-bleaching by tillage is required for correct interpretation of sediment dynamics in colluvial settings. It prevents underestimation of deposition rates during times when a shift in land use occurred, and prevents overestimation of deposition rates near the soil surface. The larger uncertainty in age that originates from the heterogeneous sediments was effectively constrained by the use of Bayesian techniques. Our results show the need for numerical dating techniques that take archeological and soil-geomorphological information into account to correctly interpret landscape dynamics in anthropogenically influenced hilly landscapes.

**P-4610**

## **OSL surface exposure dating of wave-emplaced tsunami and/or storm boulders from Morocco**

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Fields of wave-emplaced blocks and boulders represent impressive evidence of cyclone and tsunami flooding over Holocene time scales. Unfortunately, their use for coastal hazard assessment is in many cases impeded by the absence of appropriate dating approaches, which are needed to generate robust chronologies. The commonly applied AMS-<sup>14</sup>C, U/Th or ESR dating of coral-reef rocks and marine organisms attached to the clasts depends on a – mostly hypothetical – coincidence between the organisms' death and boulder displacement, and inferred event chronologies may be biased by the marine <sup>14</sup>C-reservoir effect and reworked organisms. Here we discuss the potential of the recently developed optically stimulated luminescence (OSL) surface exposure dating technique to directly date the relocation process of wave-emplaced boulders.

For this, we sampled 11 coastal boulders from the Rabat coast, Morocco, which were either relocated by tsunami-induced flooding (e.g. during the 1755 Lisbon tsunami and similar events) or by exceptional North Atlantic winter storms. All sampled boulders (i) show clear indication of overturning during wave transport in the form of downward-facing bio-eroded surfaces; (ii) are composed of sandstones that contain quartz with adequate luminescence signals; (iii) are of Holocene age and, therefore, in the dating range of OSL surface exposure dating. The measured signal-depth profiles indicate time-dependent resetting of luminescence signals in the freshly exposed post-transport surfaces of all investigated boulders.

Calibration samples with known exposure ages of 2 years are used to determine local values for light attenuation in the rock and signal resetting at the rock surface. These parameters are required to transform signal-depth profiles of sampled boulders into exposure ages. Results so far indicate that dating accuracy of most boulders is significantly affected by post-transport erosion of the surfaces. However, the approach nevertheless provides relative age differences for boulder dislocation, and the observed patterns agree with the relative chronology expected due to the macroscopic appearance of the boulder surfaces.

**P-4611**

## **Luminescence isochron dating of glacial sediments using cobbles**

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Application of luminescence methods to date Quaternary sediments assesses the time elapsed since the last exposure of the mineral grains to daylight. If sediment grains were not exposed to sufficient daylight at deposition to reset ('bleach') the luminescence signal then the ages may be overestimated. This type of incomplete bleaching may occur in a number of depositional environments, but glacial sediments are especially challenging because of the nature of the deposition processes.

In recent years the optically stimulated luminescence (OSL) signal from single grains of quartz has been used successfully to identify whether samples were incompletely bleached or not, and statistical models such as the minimum age model (MAM) developed to allow dating even where only a proportion of the mineral grains had their luminescence signal reset at deposition. The BRITICE-CHRONO project has demonstrated the success of this approach (e.g. Chiverrell et al., 2018). However, this approach has significant drawbacks, the most important of which is that scatter in the apparent ages of individual grains may be caused by a number of factors other than the extent to which they were exposed to daylight at deposition. This may make application of the MAM challenging.

This presentation describes the application of a novel luminescence dating method that allows an unambiguous assessment of whether a sample was exposed to daylight for sufficient period of time at deposition. Large clasts (cobbles and pebbles) are drilled and subsamples from different depths are measured. Light absorption in the clast (Ou et al. 2018) makes it possible to test for the presence of an optical-isochron i.e. where the age does not vary with depth into the clast. The existence of such an isochron is very strong evidence that the luminescence signal was sufficiently reset at deposition to yield an accurate age.

Optical-isochrons have been observed in cobbles from glacial sediments from the retreat of the last British-Irish Ice Sheet at various sites. For example, at Orrisdale on the Isle of Man, three cobbles with optical-isochrons have been dated, yielding ages of  $20.8 \pm 1.2$ ka,  $21.2 \pm 1.1$  ka and  $20.6 \pm 0.5$  ka, giving a combined age of  $20.7 \pm 0.3$  ka demonstrating the precision possible with this technique (Jenkins et al. 2018). The potential of this method, and the challenges that are faced, are discussed in this presentation.

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**P-4612**

## **Beyond the border: Infrared Radiofluorescence as a new tool for extending the age range of luminescence dating in palaeoenvironmental research**

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For palaeoenvironmental reconstruction, a wide variety of methods is applied comprising innovative techniques from different scientific disciplines such as sedimentology, micromorphology and mineralogy. However, the informative value derived from such sedimentary archives and their significance for paleoenvironmental research strongly depend on an accurate and precise dating of the investigated sediments. Numerical ages are of fundamental importance for a coherent interpretation of findings based on various investigated proxies. Thus, a reliable local or regional chronology is indispensable for the reconstruction of past environmental conditions.

Triggered by a set of technical and methodological improvements and allowing the determination of sedimentation ages by directly dating the sediments of interest, luminescence dating has become a popular tool in palaeoenvironmental and geoarchaeological research. This is particularly true for the quartz based single aliquot regenerative (SAR) dose protocol, which meanwhile has achieved the status of a well-established standard dating procedure for late Pleistocene and Holocene sediments. A major limitation of quartz-based techniques, however, is the relatively low saturation dose of quartz minerals regularly reported to be in the range of 150-200 Gy corresponding to an upper dating limit of approximately 50-150 ka.

For extending the dating range beyond the border of the last glacial-interglacial-cycle, infrared stimulated luminescence (IRSL) dating of feldspar-dominated samples in principle offers a suitable approach, using the fact that saturation doses of feldspar minerals are usually found to be an order of magnitude higher than those reported for quartz separates. However, feldspar based luminescence measurements have long been known to suffer from a phenomenon called 'anomalous fading', an athermal loss of luminescence signal over time that might result in significant age underestimations and therefore prevented feldspar based IRSL measurements from becoming a routine dating application for Quaternary sediments.

Over the last years, different approaches to cope with the problem of anomalous fading have been suggested, amongst others various fading correction methods and measurement procedures (e.g., post-IR IRSL protocols and pulsed-IRSL measurements) trying to isolate luminescence signals not affected by the fading problem. In this contribution, we would like to draw attention to an alternative approach, originally proposed as 'IR-SAR protocol' during the late 1990s and early 2000s. We will present the basic principles as well as technical and methodological innovations developed during recent time, which led to some kind of revival of the so-called Infrared Radiofluorescence (IR-RF) method. We will illustrate its potential and discuss the still manifold challenges and problems that are associated with this promising dating tool.

**P-4613**

## **Chronology of a late Neolithic site along the coast of the east China sea**

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Shell mounds are the foremost type of Neolithic sites found in coastal areas of South China. These sites can provide significant information on prehistoric human activity and climate change; however, only a few shell mounds have a systematic chronology in South China. In this study, optically stimulated luminescence (OSL) and <sup>14</sup>C dating techniques were employed to establish a systemic chronological framework for a Neolithic shell mound found at Pingfengshan in the coastal area of Fujian Province, southern China. In addition, the possible reasons for human coastal migrations that took place during this specific period, along with their associations with climate change, are discussed. The results showed that the obtained OSL ages were reliable and consistent with the <sup>14</sup>C chronology. The age of the Pingfengshan site was found to be approximately 4.0–3.3 ka. Additionally, it was found that post-depositional anthropogenic disturbances can have various influences on the resultant OSL and <sup>14</sup>C ages. Cross-validation between different dating methods proved to be of great importance to adequately determine the chronology in archaeological sites. The study revealed that climatic changes played a crucial role in prehistoric human migration during the Huangguashan cultural period (4.3–3.2 ka). Sea level fluctuation may have affected onshore living space and site selection of prehistoric settlements, and intensive winter monsoons may have caused the recession of the Huangguashan culture.

**P-4614**

## **Accelerated luminescence dating: application and assessment of the standardised growth curve approach**

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Luminescence dating is an important but time-consuming geochronological tool, especially when applied to an extensive number of samples. Samples of old age (i.e. high  $D_e$  values) or those requiring a large number of aliquots to be measured for a statistically significant age determination demand prolonged reader times. This is mainly due to irradiation times necessary to create a dose response or growth curve for each measured aliquot as suggested by the commonly applied single-aliquot regenerative dose (SAR) protocol. In order to reduce measurement duration, a protocol that uses a standardised growth curve (SGC) for all aliquots has been proposed. Recent refinement of the SGC protocol (e.g. Li et al. 2015, 2016) along with the release of two R packages (*Luminescence* and *numOSL*) are prospective for the decrease of machine time as well as for the fast analysis of produced data.

In this study, the SGC approach is applied to polymineral, quartz and feldspar samples from proglacial deposits of Northern Switzerland.  $D_e$  values are derived for datasets using the SAR and SGC protocols and compared to independent SGC datasets. Dataset size for determination of SGC parameters and grain size dependency as well as the scope of applicability are investigated.

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**P-4615**

## **Using violet stimulated luminescence (VSL) to date Quaternary sediments**

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The violet stimulated luminescence signal (VSL; stimulated at 405 nm) in quartz has been shown to grow to much higher doses than the blue optically stimulated luminescence signal (OSL; stimulated at 470 nm) normally used for dating (Ankjærgaard et al. 2016). This makes VSL an enticing prospect for dating as it has the potential to extend the age range of quartz luminescence throughout the whole Quaternary period. Different measurement protocols have been used for VSL, including the single aliquot regenerative dose (SAR) protocol (Colarossi et al. In press, Porat et al. 2017, Ankjærgaard et al. 2013) and the multiple aliquot additive dose (MAAD) protocol (Ankjærgaard et al. 2016), with mixed results.

The aim of this study is to use the VSL signal with a range of protocols to date samples from multiple sites in South Africa which possess independent age control, in the form of palaeomagnetic analyses, quartz optically stimulated luminescence (OSL) ages and K-feldspar post-infrared infrared stimulated luminescence (post-IR IRSL) ages. Preliminary results for two samples from St Paul's, KwaZulu-Natal showed the ages calculated using the VSL signal to be within uncertainty of the ages obtained using OSL and post-IR IRSL. Although these data represent preliminary measurements, they are encouraging and further investigation into the merits of the single aliquot regeneration added dose (SARA) protocol for the VSL signal is ongoing. These data will improve the understanding of VSL signal characteristics, which is imperative before the broad-scale application of VSL to dating Quaternary sediments can be achieved.

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P-4616

## The truth, the whole truth, or incremental adjustments? A reflection on 20 years of applying age-estimates to Pleistocene fluvial deposits

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When I started research on the Pleistocene geology of the Peterborough area of eastern England in 1989, ambitions of establishing a robust chronology were severely limited by the techniques then available. New techniques, however, were being developed, such as optically stimulated luminescence (OSL) and amino acid racemization (AAR), that now are able to support robust chronostratigraphical interpretation and bode well for future applications. This presentation reflects on my experience of applying age-estimate techniques to Pleistocene fluvial deposits in the Peterborough area of eastern England. Most applications of age-estimate techniques that I have been associated with relate to the complex sedimentary succession at Whittlesey: AAR established the first UK occurrence of *Theodoxus danubialis* in MIS 7 and verified the first wholly fluvial Ipswichian deposit of the River Nene catchment; OSL established aggradation in MIS 6, MIS 5e, MIS 5b/a and MIS 3; <sup>14</sup>C established aggradation in MIS 3. Plentiful age-estimate data therefore are available for the Whittlesey sedimentary succession but although they establish the chronostratigraphic complexity of the deposit, it is still not possible to provide a robust chronostratigraphy for the succession as a whole. The available data, however, do provide important constraints for River Nene terrace stratigraphy and regional palaeogeographical reconstructions. New OSL and AAR data will be presented together with discussion of the stratigraphic difficulties encountered and those that remain. New AAR age-estimate data for the equally complex Sutton Cross site, within the River Nene catchment and about 15 km upstream of Whittlesey, will also be presented. Potential application of age-estimate techniques to further improve the chronostratigraphy at both sites will be identified and presented, for example the development of OSL dating of opercula and AAR dating of Foraminifera at the Whittlesey site. In my experience provided the technique is robust and its parameters known, and the sedimentary context is well established, age-estimate data will stand the test of time, retaining their relevance as research paradigms wax and wane. As our work at Whittlesey demonstrates, it may take decades but the necessary age-estimate data can be accrued incrementally and produce robust chronostratigraphic interpretation of complex fluvial deposits that in future will constrain fluvial terrace stratigraphy and palaeogeographical reconstructions. Our goal at Whittlesey is to provide a suitably robust long terrestrial Quaternary record that can contribute to regional and global palaeoclimate and palaeosea-level modelling efforts, as well as a testing bed for future development of age-estimate and palaeotemperature reconstruction techniques.

**P-4617**

## **Solar storms as dating and correlation tool**

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Recently it has been confirmed that extreme solar proton events can lead to significantly increased atmospheric production rates of cosmogenic radionuclides. The evidence of these events can be recorded in annually resolved natural archives, such as tree rings (<sup>14</sup>C) and ice cores (<sup>10</sup>Be, <sup>36</sup>Cl).

Here we show evidence for solar storm events during the past 3000 years based on <sup>14</sup>C data from tree rings and <sup>10</sup>Be & <sup>36</sup>Cl data from ice cores. These records allow us not only to investigate and reconstruct the behaviour of the sun with its potential implications for our technological society. They also enable the very precise synchronisation of records where these solar proton events can be identified. For example, this approach has helped to rectify the differences between ice core and tree ring chronologies over the past 2500 years. We will present this method, discuss its potential and limitations and show evidence for a newly discovered solar proton event around 2610 BP.

**P-4618**

## **Through the Looking-Glass, and What Amino Acids Found There**

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Chronology underpins our understanding of the past, but beyond the limit of radiocarbon dating (~60 ka), sites become difficult to date. Amino acid geochronology uses the time-dependent breakdown of proteins in biominerals, with the racemisation reactions (conversion between mirror-images) of amino acids having the potential to date the whole of the Quaternary. Recent studies have shown that a very small fraction of 'intra-crystalline' protein within mollusc shells, opercula, coral, eggshell and enamel forms a closed system, and if this is targeted, the difficulties due to leaching, contamination and environmental factors are removed. The analysis of a coherent calcite intra-crystalline system has enabled the development of a chronology back to at least 2.8 Ma, while enamel proteins allow time resolution well into the Pliocene.

Our research is now focusing on building chronological frameworks on a wide spatial and temporal scale, from Europe to Africa, Asia and Australia. Ever expanding the range of materials we are testing, we are also gaining an unprecedented understanding into biomineralisation, and the palaeoenvironmental signal that can be contained within the fossil protein. We present here both the potential and the limitations of the technique.

P-4619

## Radiocarbon dating in lake sediments: assessing the usefulness of very small samples using the Mini Carbon Dating System (MICADAS)

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Radiocarbon dating from plant macrofossils is the most commonly used technique for dating lacustrine sedimentary records that cover Holocene and late-Pleistocene times. Assessing the uncertainty of chronologies based on radiocarbon dates is challenging, in part because researchers must consider not only the analytical uncertainty associated with the measurement of <sup>14</sup>C, but also potential offsets between the age of the dated material and the depositional age of the sediments. The Mini Carbon Dating System (MICADAS) is able to analyze samples in gas form, which allows for dating of very small sample sizes (>10 µg C) that were previously not practical with conventional graphitized samples. Smaller samples and lower costs make it possible to obtain more ages from sedimentary records with limited suitable material for dating, while reducing the time required for sample preparation and analysis. Additionally, the small sample size allows us to target specific types of material rather than mixing fragments of different material.

In this study, we compare the accuracy and precision of radiocarbon ages measured using a gas-ion source with ages measured using conventional graphitized targets. This information is used to investigate optimal strategies for constructing chronologies, in particular, the advantages and disadvantages of measuring more samples at lower precision versus fewer samples at higher precision. Terrestrial plant macrofossils were sampled from a ca. 11,000 year-long sedimentary record from Lake Żabińskie, NE Poland. Samples were measured using both graphitized targets (n=26, all >120 µg C), and the gas-ion source (n=36, 11-168 µg C). We focus on a section from approximately 2,000-6,500 cal yr BP, which contains well-preserved varves that provide an independent age verification. Within this section, we obtained 31 gas-source ages from 13 different stratigraphic levels (i.e. 2-4 individual samples per level); seven of these levels also have a graphite measurement. Gas source samples agree well with the graphitized samples from the same stratigraphic level, though smaller samples do have greater uncertainties. The average uncalibrated uncertainty of all gas-source samples is ±146 years compared to ±62 years for the graphite samples. However, the average uncertainty of gas-source samples larger than 40 µg C is only ±105 years (n=21). Age-depth models using exclusively graphitized and exclusively gas-source measurements were constructed using the software Bacon<sup>1</sup> for the period 2,000-6,500 cal yr BP. The two models differ insignificantly, suggesting neither method is uniquely biased. The average width of the 95% confidence interval of the model outputs are 311 and 357 years for the graphite- and gas-source-based models, respectively, suggesting that the larger uncertainties of the gas-source samples can be somewhat compensated for by greater sample density.

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P-4620

## **$^{10}\text{Be}$ and $^{36}\text{Cl}$ surface exposure dating of man-made excavations in northern Lebanon: Phoenician structures or not?**

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The use of terrestrial cosmogenic nuclides as geochronometers has considerably increased over the last two decades owing to major theoretical and analytical progress. Although surface exposure dating still has an unrealized potential in archaeological settings, it can be applied to anthropogenic structures such as flattened bedrock platforms or ancient quarries (Akçar et al., 2009; Rixhon, 2018). In particular, the latter may represent a favourable context for this method, provided that major issues related to (i) erosion (i.e. pristine bedrock surfaces of quarry floor/walls) and (ii) inheritance can be avoided. The second point must be critically assessed given that muon-induced reactions produce cosmogenic nuclides at greater depths (i.e. several meters below the surface).

Two archaeological sites in northern Lebanon were selected for this study: Batroun and Anfeh. Although their excavation structures are well-studied, the so-called “*Phoenician sea-wall*” related to quarrying activity in Batroun and the “*great Phoenician trench*”, i.e. a moat structure excavated in the Anfeh promontory, their age remains unknown. These structures were respectively excavated in Late Pleistocene aeolianite and Eocene limestone. Samples for  $^{10}\text{Be}$  (#5) and  $^{36}\text{Cl}$  (#4) analysis were collected accordingly. Both sites present favourable characteristics to cope with inheritance: the moat floor is located ~10 m below the original surface whereas the top of the *Phoenician sea-wall* indicates quarrying depths reaching (at least) 4-5 m. Traces of former extracting activities on the quarry floor/walls are still conspicuous at several spots; the latter were preferentially targeted for sampling. Careful field measurements allowed a reliable assessment of topographic shielding, which plays a significant role in Anfeh. Sample preparation is currently under process. Surface exposure ages should be able to discriminate between a Phoenician origin or a latter excavation (e.g. during Middle Ages), without eluding a possible stepwise, polygenetic extraction process (especially in Batroun).

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**P-4621**

## **Using Flow Cytometry to purify fossil pollen samples suitable for AMS radiocarbon dating**

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Radiocarbon dating of terrestrial plant-remains is a traditional method for age estimations of lake sediments. The absence of sufficient large plant macrofossils required for AMS dating in continental records, especially larger lakes, outlines the limitation of this dating application. Due to their ubiquitous presence in sedimentary archives, especially pollen samples are suitable for radiocarbon dating. Nevertheless, their isolation and purification without significant carbon contamination still presents a challenge. Even though commonly applied separation techniques can be used to remove the predominant portion of foreign particles, the undesired transfer of these particles into the pollen samples cannot be completely excluded, yet. Flow cytometry, a biomedical application to identify and separate molecular cells, offers the possibility to isolate huge quantities of pollen in a short period of time. This application is a highly promising alternative to remove detrital particles and generate pure pollen samples from heterogeneous limnic sediments.

In this study we present the approach to separate sufficient quantities of pollen by flow cytometry for AMS radiocarbon dating. Furthermore, we were able to generate reliable radiocarbon ages of purified pollen samples extracted from Holocene sediment samples from Lake Van (Eastern Anatolia). Nevertheless, visual inspections of the separate pollen populations reveal that an isolation without contamination of foreign particles remains difficult. Here a strong relation between the sediment composition or the sediment's organic matter, the quality of the pollen isolation, and the AMS dating becomes apparent, ameliorating with decreasing detrital content.

Our results demonstrate the importance to further evaluate and optimize the applied processing steps of the chemical pretreatment and flow cytometry. In this process the primary objective is to improve the quality of the separation process and remove large detrital particles from the sediment sample before the cytometric analysis. It is necessary to adjust the processing steps to the pollen concentration and the pollen spectra expected for each individual sample. This allows a precise distinction between pollen and non-pollen palynomorphs. Further improvements of the laboratory routine for the purification of pollen samples using flow cytometry will allow the analysis of vast amounts of samples in a short period of time. In consequence, dating of enriched pollen samples can be used as a robust contribution and independent time control of existing age estimations of lake sediments in continental records.

P-4622

## Reconstruction of the coastal development of SW Sardinia by Optically Stimulated Luminescence (OSL) dating method

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The development of aeolian deposits, such as loess and dunes, strongly depends on climate condition but also on sediment availability. Therefore, these deposits and landforms can provide valuable information about past atmospheric circulation, palaeoclimate, landscape evolution and land use and human impact. Sardinia has been considered tectonically stable, at least since the late Pliocene, and has been used as a reference for changes of mean sea level since the Last Interglacial (Coltorti et al., 2010). Within this generally stable setting, quaternary coastal deposits are very well exposed along the coast of Sardinia. Geomorphological studies and OSL-based dating are excellent tools to reconstruct the timing and formation of coastal dune fields. In this study, we provide the stratigraphy of the well-exposed quaternary deposits cropping out at Su Palloso, Porto Paglia and Capo Mannu, south western coast of Sardinia, based on the Optically Stimulated Luminescence (OSL) dating. In total 10 samples from 3 sections were studied by OSL and radiocarbon dating. The Post-IR POSL ages obtained from the Su Palloso section are in agreement with radiocarbon ages and giving evidence for dune accretion during the Holocene (3-6 ka). Apart from the uppermost ages from the Porto Paglia section, which are much younger (POSL age ~10 ka), all POSL ages of quartz are limited by saturation of the signal intensity towards high doses for the basal part, and therefore pIRIR<sub>290</sub> dating was applied, indicating sediment deposition during the late Pleistocene (~100 ka). For Capo Mannu section, both quartz and feldspar signals are in saturation. In conclusion, our OSL data do not only answer the question of the quaternary stratigraphy of the south western Sardinia coast, but improve our understanding on the formation of aeolian deposits and identify the roles of sea and climate changes in controlling the sedimentation.

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**P-4623**

## **Ice margin chronology of the North American Ice Sheet Complex: new data, new methods, new interpretations**

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The deglaciation of the North American Ice Sheet Complex (NAISC; consisting of the Laurentide, Cordilleran and Innuitian ice sheets) from its Last Glacial Maximum extent is a critical constraint for studies of sea level, glacial isostasy and Quaternary climate change. Currently, the most commonly cited work on this topic is from 15+ years ago and is based largely on the synthesis and evaluation of radiocarbon data from the glaciated region to infer the emergence of the North American landscape from under glacial cover (Dyke et al., 2003; Dyke, 2004). Over the past 15 years, improvements to geochronology and additional geological work provide the impetus to update and re-examine the NAISC deglaciation chronology. Most importantly, new dating methods (cosmogenic nuclides exposure dating and optically stimulated luminescence) allow for direct dating of the ice margin retreat instead of dating the onset of the deposition of organic material. In 2019, we are beginning a multi-year project to establish a new ice margin chronology that is independent of Dyke et al. (2003). Here, as a first step in this project, we present an updated inventory of deglaciation sites as well as an overview of key updates to the deglaciation sequence, including changes to the extent of glaciation and the timing of its retreat on Baffin and Banks islands in the Canadian Arctic, as well as in the large parts of the continental shelf. We also lay out the plans for future work, which will include a full implementation of all currently available dating methods, a new protocol for quality control of the ages included in the dataset, transparent description of the main local and regional issues and decisions taken regarding the reconstructed ice margin chronology, and the inclusion of error bounds for the individual reconstructed isochrones.

P-4624

## "Deep roots of human behaviour" - ESR dating of archaeological sites near the Victoria Falls, Zambia: first results

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Recent studies from Kenya suggest that the behavioural development of homo sapiens is closely linked to climate and landscape changes during the Middle Stone Age (MSA) around 300 ka (Potts et al., 2018). One of the behavioural aspects of human evolution during the Stone Age is the use of complex tool-making, and such artefacts can be found throughout the eastern hemisphere, especially in Africa. It is assumed that our ancestor, the homo heidelbergensis, who lived in Africa between 600 and 200 ka, was the first humans to be capable of a modern human behaviour (e.g. complex tool-making). This describes the transition from Early Stone Age (ESA) tool-making of hand axes to MSA tools like flakes or the use of hafting. However, the chronology of the homo heidelbergensis in Africa has been poorly constrained. With the further-developed ESR dating technique on sediments, a better insight in the chronology of stone tool formation is possible. ESR dating has a potential to extend the age range beyond the limits of luminescence dating techniques.

The Victoria Falls and their surroundings have been known to yield rich assembly of artefacts since the 1950s. Traces of early human life can be found along the sediments of the riverbanks of the river Zambesi. We took 19 samples from four different sites above and below the Victoria Falls. The morphology of the sites is various: Above the cataract, the wide riverbed is ascending to reddish sand scarps. Whereas below the fall, the river forms a narrow band zigzagging through steep basalt gorges, topped by reddish sand. We aim to establish a chronology of the stone tools by using ESR dating of the quartz-bearing sediments. Additionally, and for a better understanding in the Victoria Falls formation process, which is currently unknown, we also took luminescence samples for pairing the results with the ESR data as well as cosmogenic nuclide samples for an independent control.

P-4625

## Post-Isothermal IRSL as a new tool for dating sediments

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Since the beginning of the present century, optically stimulated luminescence (IRSL) of feldspar has emerged as promising techniques for dating Quaternary events and timing environmental changes. Remarkably, even though feldspar luminescence can probe 10 times deeper than radiocarbon into geological time, age shortfalls have hindered the development of feldspar as dating tool. In luminescence dating of feldspar, laboratory induced luminescence necessary to assess the naturally acquired dose in the environment suffers from a poorly understood instability over time, known as anomalous fading (AF). AF is the source of commonly observed age underestimation in optical dating of feldspar. Approaches to circumvent AF include correction methods as well as attempts to measure directly an unfading component of feldspar luminescence (eg post-IR IRSL) protocols. The former has the advantage of measuring the easily bleachable traps but requires extended extrapolations of laboratory measured fading rates. High temperature post-IRSL methods are limited by the use of difficult-to-bleach traps and hence by potential age overestimations. Herein, we propose a new dating technique for feldspar that circumvents anomalous fading but nonetheless takes advantage of the easiest-to-bleach traps.

Post-isothermal laboratory induced luminescence (plt-IR) allows probing easily bleachable traps and measuring an equivalent dose ( $D_e$ ) that is not dependent on time elapsed since irradiation. In this procedure, one measures two IRSL signals, first from an IR stimulation at low temperature (i.e.  $IR_{50}$ ) followed by a second one, at a higher temperature (i.e.  $IR_{225}$ ). Since both signals fade at different rates,  $D_e$  from  $IR_{50}$  is lower than that of  $IR_{225}$ . In plt-IR, a succession of thermal treatments is carried out before the measurement of laboratory-induced  $IR_{50}/IR_{225}$  ratio of luminescence. The dependence of  $D_e$  on thermal annealing is different for each IR signal so one can find which thermal treatment will yield the same  $D_e$  for both signals. This  $D_e$  is the true total radiation dose received by the feldspar minerals in nature following deposition for sediments, more properly known as the paleodose (P). Post-isothermal dating has been successfully applied to several samples of different ages and from various geological contexts. Post-isothermal luminescence is thus proposed as a way to circumvent AF, as extended isothermal annealing treatment is not shown to eradicate AF. The plt-IR method offers renewed hope in the quest of a truly robust and reliable dating method that could unravel the Pleistocene history of the continental landscape.

P-4626

## Testing the use of total beta counting for high-precision OSL chronologies

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Individual OSL dates tend to come with an uncertainty in the range of 5-10 %. If samples have been well-bleached before deposition, the largest sources of uncertainty come in the 'dose rate' side of the equation. The dose rate can be estimated from the concentrations of the naturally occurring radionuclides — mostly K-40 and the decay chains of U-238, U-235 and Th-232. These measurements can be performed using a number of different methods, but usually some combination of mass spectrometry, gamma spectrometry, and alpha and beta counting. However, the quality control on dose rate measurements is not yet satisfactory, and a dating inter-comparison study has found that the radionuclide measurements are by far the largest source of uncertainty in standard OSL dating [1].

Recently, a new procedure has been developed for the measurement and analysis of dose rates using total beta counting, designed to produce accurate dose rates with a random uncertainty of <2 % [2]. The procedure has very simple requirements for sample preparation and analysis, and uses equipment that is both inexpensive, and already present in many laboratories.

Here, we test the application of total beta counting on two loess sequences. The sequences have been chosen because of their high sampling resolution and absence of obvious complexities (e.g. in stratigraphy, water content, grain size, etc). Using the new beta-counting procedure leads to a substantial improvement in the precision of the dose rate data (compared to HpGe gamma spectrometry), and more convincing age-depth relationships. We further improve the precision of each chronology using a Bayesian chronological model, designed specifically for luminescence data. We find that this combination of high-precision dose rate measurements, with customised chronological models, produces luminescence chronologies with unprecedented precision.

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**P-4627**

## **Electron Spin Resonance (ESR) dating of optically quartz grains: a light at the end of the tunnel ?**

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Although the first ESR dating attempt of optically bleached quartz grains extracted from Quaternary sediment was published > 30 years ago (Yokoyama et al., 1985), the application remains relatively poorly known and not widely accepted among the community of Quaternary scientists. This situation is contrasting with Luminescence, which has become instead increasingly popular over the last decades, thanks to several major methodological developments leading to significant improvements in terms of accuracy and reliability. In that regard, ESR can probably not compete with Luminescence dating, as there are some intrinsic technical limitations (e.g., impossibility/difficulty to run automated ESR measurements or to perform single grain analyses) that currently limit any major future developments. Additionally, the reduced number of ESR dating specialists around the world working on this application is clearly another limiting factor.

That said, there are nevertheless some situations where ESR can be of special interest in Quaternary studies. It can be used to take over Luminescence when this one shows apparent limitations, or provide some useful chronological constraints when no other numerical dating method is available (e.g. Sahnouni et al., 2018; Bartz et al., 2018). In the recent years, some efforts have been dedicated among the ESR dating community to start a standardization of the method (e.g. Duval et al., 2017). Additionally, the increasing systematic use of the multiple centre approach, in combination with cross-comparisons with independent dating methods (e.g., Mendez-Quintas et al., 2018, Bartz et al., 2019; Duval et al., submitted), show that ESR can be a reliable dating tool.

The present contribution will give an updated overview of the potential and current limitations of ESR dating method based on some recently published case studies for which semi-independent age control was available.

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P-4629

## Sequential $^{14}\text{C}$ age measurements on peaty sediments to reconstruct high precision age model of marsh deposits

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Radiocarbon dating on sediment cores rely on the abundance of macrofossils such as plant remains. Alternatively, bulk sediment radiocarbon dates have been used to reconstruct the age model of sediment cores recovered from terrestrial environment. Here we employed sequential radiocarbon measurements to make better resolution and precision age model of cores retrieved from Sarutake river marshland in Hokkaido, northern Japan. High organic carbon content of the sediment allowed us to conduct bulk radiocarbon measurements relatively readily and it was supported from existence of water plants remains. However the sediment is still mixed with other materials thus the radiocarbon results are for both in-situ and ex-situ carbon. We employed sequential radiocarbon measurements (eg., Ishizawa et al., 2017;2018) to overcome this difficulties together with evaluations of reservoir effects using diatom based paleo salinity estimates (Sagayama et al., 2018). In order to evaluate the accuracy of that age model, we compare the age with the tephra with the history record. We did age comparison with Tarumae A (Ta-a) tephra erupted in 1839. The result was suggested that Sequential  $^{14}\text{C}$  age measurements would enable high precision dating of peat deposits.

P-4630

## Moving beyond the age-depth paradigm in palaeoceanography: dual $^{14}\text{C}$ and stable isotope analysis on single foraminifera.

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Late-glacial palaeoclimate reconstructions from deep-sea sediment archives provide valuable insight into past rapid changes in ocean chemistry. Unfortunately, only a small proportion of ocean floor with suitably high sediment accumulation rate (SAR) is suitable for such reconstructions using the longstanding age-depth approach based on a traditional downcore stratigraphy. We employ ultra-small radiocarbon ( $^{14}\text{C}$ ) dating on single microscopic foraminifera to demonstrate that the longstanding age-depth method conceals large age uncertainty caused by post-depositional sediment mixing, meaning that existing studies may underestimate total geochronological error. To overcome the problems associated with the age-depth paradigm, we use the first ever dual  $^{14}\text{C}$  and stable isotope ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) analysis on single microscopic foraminifera to produce a palaeoclimate time series independent of the age-depth paradigm. This new state-of-the-art essentially decouples single foraminifera from the age-depth paradigm to provide multiple floating, temporal snapshots of ocean chemistry, thus allowing for successful extraction of temporally accurate palaeoclimate data from low SAR deep sea archives. This new method can address large geographical gaps in late-glacial benthic palaeoceanographic reconstructions by opening up vast areas of previously disregarded, low SAR deep-sea archives to research, which will lead to improved understanding of the global interaction between oceans and climate.

**P-4631**

## **Amino acid racemisation in foraminifera: testing for an intra-crystalline fraction and closed system behaviour**

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A requirement for amino acid racemisation dating is closed-system behaviour of the protein fraction, which minimises external influences on racemisation rates and limits contamination and leaching of the native biomineral proteins. The intra-crystalline fraction of proteins (those occluded within the biomineral matrix) has the potential to act as a closed system during diagenesis and therefore produce more reliable age estimates.<sup>1</sup> Extensive research has been carried out to assess the suitability of a range of biominerals for AAR using this intra-crystalline approach (e.g. mollusc,<sup>2</sup> coral<sup>3</sup>).

Foraminifera have widespread applications as palaeoenvironmental indicators in Quaternary sea-level reconstructions; however, comparatively little is known about the behaviour of biomineral proteins in these protists and therefore their suitability for AAR. In this project, the intra-crystalline approach is extended to species of foraminifera widely used in palaeosea-level research. Bleaching experiments have been carried out on *Ammonia beccarii* and *Haynesina germanica* to isolate an intra-crystalline fraction of proteins, followed by high-temperature decomposition experiments determine the adherence of each species' intra-crystalline fraction to closed-system behaviour. The patterns of decomposition at diagenetic temperatures have been assessed for intra-crystalline amino acids in foraminifera using *Neogloboquadrina pachyderma (s)* from an independently dated core. This work will inform an assessment of the suitability of foraminifera as a substrate for AAR using the intra-crystalline approach.

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**P-4632**

**Stratigraphic singularity: An earthquake located off Jersey triggered the mudflow preserving the only loess outcrop actually known under the seas**

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A five meters long core sample, retrieved in 2007 from the Havre de Lessay (France) (Latitude: 49°20993, Longitude: -1°788815) and located between Jersey and the Cotentin Peninsula (France) has been studied using different techniques (image processing, granulometry, petrography, malacology, palynology and tentative dating). Between the lower part and the top, the core is a yellowish loess, a black mud and a grey shelly formation. The basal formation, which displays a typical loess granulometry, is the only loess found anywhere in situ on the seabed worldwide. Elsewhere, this fragile sediment has been always washed out by the successive Quaternary transgressions. The overlying mud formation, which displays all the characteristics of a mudflow, sealed up the loess deposit. Because this core has been sampled on the rim of a submarine valley located in front of a major onshore geological disruption (the Saint-Germain-sur-Ay transcurrent shearing), clearly associated with an active seismic zone, it is likely that the protection of the loess deposit from erosion was initiated by an earthquake that triggered the overlying submarine mudflow.

**P-4633**

## **Recent advances in Western Ukrainian loess stratigraphy**

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In the Ukrainian territory several areas with vast, thick loess covers are found. They belong to the European periglacial loess belt and are part of two geographical loess regions. The Central European region of dry loess formation extends from the Vistula River to the upper-middle Dnieper River. In the east it borders on the East European region of continental loess. At the end of the 1960s the stratigraphic division of loess-paleosol sequences (LPS) for Western Ukraine and the area from Middle Dnieper basin to Black Sea were worked out independently in the Lviv and Kiev centres, i.a. due to the difficulties in correlating LPS and divergent interpretations.

The original stratigraphic scheme of LPS in Western Ukraine was based on the main profiles of the Volhynian-Podilian Upland; age of the oldest distinguished loess layers corresponded to the Okanian (=Elsterian) glaciation. The paleosols, mainly interglacial, and additionally the horizons of permafrost deformation structures, characteristic for this area, were identified in specific stratigraphic situations and related to the main phases of permafrost development and degradation. Names of paleosols and cryogenic horizons were taken from stratotype profiles.

Further development of the Western Ukrainian loess stratigraphy was based on the research conducted in larger loess area including Transcarpathia, Pridnistrovian Podilia, East Carpathian Foreland, and adjacent Polish territories for comparison. These loess covers are a kind of bridge to the Middle Dnieper area; hence correct correlation of both regional schemes is possible. They were compared with the widely accepted in Europe today stratigraphic scheme of Chinese Loess Plateau, and with MIS stratigraphy. The LPS were related to the European division of the Quaternary.

Most of the new key and additional sections were studied using several methods (sedimentological, geochemical, paleomagnetic, isotopic (carbon, oxygen), paleopedological, paleontological, archaeological). Deposits were dated using the C<sup>14</sup> and luminescence (TL, post-IRSL, OSL) methods. The results gave new significant data for paleoenvironmental reconstructions and stratigraphic correlations. Reliable age indicators identified in the Western Ukrainian loess-paleosol sequences are: Brunhes-Matuyama magnetic polarity reversal found in loess deposits on the Dnister and Tisza river high terraces; marker horizon of under-/intra-loess till, left by the Okanian ice sheet (MIS12), occurring within complete loess profiles of the Volhynia Upland and Upper Dnister basin; other geomagnetic excursions – Pringle Falls (MIS7), Blake (MIS5), Hilina Pali (MIS2). Pringle Falls event was found in the bipartite soil S2 with the older Middle Paleolithic artefacts, and the Blake event in the pedocomplex S1 with the younger Middle Paleolithic artefacts. Based on all data, the original version of the scheme was supplemented with the loess units older than MIS12, containing paleosol complexes of the Soltvyn (S5), Zahvizdja (S6-S8) and Kopani/Skala Podilska (S9) types. Stratigraphic division of the loess-paleosol units S2-L2-S1-L1 was detailed.

**P-4634**

## **Cross-Ukraine stratigraphical correlation in the Upper and Middle Pleistocene based on a multi-proxy approach**

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Problems of Pleistocene stratigraphic correlation are very apparent in the large Ukrainian loess-palaeosol region: various parts of which have different palaeoenvironmental backgrounds, dependent on climatic, orographic distinctions, and the distance from the continental ice sheets. For instance, in the north of Ukraine, the Bug loess (MIS 2) is the thickest (up to 15 m) and the most enriched in large silt, whereas to the south of 48°N, its thickness averages 2 m, increasing only in palaeodepressions. In the south, the Dnieper (Saalian) loess is the thickest (up to 20 m), and it has a homogenous large silt grain-size. Tyligul unit (Elsterian) is much thicker in the north than in the south, and Sula loess (Donian) has its maximum thickness in the east.

The Ukrainian loess region is subdivided into an area formerly covered by Dnieper glacial lobe, an area with the Elsterian glacial deposits, and an unglaciated area. Each of them include provinces – sixteen in total (Veklich et al., 1993). The best markers for stratigraphic correlation between them are: the M/B boundary, glacial deposits, age-indicative microfaunal complexes, and the pollen successions of the Eemian and Holsteinian. The other pollen, molluscs and large mammal assemblages, archaeological layers are courser tools, of use to identify larger time intervals of Pleistocene than the terrestrial correlatives of MIS.

Palaeosols are reliable for correlation between neighboring provinces, though changes in palaeocatena and the presence of welded soils cause uncertainties. Zonal changes of palaeosols are clearly visible in well-developed pedocomplexes, e.g. MIS 3 palaeosols are gleyed and leached of carbonates in the west and north, but they are Calcaric Cambisols in areas south of 47°. Luvisols of MIS 5e and Greyzems of MIS 5c are replaced in the south by leached Mollisols and Calcaric Mollisols, respectively. Upper Middle Pleistocene pedocomplexes in the north include soils of temperate climate, but south of 48° they have well developed rubified and argillic horizons, like those seen in Mediterranean soils. Early Middle Pleistocene soils are thick Vertisols and Luvisols to the north of 49°, but in the south of Ukraine they are Ferralic Cambisols and Ferrasols. Pollen data confirm palaeoenvironmental interpretations based on the palaeosol origins. The paleosols of the Middle Dniester valley, the Transcarpathian Lowland and the foothills of Crimean Mountains contain some pollen of thermophilous taxa, which is not typical for sites in the rest of Ukraine. The soil units of the Lower Middle Pleistocene include pollen of Neogene relics.

<sup>14</sup>C dating is a secure tool for correlation of MIS 3 soils, but despite that many OLS and TL-dates were obtained from older deposits, frequently their reliability is doubtful. Cross-Ukraine correlation of reference sites in the loess-palaeosols provinces, based on multiple proxies, are demonstrated in the presentation. Most of them are included in DATESTRA project.

**P-4635**

## **Upper/Late Pleistocene stratigraphy in the Kola Peninsula (N-W Russia): glacial and marine units**

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Included the glaciomarine, glaciofluvial or glaciolacustrine depositional units and glacial tills, as well as the marine beds, sediment sequences are presented on the coastal areas and in the inner part of the Kola Peninsula. The combined finding of glacial and marine sediments in the sedimentary sequences allows the correlation of the main Upper/Late Pleistocene stratigraphic subdivisions in the Kola region. The stratigraphy hierarchical pattern can be apprehensible up to the group or supergroup, the stage, and Interglaciation-Glaciation in the lithostratigraphy, chronostratigraphy and climatostratigraphy, correspondently.

Correlated to the Late Pleistocene Subseries, the Mikulinsky (Eemian and Early Weichselian) Horizon and the Valdaisky (Mid and Late Weichselian) Supernorizon are the main lithostratigraphic units, which are corresponded to the Mikulinian Interglacial Complex and the Valdaian Glacial Complex in Russian climatostratigraphy. Marine Ponoï Beds and Strelna ones, corresponded to the members in the international lithostratigraphy hierarchical pattern, compose the entire Mikulinsky Horizon in the coastal sediment successions, and Ponoï Beds is the lower part of this Horizon in the inner Kola Peninsula. Both marine Beds compose the formation in rank. The lower boundary of this marine unit derives from lithology, spore-pollen proxies and diatoms and foraminifera data; there is no hiatus in transition zone of marine deposition succession since the marine inundation took place in the Kola Peninsula in previous deglaciation and was lasting in coastal areas during entire MIS 5. Upper parts of all referred sequences are deformed, and marine sediments are overlaid by glacial deposits with erosion.

Valdaisky Superhorizon (Valdaian Glacial Complex), which is a supergroup in the international lithostratigraphy, subdivides into Glacial Podporozhsky, Interstadial Leningradsky, and Glacial Ostashkovsky Horizons, not strongly correlated to the grope in rank. The chronostratigraphic equivalent of the Horizons should be considered Podporozhian (early Mid Weichselian), Leningradian (late Mid Weichselian) and Ostashkovian (Late Weichselian) stages. Derived from sedimentology secessions in the coastal and inner Kola Peninsula and different proxy environment indicators, large-scale deglaciation of land took place and the marine reservoir in the White Sea depression occurred here in the Last Glaciation during MIS 3. Corresponding deposits form the Leningradsky Horizon, underlaid and overlaid by tills or melt-water sediments, which represent the Glacial Podporozhsky Horizon and Ostashkovsky one. In coastal Kola Peninsula, the lithostratigraphy boundary between Glacial Podporozhsky Horizon and Interstadial Leningradsky one indicates the transition zone in the sediment succession with Mid Valdaian (Mid Weichselian) marine unit. Available 8 key sites from Kola Peninsula provide here the lithological, geochronological and various proxy data for Upper/Late Pleistocene regional stratigraphy.

This is a contribution to the DATESTRA project. The studies have been carried out within the framework of the GI KSC RAS research projects.

**P-4636**

## **New data on the structure and genesis of Quaternary perennially frozen sediments in Central Yakutia (Eastern Siberia)**

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In the spring of 2018, on the watershed of the Lena and Amga rivers (Central Yakutia), we drilled a borehole to a depth of 100 m, and having encountered a full section of the Quaternary sediments bedding here. The complete sampling of frozen core was made to a depth of 94.5 m. Based on comprehensive studies, we identified five stratigraphic stages of the formation of Quaternary sediments, from top to bottom:

I. 0-2,65 m. Holocene soil of slope genesis.

II. 2.65-26.15 m. Ice complex (yedoma), represented by massive loams with schlieren cryostructure, containing ice-wedges.

III. 26.15-63.45 m. Lacustrine complex, formed by silt with horizontally and wavy-layering. Inclusions of freshwater shells and plant detritus are noted. Into the layer, thin separate 'closed' cracks filled with ice are encountered.

The significant difference in the cryostructure between yedoma and lacustrine sediments allows separating these complexes according by type of freezing. Besides having ice wedges, loam cryostructure enclosing advantageously thin- and mikroschlieren, indicating that discontinuous sedimentation mode with alternating subaqueous and subaerial conditions, and syngenetic type of accumulation were predominant. Stratigraphic position and  $^{18}O/^{16}O$  analyses data allow us attributing yedoma to the Sartanian LatePleistocene horizon (MIS 2). Lacustrine sediments cryostructure is massive, which together with structural features, could indicate significant diagenetic fluctuations in the basin and epigenetic type of freezing. Thickness of lacustrine complex is the greatest (37.3 m), among the considered complexes, which confirms the earlier conclusions about distribution of the deep lake basin in Zyryan time (MIS 4).

IV. 63,45-78,9 m. Lacustrine -alluvial complex represented by interbedded sands and silts. This is a transitional layer between the Elginskaya and Mavrinskaya formations, revealed in the outcrops of the Mamontovaya Gora and the Bestyakhskaya terrace. Sediments were formed in large flowing water basin under more dynamic conditions than the lacustrine sediments overlying it. The character of sediments freezing is epigenetic. Based on the similarity of the lithological composition and stratigraphic position, we attribute this stratum to the end of the Mid-Pleistocene (MIS 8-6).

V. 78.9-94.5 m. Alluvial complex, represented by medium and coarse sands. The section ends by pebble horizon lying on bedrock. Sands correlate with the Bestyakhskaya formation bedding at the base of section of the Bestyakhskaya terrace. Underlying pebbles correlate with pebbles of the Elginskaya formation of Mamontovaya Gora. This allows us to relate this complex to the Tobolskiy horizon of the Mid- Pleistocene (MIS 9-11).

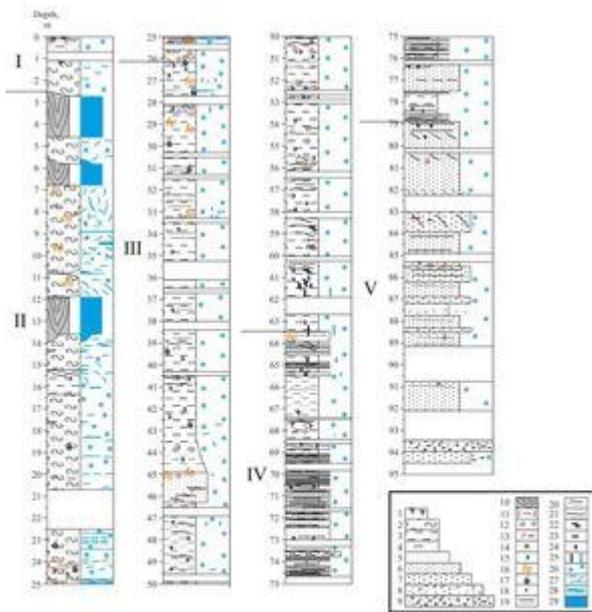


Figure 1. Lithological and cryolithological section of Borehole 18/1.

The reported study was funded by RFBR according to the research project № 18-55-53054.

**P-4637**

## **Pleistocene chronostratigraphy of the southeastern White Sea and adjacent areas (Arkhangelsk region, Russia)**

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The White Sea which is an inner basin of the Arctic Ocean located in the Northwestern Russia is of high geological interest because of its binary structure: its northwestern half is located on the tectonically active Baltic crystalline shield, and the southeastern one is a part of the East European platform with developed sedimentary mantle and comprises the onshore areas of the Onezhski peninsula, Kuloi plateau and southern side of the Gorlo strait (Fig. 1). According the current Quaternary System subdivisions for European Russia (Zastrozhnov et al., 2018) it lies within the Northwestern subzone of Late Neopleistocene glaciations (W-Ia).

The Quaternary stratigraphy starts with Eemian which deposits are widespread both within the Gorlo strait and in the coastal zone (Demidov et al., 2007; Sobolev, 2008; Rybalko et al., 2017) and are mostly marine sands and silty sands with shells and shell detrital matter. The luminescent dating results are 160-110 kyr BP (Sobolev et al., 1995). In the coastal outcrops these deposits are presented by binary layer of dark-grey massive clays covered by light-grey sands, often directly overlain by LGM deposits.

The middle Weichselian interstadial deposits were identified in one section of Zimniy coast and are presented by sands and gravels interlayered with silts and loams. The origin is controversial: fluvial (Larsen et al., Demidov et al., 2006) or marine (Sobolev, 2008). One radiocarbon date is  $27.9 \pm 1.16$  (shells), and TL dates are  $55.8 \pm 8$ ,  $63.0 \pm 11$  and  $71.0 \pm 11$  BP (Sobolev, 2008), OSL-dates are  $77 \pm 8$ ,  $31 \pm 3$  and  $19.9 \pm 1.4$  (Demidov et al., 2006).

Late Weichselian (LGM and deglaciation) tills are the most widespread in this area (Demidov et al., 2006; 2007; Rybalko et al., 2017), forming the gently undulating uplands with blanket bogs. This area was covered by last SIS glacier from 22 to 16-15 kyr BP (Hughes et al., 2015). The thickness of till layer varies from 1 to 8-9 m, and sometimes is underlain by the rhythmically interlayered sands and clays probably deposited in proglacial conditions of early LGM.

The deglaciation of this area left the well expressed marginal landforms; moraine ridges of Neva deglaciation stage (Older Dryas) are identified both in the coastal area (State..., 2012) and within the Gorlo strait (Sobolev, 2008; Rybalko et al., 2017). The Late Glacial – early Holocene basin deposits are found up to the height of 14-20 m a.s.l., and the Holocene marine (supported by diatom data) - up to 4-5 m a.s.l.; these are grayish or brownish-grey heavy silts and clays, usually covered by aeolian sands or peat and gyttja.

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Figure 1. Topographic map of the White Sea with local names.

P-4638

## What was the rank of the Warthe cold period (Younger Saalian, MIS 6)? New facts from eastern Poland

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In the present-day stratigraphic subdivision of Middle Pleistocene the Warthe cold period is in the rank of recessional stadial of Drenthe Glaciation, correlated with Marine Isotope Stage 6 (MIS 6), that follows the Schöningen Interglacial (MIS 7). We found a previously unknown sedimentary succession in eastern Poland, outcropping in the area of maximum extent of the Warthe ice sheet. Our study sheds a new light on stratigraphic significance of the aforesaid glacial period. The succession has been divided into four lithostratigraphical units: lower glaciofluvial deposits and basal till (unit A), fossil luvisol (unit B), periglacial horizon with involutions, frost wedge structures and deflation pavement (unit C), upper glaciofluvial deposits and flow till (terminoglacial fan – unit D). The studied units represent sedimentary record of two distinct cold periods connected with the advances of the youngest Saalian ice sheets in eastern Poland (unit A - Drenthe A; units C, D - Warthe). Warthe cold period has been documented by luminescence datings (approx. 134-170 ka) of sands infilling the frost wedges (unit C). These results comply with global climatic cooling during MIS 6. Two generations of cryogenic structures (involutions and frost wedge structures) and their frequency indicate a change of climatic conditions towards decrease of average annual temperature and humidity reduction. That indicates well-developed, continuous permafrost. This cold period was culminated by ice-contact sedimentation of marginal moraine (unit D). The soil with well-developed Bt horizon (unit B) derived from illuviation in conditions of mixed forest during long-lasting interglacial warming preceding the Warthe cold period – the Schöningen Interglacial (MIS 7). To conclude, the younger cold period of Saalian – the Warthian – should be regarded as an individual glaciation, similarly as Drenthian, which we suggest to locate as MIS 8 in the Quaternary stratigraphic chart.

P-4639

## Middle Pleistocene interglacial environmental changes inferred from aquatic microfossils at the paleolithic site of Schöningen, Germany

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Although multi-proxy paleoclimatic data from Middle Pleistocene archeological sites are important to understand patterns of climate variability as well as prehistoric human adaptation, only few well-preserved records exist in Central Europe. The Lower Paleolithic sites in the open-cast mine of Schöningen, Northern Germany, have become internationally renowned because of their worldwide oldest wooden hunting weapons associated with exceptional preservation of remains of a diverse flora and fauna. The Middle Pleistocene paleolake sediments of the locally named Reinsdorf Interglacial, deposited between the Elsterian and Saalian glaciations and correlated at archaeological site Schöningen 13 II with MIS 9, provide a valuable environmental archive for investigating an interglacial transition into an early glacial phase. Diatoms and ostracods were analyzed for more detailed information about the characteristics of the paleolake development and thus smaller-scale climate fluctuations. The lake was characterized by brackish water within the oligo- to mesohaline range. Taxa preferences show deposition near the lakeshore, often associated with abundant aquatic plants. Calcium content was elevated with at least 18 mg Ca L<sup>-1</sup>. Distinct changes in assemblages, concentrations and taxa dominances point to highly variable lake conditions throughout the terminating interglacial. Presence and absence of shallow water ostracods and abundances of benthic diatom taxa suggest that the paleolake was characterized by strongly fluctuating lake levels with repeating shallowing-upward cycles, probably climatically induced. High abundances of tychoplanktonic diatoms and ostracod taxa associated with streaming water and less brackish conditions in certain levels are indicative of a variable freshwater inflow from springs nearby. Average paleo-temperatures were reconstructed using the Mutual Ostracod Temperature Range method. Mean values varied between approx. +16 and +20 °C for July and approx. -11 and +1 °C for January. Highest numbers and best preservation of ostracod shells were found not in sediments representing full interglacial conditions but during a later phase. This climate oscillation at the transition into the following glacial period led again to more favorable conditions for aquatic organisms. The youngest part of the sequence was void of ostracods hinting at desiccation of the site and preceding climate deterioration during the early glacial. Our findings highlight the relevance of Schöningen for understanding Central European interglacial climate dynamics.

P-4640

## Unravelling chronology and geochemical signatures of Mid-Pleistocene periodic palaeolakes from NW Poland, Central Europe

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We performed detailed multiproxy analyses of 11 m thick lacustrine sediments sections from the two superimposed Pleistocene lakes from NW Poland. Lakes deposits geochemical, palynological and macrofossils analyses have been supplemented with optically stimulated luminescence and radiocarbon datings. Analysed sections represent a unique record of Mid-Pleistocene climatic changes in Central Europe associated with the Scandinavian Ice Sheet oscillations. According to the OSL dating results, the onset of lower lake formation coincides with the recession of the Late-Saalian (MIS6) ice-sheet from NW Poland (OSL 141.4±3.0 ka). As a result, hilly and hummocky landscape originated, wherein local hollows had been fed by the Ca-rich groundwater and surface outwash. Climate change from cold to warm conditions during the Eemian Interglacial (MIS 5e), resulted in limnic cycle onset and succession of thermophilic plants in the basin area. Existence of first (lower) lake ceased with a peat horizon overlaid by sands and sandy silts, to be linked with Early Weichselian glaciation (OSL 109.9±2.5 ka). In the upper part of lower paleolake, the nearly complete skeleton of rhinoceros *Stephanorhinus kirchbergensis* (Jäger, 1839) has been excavated. Second (upper) paleolake formed in superimposed position during the Early Weichselian (MIS 5d-b) glaciation, and uppermost section of lacustrine organic matter (peat horizon) profile, revealed Middle Pleniglacial (MIS 3/2) radiocarbon ages in the range of ~41-32 ka cal BP associated with interstadial conditions (Hengelo – Denekamp Interstadials). During the Last Glacial Maximum (MIS 2), Scandinavian Ice Sheet has overridden the area of analysed palaeolakes reaching its maximum position around Leszno, ca. 150 km to the south. If ones assumed a normal *post-mortem* position of rhinoceros skeleton preceding burial processes, ice-sheet overriding fossilised lacustrine sequence could be at least partly responsible for on-site observed *Stephanorhinus kirchbergensis* skeleton disarticulation.

P-4641

## Input to the stratigraphy of MIS 12-6 in eastern Europe, based on record from the site Rechitsa in western Belarus

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The site Rechitsa in western Belarus is located in the end morainal zone of the Warta/Sozh Stadial of the Odranian Glaciation (Saalian, MIS 6). It is a big outcrop in which the Quaternary sands and gravels are excavated. This site is extremely important to reconstruct the late Middle Pleistocene environment in central Europe. Referring to a regional palaeogeography, the sequence starts with sand of the late Berezinian (Elsterian; MIS 12) braided river that is overlain by peat of the Alexandrian Interglacial (Holsteinian; MIS 11). The interglacial sequence terminates in peaty gyttja that comprises pollen spectra of a pine-birch forest with substantial participation of steppe vegetation. The overlying sequence is composed of peat and gyttja interbeds reflecting varying lake water levels, in turn dependent on mutual relation of temperature, precipitation and evaporation. The sequence terminates with clay, the top of which was eroded and a channel was cut. At the base of this channel, just above the erosive contact with the clays, rip-up casts of a gyttja deposit are present that is not preserved in situ. They are overlain by a thin (0.15-0.20 m) layer of peat, the pollen spectra which indicates predominance of pine-birch forest with steppe elements (*Pinus-Betula*-NAP) including 40% of *Artemisia* and 10-15% of *Betula nana*. The peat is overlain with brown massive clay with organic material, pollen spectra of which suggests an open vegetation with *Juniperus*, but successively suggesting a progressive cooling. It is overlain by massive decalcified clay without organic matter and with isolated gravels to 0.2 m in diameter that are explained as dropstones deposited from floating lake shore ice. In the top of clay there are two involution horizons and aeolian cover sands. The afore-mentioned series is cut by immense ice wedges with primary infilling, OSL-dated at 210-220 ka BP. Their magnitude (2.0 and 3.5 m long and 0.6 – 0.8 m wide at the top) is unusual in this part of Europe and it suggests to have been developed either during a single long and severe periglacial episode, or in a few shorter but equally severe glacial episodes. This last option seems more probable, because aliquots of the OSL-dated quartz grains in sandy infillings of the ice wedges indicated several sets of ages including 284-272, 219, 199-187, 169-164 and 138 ka BP. Based on sedimentological context and temperature and vegetation curves, the most probable is that the last time the wedges opened at least twice, during MIS 8 and 6 i.e. corresponding to the first and third ages. The research project was funded by the National Science Centre in Poland (decision no. DEC-2013/09/B/ST10/02040).

**P-4801**

## **Dating fault gouges and Quaternary sediments in the Wangsan fault, southeastern Korea**

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Geochronological data provide a fundamental basis for assessing hazard risks of the fault. Quaternary faults near the Wangsan Fault System, southeastern Korea, have attracted much attention because they are close to the nuclear power plants and heavy industrial complexes that have been constructed since the early 1970s. We here summarize Rb-Sr and optically stimulated luminescence (OSL) ages of fault gouges and fluvial sediments from a remarkable thrust fault exposed on the bluff of a river terrace near the Wangsan village. Both unconsolidated sediments and the basement andesite are cut by the fault with a vertical slip of 16 m. The net displacement along the fault plane is estimated as 28 m. A 40–120 cm thick, light gray and brown fault gouge layer consists of quartz (~40%), feldspar (~35%), illite and smectite with minor kaolinite. Acid (1N hydrochloric acid)-leaching experiments for the fine (< 0.2 $\mu$ m) fractions of two gouge samples yielded reproducible isotope dilution thermal ionization mass spectrometric Rb-Sr ages ( $14.0 \pm 0.3$  Ma and  $13.5 \pm 0.3$  Ma). These ages are consistent with the K-Ar result ( $14.8 \pm 1.3$  Ma) obtained for the comparable size fraction (0.35–0.05 $\mu$ m) of the gouge, and interpreted as representing the time of faulting and subsequent hydrothermal alteration. Taken together with the published electron spin resonance (ESR) ages of the gouge (~550 ka), it is concluded that the Wangsan fault was formed in the Middle Miocene and reactivated in the Middle Pleistocene. The Rb-Sr and ESR ages, however, do not represent the timing of the last fault movement because it is evident that the fault rocks were not generated in unconsolidated sediments near the surface. Five sediment samples were selected for OSL dating to constrain the upper limit for the time of surface faulting. Three dates from the footwall block, ranging from 90 ka to 54 ka, were stratigraphically consistent, and two dates from the hanging wall block ( $81 \pm 5$  ka and  $82 \pm 5$  ka) were in good agreement with each other. The OSL dating reveals that the fluvial sediments cut by the Wangsan fault were deposited in the Late Pleistocene with an average accumulation rate of ~0.04 mm/y, and the last fault activity occurred sometime after 54 ka. This research was supported by a grant (2017-MOIS31-006) from the Research and Development of Active fault of Korea Peninsula funded by the Korean Ministry of the Interior and Safety (MOIS).

P-4802

## Teotihuacan ancient culture depressed by a megaearthquake associated to the seismic Guerrero gap recorded in Cacahumilpa Cave and EAEs (Mexico)

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Teotihuacan was one of the more blossom cultures in the Mesoamerica pre-Hispanic times, located in the central part of Mexico. The archaeological remains are one of the most famous tourist places in our days. During his highest splendorous time (Classic Period, ca 600 CE yr.), close to 200.000 people lived in an urban city with monumental buildings. The city was arranged in one main street of 2 km, oriented N15°E (Avenida de los Muertos), with impressive religious buildings like the Sun Pyramid, one of the greatest pyramid in America, the Moon pyramid at the north and the Feathered Snake Pyramid (the Citadel), at the south part of the city. The city was a dominant center point of the Mesoamerican culture between the years 125 and 650 CE. In the year 650 CE (Epiclassic period), a dramatic decrease of the urban population was noted by several authors and archaeologists. Finally, the city was totally abandoned sometime before the Aztec culture rose as dominant (c.a. 800 CE). A systematic analysis of the main pyramids shows several Earthquake Archaeological Effects (EAEs) affecting the south staircase of the Sun Pyramid, with reinforcement of the E-W sides and high damage affecting the original south staircase of the Feathered Snake Pyramid. All of these building damages appears to be coeval between the years 600 and 650 CE. Furthermore, a speleoseismic analysis of the Cacahuamilpa cave shows multiple coseismic stalagmite and stalactite oriented collapses, cave located at Tasco city (130 km away from Teotihuacan). Numerical dating of these sismothems suggests that the speleothems collapse and tilting occurred between the year 463±50 and 1064 ±20 yrs. CE, according to diverse authors. To check our proposal, we produced a ShakeMap for an Mw 8.1 to Mw 8.4 earthquake, with a theoretical epicenter located at the Guerrero seismic gap segment of the pacific subduction zone (388 Km from Teotihuacan, N210°E direction), simulating a rupture between 150 to 292 Km of reverse faulting of this segment of the Middle American Trench (MAT). Calculated seismic ground accelerations for these theoretical events can explain both the cave damage at Tasco and building damage at Teotihuacan (0.32 g; VIII ESI-07). Therefore, we consider the possibility that a strong earthquake (Mw>8) associated to the Guerrero segment could be the responsible for the great population decline and subsequent abandonment of the ancient Teotihuacan. In this way, there is the possibility to link strong seismic activity with outstanding “cultural reliefs” occurred in Mesoamerica. This proposal does not conflict with either of the existing theories for the Teotihuacan abrupt collapse (droughts, revolutions, volcanic eruptions, etc.), because the sudden overlapping of natural disasters would increase famine episodes, internal warfares and community unrests for brief periods of time.

P-4803

## A Worldwide and Unified Database of Surface Ruptures (SURE) for Fault Displacement Hazard Analyses

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Fault Displacement Hazard Assessment is based on empirical relationships which are established using historic earthquake fault ruptures. These relationships evaluate the likelihood of co-seismic surface slip considering on-fault (i.e. along the primary earthquake fault) and off-fault (i.e. distributed surface rupture off the primary rupture) ruptures, for given earthquake magnitude and distance to fault. Moreover, they allow to predict the amount of fault slip at and close to the active fault of concern. Applications of this approach include land use planning, structural design of infrastructure and critical facilities located on or close to an active fault.

To date, the current equations are based on sparsely populated datasets, including a limited number of pre-2000 events. In 2015, an international effort started to constitute a worldwide and unified surface co-seismic displacements database (SURE) to improve further fault displacements estimations, in the framework of the INQUA International Focus Group EGSHaz. To date, two workshops have been held to start discussions on how to build such a database. Outcomes from these discussions are (1) the first step should be to unify the existing datasets; (2) the future database will include recent cases which deformation have been captured and measured with modern techniques; (3) new parameters, relevant to properly describe the rupture (such as surface geology and location of rupture with respect to primary fault complexities) will also be included.

This contribution will present the status of the SURE database and will delineate some perspectives to improve the hazard assessment related to surface faulting. The database encompasses 41 earthquakes from magnitude 5 to 7.9, with more than 6 thousands slip measurements and 45 thousands of rupture segments. Twenty earthquake cases are from Japan, 13 from the USA, 2 from Mexico, 1 from New Zealand, Kazakhstan / Kyrgystan, Italy, Ecuador, Turkey and Argentina. Twenty three earthquakes are strike-slip faulting events, eleven are normal or normal-oblique, and eight are reverse faulting.

To pursue the momentum, the initial and common effort needs to be continued and coordinated; and the maintenance and life of the database must be guaranteed. We stress that this effort must remain based on a large and open community of earthquake geologists to create a free and open access database.

P-4804

## Use of the ESI-07 Scale for generation of seismic scenarios in Spain: from ancient earthquakes to future simulated shake exercises

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The combination of macroseismic data-points from the environmental earthquake effects (ESI-07) and building damage (EMS-98), leads to the refinement of seismic scenarios for instrumental and historical earthquakes. In particular, seismic information from Earthquake Environmental Effects (EEEs) allows to multiply, sometimes by ten (x 10), the number of macroseismic data-points, especially in non-populated zones, which allows improving identification of historic to ancient epicentres located away from old urban areas. In Spain, the 2<sup>nd</sup> edition of the Catalogue of Earthquake Environmental Effects (to be published in 2019 by the Geological Survey of Spain, IGME) provides hybrid EMS-ESI macroseismic maps for most of the strong historical and instrumental earthquakes with intensities  $\geq$  VIII EMS-98 (c. 70 events). In most of the cases (especially after the 17<sup>th</sup> Century), the incorporation of multiple ESI-07 macroseismic data resulted in a better identification of both: (1) the probable seismic sources; and (2) the participation of secondary earthquake geological effects in the resulting damage scenarios. In this contribution we present data on the AD 1764 Estubeny (Valencia) and the AD 1862 Huércal-Overa (Almería) earthquakes occurred in different sectors of the Spanish Betic Cordillera, the more seismically active zone of the Iberian Peninsula. The obtained macroseismic scenarios are converted in seismic acceleration (PGA) maps on the basis of standard ground motion prediction equations (GMPE) and specific algorithms for seismic amplification. On the other hand, routines learned from the generation of seismic scenarios (ShakeMaps) developed for instrumental and historical earthquake in Spain have been implemented for the generation of earthquake simulation exercises. The collaboration among the Salamanca University (USAL), the Geological Survey of Spain (IGME) and the “*Unidad Militar de Emergencias*” (UME) of the Spanish Army, leads to the generation of future earthquake scenarios by means of the lessons learned of ancient earthquakes applying methodologies similar to those used by the USGS ShakeMap Program. Recent “earthquake drills” in densely populated areas of the Guadalquivir basin (Sevilla, 2016) and the Lorca-Alhama de Murcia Fault (Librilla, 2018), were based on seismic scenarios provided by the USAL and managed by the IGME, considering the highest emergency levels considered in Spain (Level 3). The main goal of this research is the generation of scientific maps to be used by civil and military authorities during the management of natural disasters as earthquakes, giving a real vision about what we can expect during large earthquakes ( $\geq$  6.0 Mw) affecting wide areas within Spain. Research funded by the MINECO-FEDER Spanish research projects CGL2015-67169-P (QTETC-SPAIN-USAL)

P-4805

## Neotectonic Environment and Geodynamic Significance in South Korea: An Overview

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The Korean peninsula is situated within the eastern part of the Eurasia plate, and has long been regarded as a tectonically stable region. Since 1990s, increasing number of researches have reported the evidences, which are against this conventional view through historical ( $\text{MMI} \geq \text{VIII}$ ) and modern instrumental ( $\geq M_w 4.0$ ) earthquake records. Further, more than 60 Quaternary fault outcrops were also newly observed along the major inherited fault zones in SE Korea (e.g. Yangsan Fault System, Ulsan Fault, Yeonil Tectonic Line, Ocheon Fault System). The conspicuous features of the Quaternary faults are: (1) attitudes similar to those of adjacent major faults (generally NNW–SSE- to NNE–SSW-strikes), (2) dominantly top-to-the west reverse fault geometries with upward decreasing dip pattern, (3) strike-slip with reverse component or reverse-slip kinematics, and (4) reactivations under ENE–WSW to E–W compressional stress field. Based on majority of the observed Quaternary fault outcrops and resultant crustal uplift as well as high rates of microseismic activities, the NNW–SSE-striking Ulsan Fault and the Yeonil Tectonic Line (in Gyeongju–Ulsan areas), which were acted as western principal displacement zone of the Miocene crustal deformation in the Korean peninsula, are interpreted as ones of the most active faults under the Neotectonic stress field. However, on 12<sup>th</sup> September 2016, the  $M_w 5.8$  earthquake occurred in Gyeongju-city, which is the largest ever instrumental earthquake in the southern Korean peninsula since the first instrumental monitoring in 1978. This earthquake is interpreted to have occurred by the reactivation of a subsurface subsidiary fault of the NNE–SSW-striking Yangsan Fault. In addition, in 15<sup>th</sup> November 2017, another earthquake shock with  $M_w 5.4$  due to reactivation of the other NNE–SSW-striking fault hit the Pohang-city, which is ~30–40 km to the northeast of Gyeongju-city. The geodynamic setting that causes the present-day stress regime in the Korean peninsula is a combined result of the convergence of Eurasian, Pacific, and Philippine Sea plates, as well as far-field stress induced by India-Eurasia collision and continuous northward movement of the India plate. It has been interpreted that the current stress regime in the Korean peninsula have initiated with the change of the Pacific Plate motion during 5–3.2 Ma.

At present, the historical and instrumental records of earthquakes in Korean peninsula are not enough, and full understanding of the recurrence history and magnitudes detected by observed Quaternary faults has been limited so far. Therefore, more advanced approaches for studying the active faults and concomitant rupture processes are required. In particular, recent advances in numerical dating, such as luminescence,  $\text{Be}^{10}$ ,  $\text{C}^{14}$ ,  $\text{Al}^{26}$  dating methods, are expected to play important roles for the reconstruction of the Quaternary fault activities in South Korea.

P-4806

## Environmental Effects and ESI-07 intensity of the September 8, 2017, Mw 8.2 Tehuantepec-earthquake: geological signature of a large intraslab event

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The September 8, 2017, Mw 8.2 earthquake with epicenter in the Gulf of Tehuantepec offshore, 133 km Southwest of Pijijiapan, Oaxaca, Mexico, generated considerable environmental effects in a vast region including central-southern Mexico and Guatemala. Immediately after the event, we carried out field reconnaissance surveys of the geological phenomena induced by the event. In the following months, we analyzed and interpreted additional data made available by the National Geological Survey of Mexico and other sources, and those published in the literature meanwhile. This allowed us to compile the first database of the earthquake-induced environmental effects and ESI-07 macroseismic field for an event due to slab bending and rupture. In fact, the Tehuantepec event represents an intraslab earthquake characterized by a hypocentral depth of 45.9 km, and a focal mechanism indicating a WNW-trending, subvertical, normal fault.

The total area affected by secondary effects is in the order of 54.000 km<sup>2</sup>. Intensity of VII to IX<sub>ESI-07</sub> has been assigned in the Gulf of Tehuantepec region. In the epicentral area, coseismic coastal subsidence up to 0.5 m has been documented at Salina Cruz and Juchitán, Oaxaca (figure 1). Oceanic tsunami reached Puerto Chiapas (run-up of 3.4 m above tide level), Salina Cruz (1.89 m), and Huatulco (1.37 m; MNSS). Intensity of X<sub>ESI-07</sub> has been assigned to the epicentral area and IX<sub>ESI-07</sub> to this coastal area. VIII<sub>ESI-07</sub> is assigned to Cañón del Sumidero and Tuxtla Gutiérrez city, ground effects included landslides and rockfalls up to 10<sup>4</sup> m<sup>3</sup>. In beachfront areas, cracks on alluvial soils reached 40 cm of width and 1.40 m of depth (figure 2). A value VII<sub>ESI-07</sub> is assigned to Tuxtla Gutiérrez and Juchitán, the most notable ground effects were lateral spreading with up to 10 cm wide longitudinal fractures in paved roads and 20 cm wide in riverbanks. In Tuxtla Gutiérrez city, rock falls and landslides up to 10<sup>2</sup> m<sup>3</sup> occurred. Lateral spreading and longitudinal and transversal fractures up to 10 cm wide are observed along paved roads in Juchitán, Oaxaca.



Figure 1. Tectonic subsidence, IX<sub>ESI-07</sub>. Area of restaurants flooded by sea water. Juchitán, Oaxaca.



Figure 2. Cracking in natural soil road, VIII<sub>ESI-07</sub>. Salina Cruz, Oaxaca.



The attenuation of ESI-07 intensity was more pronounced to the ESE than to the opposite direction, in agreement with rupture directivity deduced from instrumental data. The application of ESI-07 scale will provide data for the generation of a new intensity map and will allow its comparison with published macroseismic data based on traditional intensity scales (MM, EMS). Such map will contain reliable information according to the distribution and size of damage in the natural environment, as a scenario to take into account in future hazard and seismic risk studies in the country.

**P-4807**

## **Analysis of geomorphology and tectonolineaments related with earthquakes around Gyeongju, Korea**

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Gyeongju is located in the junction area of the Yangsan and Ulsan faults in the southeastern Korea. The Yangsan Fault have a N-S or NNE-SSW directions, and the Ulsan Fault have a NNW-SSE direction around Gyeongju. Recently, two important earthquakes in Korea occurred in 2016 (Mw 5.8) and 2017 (Mw 5.4) in the vicinity of the Gyeongju city. We analysed the geomorphology and tectonolineaments to well understand the relationship with seismotectonic environment and seismic damage zones around Gyeongju, Korea. Several active faults around Gyeongju have a N-S strike dipping to the east and are closely related with westward convex lineament, showing top-to-the-west movements. And also, the eastern margin of the Tertiary extensional basins are mainly reactivated, damaged, evolved and developed as active faults showing westward convex lineament pattern. We also discuss an intracontinental seismotectonic environments around Gyeongju, which is not related with continental collision effect from Himalaya-Tibet but with subduction effect from Pacific.

**P-4808**

**Stereopaired morphometric protection index red relief image maps (Stereo MPI-RRIMs): effective DEM visualization for interpreting and mapping tectonic geomorphic features**

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We propose stereopaired morphometric protection index red relief image maps (Stereo MPI-RRIMs) for effective visualization of high-resolution digital elevation models (DEMs) to interpret and map small tectonic geomorphic features along active faults. Stereo MPI-RRIMs resolve problems of an original red relief image map (RRIM) in active fault studies and allow simultaneous expression of all of the three basic topographic parameters of elevation, slope, and convexity and concavity with minimal degradation of original data quality. Although stereographic viewing may require some practice and/or supporting devices, this is a big advantage over the most often used DEM visualization of shaded relief maps and slope maps, both of which only represent one aspect of 3D morphology. We show that Stereo MPI-RRIMs vividly visualize various tectonic geomorphic features and even errors from DEM production processing, thereby maximizing the potential of the digital topographic data for active fault studies. We argue that those who use DEMs need to pay more attention to DEM visualization, and our proposed method, along with our simple calculation programs, would aid in more complete interpretation and mapping of small tectonic geomorphic features.

P-4809

## Environmental effects accompanying the Mw 7.3, November 12, 2017, Sarpol-e-Zahab earthquake: observations from the Iran border and preliminary ESI2007 intensity

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The Mw 7.3 earthquake occurred in the region of Iran-Iraq border on Sunday, November 12, 2017, is the largest instrumental and historical seismic event recorded around this border, and was felt over an area of more than 800,000 km<sup>2</sup>. According to the Iran legal medicine report, until 2017.12.12 about 579 people were killed, most of them were in Sarpol-e-Zahab with 518 killed and about 12000 people injured.

No unequivocal surface faulting has been mapped. The affected zone of this strong seismic event contains the Mountain Front Fault and High Zagros Fault of main Zagros structures both in strike of NW-SE which located closer to each other in the NW. Heavy engineering damages and numerous related environmental phenomena were caused by this earthquake. According to the several reported environmental effects, essentially from the Iran side of the epicentral area, in this study we assess the macroseismic intensity field. Considering the observed landslides, rock-falls, liquefaction, ground features and other effects, maximum intensity value of this earthquake based on ESI 07 intensity scale proceeds to the value X near to Sarpol-e-Zahab city. Two more effective effects were observed by landslides (Fig. 1) and rock-falls (Fig. 2).



Figure 1. Mela Kabood- Gorchi Bashi landslides (in the north of Sarpol-e-Zahab); we assess X ESI 07 intensity at this site.



Figure 2. Rock fall on the way of Baba-Yadegar to Ban-e-Zarde (in the north of Sarpol-e-Zahab); we assessed ESI 07 = VIII at this site.

The other largest earthquakes of this region are two historical events occurred in 958 AD and 1150 AD, both with reported magnitude 6.4; then, more investigation is needed to find relevant information of the region's seismicity and seismic hazard. In fact, the analysis of the 2017 Sarpol-e-Zahab earthquake macroseismic information and ground effects will allow a better understanding of source parameters of strong historical events in the region.

**P-4810**

## **Research of active tectonic changes in Korea using In situ Cosmogenic radionuclides**

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Since the Gyeongju (Sep.12.2016,  $M_w$  5.8) and the Pohang (Nov.15.2017,  $M_w$  5.4) earthquake in the Korean peninsula in recent years, the need for research on active faults considering the characteristics of seismic and geological characteristics of Korea has been emphasized.

In order to activate the research to track the active tectonic changes in Korea, this paper want to discuss how to apply the information such as surface exposure dating, depth-profile dating, and burial dating that can be derived about active tectonic processes, utilizing concentrations of in situ produced cosmogenic radionuclides  $^{10}\text{Be}$  (half-life = 1.38 Ma),  $^{26}\text{Al}$  (half-life = 0.7 Ma) and  $^{14}\text{C}$ (half-life= 5.7 ka) in a variety of tectonic change. The main purpose of this study is to determine the displacement rate and recurrence interval of the fault through the age dating of the quaternary deposit which was cut by faults existing in Korea. Ultimately, it can be used as a key index to identify the recurrence model of large scale earthquake occurred in intraplate area. This paper summarize the methodology and concept to research active tectonics on the Korean Peninsula using multiple cosmogenic nuclides and discusses the matters to be considered when applying these research methods in Korea. We hope that the technique of measuring in situ cosmogenic radionuclides holds promise for quantitative studies of processes and time-scales in a wide range of active tectonic problems.

**P-4811**

## **A possible change of Holocene paleoearthquake recurrence patterns along the Lucaowan – Shibaocheng segment of the eastern Altyn Tagh fault, China**

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Surface-rupturing paleoearthquakes provide centennial to millennial scale records of active faulting for major seismogenic faults. As the fast slipping northern boundary fault, the left-lateral Altyn Tagh fault was poorly understood on its paleoseismological behavior. Although some results were published recently for the central segment, few studies were known for the eastern and western segments. We excavated a 22-meter-long and 3.5-meter-deep trench on an offset alluvial fan across the Lucaowan – Shibaocheng segment of the eastern Altyn Tagh fault near Hongliuxia Village. Eight to twelve sequences of alluvial deposits were exposed within the fault zone in the trench walls. The alluvial sequences consisted of a sandy gravel layer in the lower part and a fine sand layer in the upper part. At least seven surface-rupturing events are identified from offset deposition units since 6500 Cal BP. The last three events occurred during the last 4000 years within the upper half meter deposit, while the earlier four events recorded within the 1.5 meters deposit between 4600 to 6500 Cal BP. The average recurrence interval for the last three events is obviously longer than that for the earlier four events. This result implies a possible change of paleoearthquake recurrence patterns during the Holocene along the Lucaowan – Shibaocheng segment of the eastern Altyn Tagh fault.

**P-4812**

## **Surface deformation features associated with MW=5.4 Pohang earthquake, SE Korea, 2017**

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The Korean Peninsula has been historically considered to be tectonically stable compared with neighbouring countries (e.g. China, Japan, Taiwan), since it is located within the Eurasian intracontinental region. However, quite recently, two moderate earthquakes hit Gyeongju ( $M_w=5.8$ ; September 12, 2016) and Pohang ( $M_w=5.4$ ; November 15, 2017) areas in southeast Korea, those are the largest earthquakes in South Korea since the modern instrumental recording period. The Pohang earthquake occurred in the northern part of Pohang city with a very shallow depth ( $\sim 4$  km). According to the focal mechanism, it triggered by the reverse fault movement with minor strike-slip component. However, surface ruptures associated with the earthquake have not been reported. This is despite some buildings, roads, bridge, and wall being moderately or severely damaged as a result of sudden ground shaking associated with the earthquake. Although the surface fault have not been developed, various types of surface deformation features were broadly developed. We immediately conducted field investigation on surface deformation features, such as ground cracks, ground failure, rock falls, uplift of buildings, and liquefaction, etc. Moreover, we traced and measured the damaged elements on cracks of road and ground, failure of ground and slope, uplift of buildings. Based on the field data, we tried to predict to subsurface deformation features associated with the earthquake. Finally, we suggest that surface deformation features of the Pohang earthquake were coincided with reactivation of subsurface pre-existing high-angle of reverse fault.

**P-4813**

## **The movement history of the southern part of the Yangsan Fault Zone, Gyeongsang Basin, Korea**

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The Yangsan Fault Zone (YFZ) was developed into the NNE trend in the Gyeongsang Basin, the southeastern part of the Korean Peninsula, and the Quaternary faults have been reported in the YFZ up to recently. This study suggests that the tectonic movement of the southern part of YFZ can be explained at least by two different strike-slip movements, named as D1 and D2, and then two different dip-slip movements, named as D3 and D4. (1) D1: a sinistral strike-slip movement, which caused the bedding of sedimentary rocks to be high-angled toward the main fault of YFZ, formed the (E)NE trending open fold in the earlier phase and the (N)NE trending tight fold in the later phase. (2) D2: a dextral strike-slip movement, which was marked by the slipping of the high-angled beddings as fault surfaces, formed the predominant sub-horizontal slickenlines and sub-vertical slickensides and the main fault rocks of YFZ. The second order R and R' faultings and X faulting occurred in the earlier and later phases, respectively, and formed the sigmoidal drag folds accompanied with these movements. (3) D3: a conjugate reverse-slip movement slipped along fault surfaces which trend (E)NE and moderately dip (S)SE or (N)NW. The slickenlines, which plunge in the dip direction of fault surfaces, overprint the previous sub-horizontal slickenlines. The fault is characterized by S-C fabrics, which were superimposed on the D2 fault gouges, and fault surfaces, which show ramp and flat geometry, and formed the asymmetric and drag folds and collapse structures accompanied with it. The D3 dispersed the orientation of the main fault surface of YFZ. (4) D4: a Quaternary reverse-slip movement offset the Quaternary deposit, and formed S-C fabrics on it. The D4 fault surfaces are developed in the extensions of the D3 fault surfaces of basement rocks, like the other Quaternary faults within YFZ. It indicates that these faults were formed under the same compression of (N)NW-(S)SE direction. And after that, the active faults are assumed to occur in the Korean Peninsula under the compression of ENE-WSW direction.

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**P-4814**

## **Database of the paleoseismological surveys on active faults in Japan**

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Geological Survey of Japan/AIST has opened the Active Fault Database of Japan since 2005. This database contains results of paleoseismological surveys on active faults in Japan, which were published in scientific journals and surveys reports. Active fault traces in this database are divided to "behavioral segment" based on both of the faulting events and geometry of them. Several segments close to each other make "fault system" that could generate large earthquakes with multiple ruptures.

Current version of the database includes 583 behavioral segments and 320 fault systems. Each behavioral segment is evaluated in length, trend, dip, slip-rate, timing of the last faulting event, average recurrence interval, ratio of elapsed time and 30-years-probability of the future faulting event. For calculation of 30-years-probability, time-dependent model is used for behavioral segments of which both of a recurrence interval and age of the last faulting event are known, whereas Poisson model is used for them of which only a recurrence interval is known.

Recurrence interval is one of the important paleoseismological data to calculate the ratio of elapsed time and the 30-years-probability. However, only 63 behavioral segments were known there recurrence intervals based on paleoseismological surveys. And, for 33 behavioral segments, recurrence intervals are estimated by the ages of more than 3 faulting events, whereas recurrence intervals for the other 30 segments are calculated based on the ages of only 2 faulting events. Furthermore, for other 135 segments, average recurrence intervals are calculated by their slip-rate and the amount of slip per event. The age of the last faulting event are another important paleoseismological data. In the Active Fault Database of Japan, those of 208 behavioral segments are contained. The age of most recent events on 47 behavioral segments are related to historical earthquakes recorded in documents.

**P-4815**

## **Geomorphic and paleoseismic investigation along the central part of the Ulsan Fault at Singye-ri, Gyeongju, SE Korea**

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The Ulsan Fault is the one of the major active fault in SE Korean Peninsula. The NNW-SSE trending Ulsan Fault is a reverse dominant oblique slip fault dipping to the east and extends ~50 km on land. Along the central part of the Ulsan Fault, especially Singye-ri area, several sub-parallel faults and dome-shaped hills are developed. To understand the topographic formation process and propagation process in the central part of the Ulsan Fault, detailed geomorphic analysis using remote sensing data and paleoseismic investigation were carried out.

First of all, we deciphered the old aerial photo and DEM (Digital Elevation Model) produced by 1:5,000 digital map. From the analyses, several lineaments, deformed alluvial fans, and back-tilted surfaces were identified. Extracted lineaments are well matched with the slope changing positions where induced to develop the back-tilted surfaces. Along this zone, we could not observe any clear evidence of river erosion. indicating dominance of tectonic deformation in the mechanism of these geomorphic features. Second, on the basis of aforementioned data, we investigated all streams flowing perpendicular to the fault. During the fieldwork, we found several fore-thrust dipping to the east and back-thrust dipping to the west. The locations of these faults are well-matched with lineament and slope transition zone. Both fore- and back-thrust displaced Quaternary layers indicating Quaternary activity. For further detailed study, we have collected OSL and 14C samples. After obtaining age data, we could understand the formation process of back-tilted surface and propagation of central part of the Ulsan Fault.

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**P-4816**

## **Luminescence dating of terrestrial sediments in Quaternary faults along the Yangsan and Ulsan Faults, South Korea**

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The Korean peninsula, located in the eastern margin of the Eurasian plate, has long been regarded as a tectonically stable region. However, since the early 1990s when luminescence dating emerged as one of the useful tools for Quaternary dating, a growing number of chronological evidence has revealed that not a few faults in the Korean peninsula, particularly in its southeastern part, were active during the Quaternary (Choi et al., 2003a, b). In addition, in the last few years, two consecutive earthquakes occurred in southeastern Korea, one in Gyeongju ( $M_L$  5.8, 12 Sep. 2016) and another in Pohang ( $M_L$  5.4, 15 Nov. 2017), which have drawn keen national-wide attention to seismic safety of Korea. Recently, along the Yangsan and Ulsan Faults (SE part of the peninsula), unconsolidated terrestrial sediments were found to be cut by two age-unknown faults (Byeog-Gye and Cheon-Gun faults), thus establishing chronology of these sediments is expected to provide essential information to reconstruct the history of the fault movements. To figure out the depositional ages of the sediments, we applied luminescence dating methods using various signals in quartz and feldspars; these are conventional optically stimulated luminescence (OSL), thermally transferred OSL (TT-OSL) and isothermal thermoluminescence (ITL) signals for quartz and post infrared-infrared stimulated luminescence (pIR-IRSL) signals for K-rich feldspars. For both Byeog-Gye and Cheon-Gun sites, with the measurement protocols and materials that passed through several suitability tests, we obtained luminescence ages of ~ 60–100 ka for sediments cut by the faults. Also, it appears that both faults are covered by the late Holocene (Meghalayan Stage) sediments (~ 2–3 ka). These age constraints argue against the conventional view that the Korean peninsula has been tectonically stable during the Quaternary.

### Acknowledgment

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**P-4817**

## **Dual polarimetric GPR survey for investigation of quaternary seismic faults**

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A quaternary seismic fault holds records of seismic history of the area. Mapping and studying quaternary seismic faults of an area provide us important information for evaluating potential hazards of the area. Geophysical exploration techniques are practical method to investigate faults. Ground Penetrating Radar (GPR) is one of such geophysical exploration tools. A GPR transmits radar pulses (electromagnetic waves) into the subsurface to receive echo pulses that are reflected from objects. Analyzing received echoes, one can obtain information about subsurface structure.

GPR has long since been put in the field of fault study, and the results have been reported in literatures. A quaternary fault, however, has turned out to be rather a difficult target for GPR for two reasons. Firstly, the difference of dielectric constant of materials over the fault face is very small, which makes a radar echo from the boundary very weak. Secondly, the fault face in most cases is a vertical boundary rather than a horizontal one hence much of incident GPR pulse energy is deflected to directions off the surface, which makes the received echo even weaker. The problem has been managed by applying signal processing technique to the measurement data. However, one has to know that some processing such as filtering process can spoil the target signal whereas deconvolution process, which is practiced to enhance the target signal, could introduce false information into the processed data.

In this paper, we propose dual polarimetric GPR measurement as an alternative technique to manage the problem. The proposed technique carries out 2-D GPR survey on the ground surface twice using two polarizations which are orthogonal to each other (single polarization in a 2-D survey). This technique produces two polarization measurements data at every measurement point in the survey area. Vertical boundary does not return strong coherent radar echoes but weak incoherent scattering echoes whereas subsurface objects that are larger than the scale of wavelength of GPR pulse returns strong coherent echoes which mask weak scattering echoes. We take difference of two measurements to cancel the strong coherent echoes. Weak scattered echoes from fault face might be spoiled by this operation to some degrees, but, echoes thanks to its incoherent nature, the degree of being spoiled is much smaller than that for the case of coherent echoes.

We have so far examined this technique by applying to a liquefaction vestige which was found after the M5.2 earthquake that had taken place on 14, November in 2017 in South Korea. A 100 MHz GPR was used in the test. The effect of technique was confirmed by improved GPR image of the thin vertical flow pass of ground water.

**P-4818**

## **Late Holocene shoreline deformations along the Gökova Bay, SW Turkey**

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Gökova Bay is located in the south Aegean Sea and is one of the most seismically active regions in Western Turkey. One of the challenging aspects of the seismic hazard assessments in the region is the offshore faults. There is almost no information about their paleoseismic activities. In contribution, we carried out fieldwork along the shorelines of the bay and strive to identify the geomorphic and sedimentological markers of modern and historical coseismic deformations. We started from Bodrum area (the largest coastal touristic centre) right after the 21 July 2017 Bodrum-Cos (Mw: 6.6) Earthquake. We found co-seismically uplifted (20 cm) tidal-notches associated with this earthquake together with up to 80 cm a.s.l. uplifted beach deposits on Karaada Island (1 km South of Bodrum). Radiocarbon (<sup>14</sup>C) ages from uplifted beach deposits yield 2800±30 yr BP (uncalibrated) indicating late Holocene seismic activity. There are also geomorphic markers of historical coseismic uplift along the southern and northern shoreline of the bay. We could not find datable material from the southern shores but the presence of uplifted tidal notches at 40 cm to 120 cm higher than modern sea level was ample. Nevertheless, tidal notches are higher along the northern shores of the bay. We identified at least 5 levels of tidal notches, which are at 20 cm to 170 cm higher than modern sea level. Radiocarbon (<sup>14</sup>C) age of a lithophaga fragment from 100 cm high tidal notch yielded 2314±32 yr BP (uncalibrated). Although there are no other age data from higher and lower levels for the time being we plan further research on the area. This contribution provides first evidence of the presence of coseismically uplifted shorelines along the Turkish coasts of the Aegean Sea. It also demonstrates the presence of active faults very close to the shoreline that are capable of producing large earthquakes and might be important for the regional seismic hazard. This project is supported by TUBITAK 1002 Program (Project No: 118Y116) and Istanbul Technical University Research Fund (Project No. TGA-2018-411184).

**P-4819**

## **Archaeoseismic evidence for a Late Roman earthquake in Ceuta (northern Africa)**

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We present the first archaeoseismic evidence for earthquake damages in Northern Africa, in Roman buildings in the Spanish city of Ceuta. Strong earthquakes above a Richter magnitude of M 5.5 usually leave traces on the Earth's surface along a fault, which are mapped and evaluated. In addition, there are other earthquake effects, such as soil liquefaction or mass movements, e.g. landslide, which can also occur away from the fault. This does not necessarily include collapsed buildings, so-called archaeoseismological studies. This requires very detailed knowledge of the buildings, their history and architecture and any structural modifications or changes in use over time and cooperation with archaeologists and other professionals. In Ceuta, we have almost no large outcrops and access to geological features and structures. In the 1540s the Portuguese invaders began building the Royal Walls including bastions, like the Baluarte de la Bandera. The bastion is built on Arabic and Roman remains dating back to the first century AD. In the excavations of the fortress, many open cracks in the masonry and foundation could be documented. The cracks are often traceable over several meters and rotated Roman walls of a tower constructed very late second AD/early third century AD (*terminus post quem*) in an anti-clockwise sense. Most probably, an impulsive event led to the tearing of the bedrock and rotation of the wall in the foundation. The well-known building history of the fortress and its predecessor buildings and dates suggest a "late Roman" destruction phase in the second half of the 7th century (younger than 650 AD; *terminus ad quem*), documented in several places. We present T-LiDAR scans and an assessment of the structural damage. The historical earthquake catalogues do not contain a strong event at the wake of the Dark Ages. The causative fault may be situated at along the nearby contact of Alpujarride and Malaguide complexes in Ceuta peninsula, that may have been reactivated. However, we cannot exclude a far-field earthquake within the geodynamical context of the Straits of Gibraltar.

**P-4820**

## **Far-field effects induced by the 2016 Oct. 30th Central Italy earthquake on Roma historical monuments: the Necropoli Ostiense case study**

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The 2016 October 30<sup>th</sup> Norcia earthquake has been the largest main shock (Mw 6.5) of a seismic sequence that affected Central Italy since 2016 August 24<sup>th</sup>, causing more than 300 casualties and very large damage in Amatrice and surrounding villages (MCS intensities up to X-XI).

The event was clearly felt all around in Central Italy and even in Rome, at a linear distance of about 130 km, where it caused locally damages, especially to historical buildings, and threatening the stability of some infrastructures. In a few hours almost 200 surveys were conducted with the aim to verify effects (mainly fissures and cracks) on both historic and modern buildings. Strongest damages were concentrated mostly in the southern area of the city centre: in particular, the San Paolo basilica was closed to verify local instabilities, after the opening of cracks and fall of cornice's pieces. Similar damages were also observed on other relevant historical and artistic monuments (e.g. Porta Portese gate, Sant'Ivo alla Sapienza church and San Lorenzo and Santa Maria Maggiore basilicas).

Immediately after the earthquake, ISPRA experts in cooperation with local archeological superintendence authorities were asked to implement a damage assessment in the Necropoli Ostiense archaeological site, located next to the San Paolo basilica. This is the best preserved part of a vast necropolis, flanking the eastern side of the ancient via Ostiensis, within the alluvial plain of Tiber river and it lays at the foot of a 20 meters high cliff, made with pyroclastic deposits.

The whole archaeological site was affected by a set of N-S trending parallel cracks presumably induced by the earthquake. In order to characterize with great detail this site in terms of geology and stratigraphy, an active seismic survey was carried out in the archaeological site, by using the surface-waves method, aimed at the characterization of alluvial deposits in terms of shear waves velocity ( $V_s$ ), that is a parameter directly related to stiffness of buried material. After a preliminary survey (November 2016), according to the above evidences and to the original hypothesis that the observed crack pattern are co-seismic effects induced by the seismic shaking, a simple manual crack gauge network on 5 main discontinuities was implemented and installed. The general stability of the cracks seems to confirm the hypothesis of a single shock due to the earthquake's dynamic input. The relationship between the Necropoli and the neighboring Tiber's valley has been also investigated. Further geophysical surveys will allow to better define the interaction between archeological structures and underground setting.

These actions are needed to characterize the impact of strong earthquakes from Central Apennines on cultural heritage in Roma in order to identify proper mitigation measures.

**P-4821**

## **Cone penetrating testing and continuous coring combine to infer a mid-term plate-boundary slip rate for the Imperial Fault, California**

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We collected cone-penetrometer (CPT) soundings and continuous cores to extend the subsidence record for a sag depression along the high-slip section of the 1940 Imperial fault rupture where 6 m of right-lateral slip was documented. The Imperial fault is the main plate boundary fault at the international border with Mexico and has been interpreted in the past to accommodate up to 40 mm/yr of plate boundary shear. The site is a 20 m-wide releasing step along the rupture, and sustained about 90 cm of subsidence in the 1940 earthquake. Previous paleoseismic work at the site has demonstrated that earlier earthquakes in ca 1726 and 1500 produced nearly identical amounts of vertical subsidence in the sag suggesting that they also likely sustained a similar amount of dextral slip. In contrast, two other interpreted earthquakes produced 0-6 cm of subsidence and were interpreted to be the result of moderate earthquakes, as occurred in 1979.

Two cores and 26 CPTs were acquired across the sag that penetrated a succession of lake and deltaic deposits to ~25 m depth: the sediments west of the fault date to about 4500 years at the base of the core whereas in the sag itself, the sediments are about 2-2.2 ka at 25 m depth. Thus, the sag records about 8 m of vertical subsidence in the past 2.2 ka, which suggests the occurrence of about 9 events if the 1940 and 1726 events are used as a guide. This results in an average recurrence interval for such events of about 230 years (considering the ~80 year open interval). If each of these larger events was produced by a similar amount of strike-slip as in 1940, then this implies a slip rate of about 26 mm/yr, which is consistent with recent InSAR and GPS studies that suggest a lower rate with additional slip on faults to the west.

P-4822

## Surface Ruptures Following The 26 December 2018, Mw4.9, Mt. Etna Earthquake, Sicily (Italy)

EMERGEO WG

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The Mw4.9, Mt. Etna earthquake occurred on 26/12/2018 at a depth of about 1 km (<http://cnt.rm.ingv.it>). The event struck the southeastern sector of the volcanic area producing severe damage in several towns. The earthquake was likely induced by the magmatic dike intrusion of Mt. Etna accompanied by deformation of the volcanic edifice and thus generating the stress redistribution in the surrounding faults. The Mw4.9 causative fault is the Fiandaca fault (FF), belonging to the Timpe tectonic system in the eastern flank of the Mt. Etna (Fig. 1).

The FF is NW-SE oriented and turns in ~NS direction in the southern portion. The fault is locally characterized by aseismic slip and in the past by coseismic surface ruptures.

The EMERGEO group (geological emergency group of the Istituto Nazionale di Geofisica e Vulcanologia) promptly activated to map the coseismic ruptures along the FF. The survey is presently ongoing. About 1000 points of measurements relative to geometry and kinematics of the ruptures have been collected so far (Fig. 1).

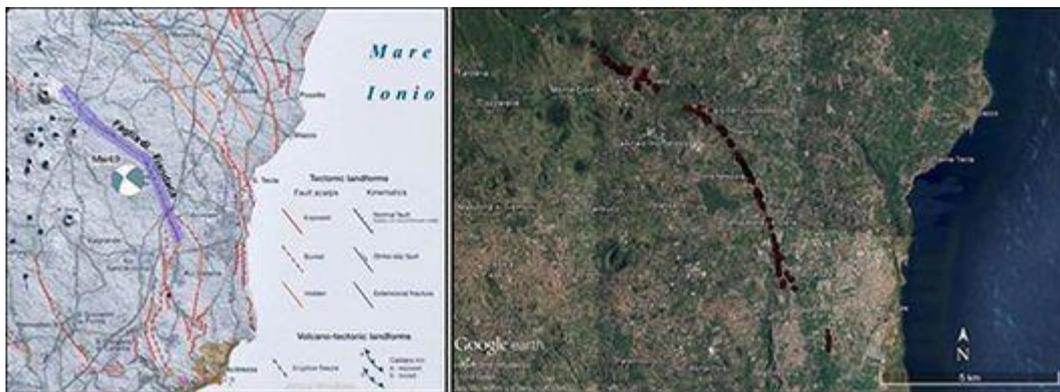


Fig. 1 – Left: Active faults in the south-easternmost flank of the Mt. Etna (Azzaro *et al.*, 2012). Light blue band includes the area of coseismic ruptures surveyed by EMERGEO WG along the Fiandaca fault. The TDMT solution of the event is placed at the epicentral location (<http://cnt.rm.ingv.it>). Right: Points of measurements (red circles) collected by Emergeo WG (from 26/12/2018 to 5/01/2019).

We documented significant surface faulting for a minimum extent of 7 km. The ground ruptures are aligned and continuous along the FF, displacing coherent and incoherent deposits and anthropic materials (Fig. 2). They exhibit right lateral transtension, with values of slip also of 30 cm. The main deformation zone is tens of meter wide and is composed by sub-parallel rupture traces in a left-stepping en echelon arrangement. Where present, ruptures occur in coincidence to the long-term expression of the fault, that is generally expressed as a topographic inflection. Intense damage at buildings is localized over and close to the ground rupture “line”.

The integration of the geological data with seismological and geodetic data will lead to an accurate comprehension of the seismic process. Given the accurate mapping of the ruptures, the 2018 Mt. Etna earthquake represents a

fundamental case to analyze the hazard associated to ground displacement along the faults in Mt. Etna area, and to increase our knowledge on surface faulting process in volcano-tectonic environments.



Fig. 2 – Coseismic ruptures of the Mw4.9 event.

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**P-4823**

## **Structural architecture and glacitectonic evolution of the Mud Buttes cupola hill complex, southern Alberta, Canada**

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The Mud Buttes in southern Alberta (Canada) is a large, arcuate cupola hill composed of intensely folded and thrust sandstones, siltstones and mudstones of the Cretaceous Belly River Formation. It forms one of a number of glacitectonic compressional structures (e.g. Neutral Hills) which occur within a geomorphologically complex area separating the strongly streamlined trunks of the former Central Alberta and Maskwa palaeo-ice streams. Glacitectonism responsible for the development of the internally complex Mud Buttes landform occurred at the margin of the Prospect Valley glacier lobe of the Laurentide Ice Sheet. Analysis of the deformation structures reveals that construction of this landform occurred in response to at least two phases of south-directed ice sheet advance separated by a period of retreat. The first phase led to the formation of a forward propagating imbricate thrust stack leading to polyphase deformation of the Belly River Formation. D1 thrusting led to the detachment of thrust-bound slices of bedrock which were accreted to the base of the developing imbricate stack. This process resulted in the structurally higher and older thrust-slices being progressively “back-rotated” (tilted), accompanied by D2 thrusting and folding. Further thrusting during D3 was restricted to the core of the Mud Buttes as the deforming sequence accommodated further compression imposed by the advancing ice. Minor oscillations of the ice margin led to localised brittle-ductile shearing (D4) of the bedrock immediately adjacent to the ice contact part of the thrust stack. The second ice advance led to the accretion of a relatively simple thrust and folded sequence seen on the northern side of Mud Buttes. The resulting glacitectonic landform was subsequently overridden by ice advancing from the north-northwest.

**P-4824**

## **The potential of periglacial slope deposits for chronological studies on glacial sediments in the Central Spanish Pyrenees**

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Due to the diamictic character and the complex depositional environment of glacial deposits chronological analyses on these deposits are often problematic. The post-LGM reshaping of glacial sediments in a periglacial environment often resulted in the formation of so-called periglacial slope deposits (PSD) that are mainly characterized by solifluction and the aeolian admixture of silt. Our study presents findings from glacial sediments in the Central Spanish Pyrenees that were associated with an MIS 3 glaciation. The presence of periglacial deposits that have OSL ages between 14 ka to 11 ka raise doubts about the MIS 3 age of the glacial deposits. According to the state of knowledge, the glacial advances in the Eastern Pyrenees were synchronous with the global LGM during the Late Pleistocene (MIS 2), but the glacial advances in the Central Spanish Pyrenees at MIS 3 were asynchronous with the global LGM. Whereas in the Eastern Pyrenees the glacial advances are dated in several well agreeing studies by surface exposure dating of boulders from lateral or terminal moraines, the asynchrony of the Central Spanish Pyrenees was postulated mainly by OSL dating on glacial and fluvial sediments and on radiocarbon dating of pollen from lacustrine deposits. We therefore applied a combined approach of geomorphological, sedimentological and pedological investigations to reconstruct the Late Quaternary landscape development under a special consideration of periglacial deposits in the Aragon- and Gallego Valley of the Central Spanish Pyrenees. Our study reveals that in both valleys the Pre-Holocene geomorphodynamics on the Late glacial deposits show clear analogies with findings from Pleistocene periglacial landscapes in Central Europe. For MIS 4 and early MIS 3 periglacial processes are proven by loess deposition and formation of solifluction sediments. The glacial sediments, which were dated in earlier studies into mid MIS 3 and counted so far as prove for the asynchronous LGM of the Central Spanish Pyrenees, are covered by periglacial deposits of Late glacial age (14 ka to 11 ka). Because we can clearly differentiate further phases of geomorphodynamics during the Holocene with truncated soil profiles and the correlate sediments of soil erosion next to undisturbed soils in periglacial sediments with a Late glacial age, we challenge the thesis of an asynchronous LGM in the Central Spanish Pyrenees and advocate a synchronous LGM in the Gallego- and Aragon valley analog to the Eastern Pyrenees.

**P-4825**

## **Erosion landscape on the East European plain, formed in periglacial conditions and its recent analog at the Yamal peninsula**

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One of the most interesting features on the East European Plain is the net of dry valleys and hollows. Dense vegetation usually covers their bottoms and slopes, so the modern erosion here is negligible in the pristine conditions. Coring in these valleys showed the features and deposits of at least two erosion events, first during late MIS-6 and the second during late MIS-2. The both periods were characterized by periglacial conditions with low air temperatures and deep permafrost, as well as very high surface runoff. The structure of these systems of dry valleys and hollows is well described with power-law magnitude-frequency relationships, close to determinations of the fractal theory. These power-law relationships don't act only near and within the belt of no erosion, where probability distribution functions of morphometric characteristics takes another form.

The same type of the erosion landscape is typical for the Arctic regions with the modern periglacial conditions, especially for Yamal, Gydan and Tazovskiy peninsulars. The size, density and structure of such valleys and gullies is quite similar to those on the East European Plain, but these features are active there (especially in the conditions of natural or anthropogenic vegetation cover deterioration). Therefore, the landscape and hydrological conditions at the modern belts of no erosion in Arctic, can be used to reconstruct the same characteristics of the erosion landscape in former periglacial conditions, first of all, typical values of the critical velocities of erosion initiation. Gully erosion and thermoerosion model was used to find the most suitable values of these critical velocities, which can explain the structure and density of dry valleys systems on the East European Plain.

This study was developed under RFBR grant 18-05-60147 "Extreme hydrometeorological phenomena in the Kara Sea and the Arctic coast"

P-4826

## **Pleistocene Periglacial Slope Deposits (PPSD) in the mid-latitudes - Is a trans-regional genetic classification reasonable?**

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Pleistocene Periglacial Slope Deposits (PPSDs) are very common in the mid-latitudes and fundamentally control the distribution and properties of the soil's parent material. The main distribution areas of PPSDs are regions more or less close (tens to hundreds of kilometres) to the ice limits of the Last Glacial Maximum (LGM) where permafrost conditions during Quaternary cold periods have favoured the formation of slope sediments by solifluction, cryoturbation and eolian processes. In mainland Europe this area stretches over hundreds of kilometres from the Weichselian ice-margin in the North European Lowland to the Central European low mountain ranges. This "periglacial corridor" between the LGM of the Scandinavian Ice Sheet (SIS) and the Alpine Piedmont Glaciation (APG) has been subject of PPSD studies for more than 50 years, and the basic concept of PPSD stratigraphy has been established starting with the description of type localities in central Germany by Semmel in 1964 and Schilling & Wiefel in 1962. In North America the effect of Late Quaternary periglacial processes on soil is increasingly acknowledged but stratigraphic PPSD concepts based on facies description that consider the environmental conditions of PPSD formation (e.g. clast fabric orientation as a matter of gelifluction, increased silt+clay content resulting from eolian admixture) have rarely been applied. A genetic taxonomy of PPSDs comparable to the one that has been used in Germany for many years is entirely missing in mapping units of Pedology and Quaternary geology. Instead of a genetic taxonomy of PPSDs an effective classification is applied based on facies-neutral properties (mainly textural and lithological parameters), and sediments of periglacial origin are mostly called colluvium. Unfortunately, the term colluvium has different meanings in North America and Europe creating further confusion in discussions. Though there are obvious terminological differences, relicts of periglacial dynamics have actually been very well known for many areas in North America and especially for the Appalachian Highlands and Interior Highlands south of the maximum extent of the Late Wisconsin Laurentian Ice Sheet (LIS), e.g. in central Pennsylvania. This contribution seeks to close a gap between North America and Europe regarding the knowledge of PPSDs and the usage of a genetic PPSD classification. We intend to start a discussion on a coordinated transcontinental approach which is needed to achieve a harmonized PPSD taxonomy. Main questions for this international research are: (i) what findings from the NE USA match with results from PPSD studies in Central Europe, (ii) is the German PPSD taxonomy suitable for a proper classification of PPSDs in NE USA, (iii) what could an international PPSD taxonomy look like and is a genetic classification feasible?

P-4827

## Reconstruction of high- and low-drag alpine glaciers in the Little Ice Age: implications for palaeoclimatic inferences from former glaciers

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Basal shear stress represents the driving stress required to overcome frictional resistance to glacier flow. Modelled reconstructions of former glaciers conventionally use a value of  $100 \text{ kPa}^{-1}$  based on the yield stress of perfectly plastic ice. This allows construction of longitudinal profiles from which topographic maps of glacier surfaces are used to calculate hypsometry and equilibrium line altitudes (ELAs). We test the universality of the  $100 \text{ kPa}^{-1}$  yield stress by reconstructing longitudinal basal shear stress profiles from glaciers in the western Alps based on their Little Ice Age (LIA) extents. Glacier retreat from LIA maximum terminal moraines (c. 1820-1860) has created forelands of well-preserved subglacial and ice-marginal landforms. Landform-based reconstructions are checked against the cartographic representations of glaciers in the 1862 Carte d'État Majeur. Ten glacier forelands are used to reconstruct LIA maximum glaciers and cross-sectional form ratios, from which basal shear stress ( $\tau_b$ ) profiles are calculated empirically for former ablation zones. These reveal that few glaciers conform to the conventional  $\tau_b$  of  $100 \text{ kPa}$ . We find that glaciers resting on till beds averaged  $59 \pm 29 \text{ kPa}^{-1}$ , and glaciers on scoured rock beds averaged  $151 \pm 72 \text{ kPa}^{-1}$ , while two glaciers with mixed till and bedrock beds had mean  $\tau_b$  of  $113 \text{ kPa}^{-1}$  and  $145 \text{ kPa}^{-1}$ . At one glacier overburden stress was calculated from laboratory oedometer testing of a till block, which implied a lower shear stress than calculated from geomorphological evidence.

The spread of values indicates that basal shear stress accumulates to overcome those bed elements imparting the greatest resistance to ice flow. The implication for glacier reconstruction is that an appropriate shear stress should be used to model a glacier long profile where geomorphological evidence of former bed conditions is preserved. We then examine the sensitivity of reconstructed ELAs of Younger Dryas age glaciers to basal shear stresses ranging from  $\tau_b = 50 \text{ kPa}^{-1}$  to  $150 \text{ kPa}^{-1}$ . We find that the effect on ELA and palaeoclimatic reconstruction is potentially significant, but only if a uniform bed resistance is applied to the entire long profile. More realistic iterations suggest ELA is not critically sensitive to shear stress differences in the lower glacier. In the field it has proved hard to determine how extensive former till beds were in the alpine environment, due to rapid post-depositional reworking of frost-susceptible basal tills. We suspect that such low-drag bed conditions have been widely underestimated in existing reconstructions.

**P-4828**

## **Glacial vs. periglacial forming in Central Germany during the Pleistocene – examples from the Hohburg Mountains and the Rhoen Mountains**

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After Otto Martin Torell's speech in Berlin 1875, it became accepted, that the Pleistocene Scandinavian glaciation had covered large parts of the Central European Lowland and some of the highland mountain areas. 31 years before Torell's speech, Bernhard von Cotta, Carl Friedrich Naumann, and Adolph von Morlot had already described independently both glacial and periglacial traces in the Hohburg Mountains, a transaction site northeast of Leipzig, located between the German Highlands and the North-German Lowland. But Charles Lyell and Albert Heim, who had already studied glacial traces in the Swiss Alps, still declined the glacial traces of the Hohburg Mountains in 1874 as purely periglacial features. Later on and until today, the glaciation of the Hohburg Mountains during the Saalian glaciation became recognized as well as the periglacial forming during the Weichselian glaciation. Results of geomorphological field survey and both field and laboratory analyses of the sediments prove the glacial and periglacial forming of the Hohburg Mountains.

Some authors (c.f. Liedtke 1981, Rother 1995, Raab 1999) presented clear evidence of the mountain glaciation of the Black Forest, Bavarian Forest and Harz Mountains during the Pleistocene. Until now the autonomous glaciation of the Ore Mountains and of the Rhoen is declined by most of the authors. But others, c.f. Härtung, described the relief forms as of both glacial and periglacial origin in different locations of the Rhoen Mountains throughout the 20th century's literature. Geomorphological field surveys and both field and laboratory analyses of these sediments, conducted during the last two decades, showed no glacial forming features. However, the largest and mightiest fossil rock glacier and block accumulation in Germany was identified in the Rhoen Mountains. The Schafstein rock glacier is a clear evidence of a strong periglacial influence of the Rhoen Mountains during the Pleistocene. Results of its characterization (cf. block sizes, block roundness), refraction seismic profiles, temperature measurements between the blocks and drone based IR camera measurements will be presented.

**P-4829**

## **Schmidt hammer exposure-age dating of (peri-) glacial landforms thanks to R-values calibration by historical data in the Southern Swiss Alps**

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Within the framework of scientific researches related to geomorphoclimatical evolution of the Alps during Lateglacial and Holocene, only few studies were carried out on periglacial sedimentary terrains. In order to reconstitute the palaeoenvironmental history of the alpine periglacial domain, this research has focused on the morphostratigraphy of periglacial and glacial landforms of the Splügenpass region (transnational pass between Switzerland and Italy) and of the upper part of Val Scaradra (north-eastern part of the Ticino Canton).

The surface dating was performed with the analysis of Schmidt hammer rebound values (R-values). The joint utilisation of palaeogeographical method, allowing the reconstruction of past glacier and rock glacier extensions, and the definition of age-calibration curves of R-values on historical constructions and thanks to historical cartography, allowed Schmidt hammer exposure-age dating (SHD) and the definition of relative chronologies with high temporal resolution.

In the Splügenpass region, Schmidt hammer R-values measured on metagranite porphyr were calibrated thanks to two historical retaining walls for a mule track, attributed respectively to the Roman Epoch (1.65 ka cal BP) and to the Late Middle Ages (0.7 ka cal BP). Thanks to SHD, it was possible to establish a chronology of the Lateglacial glacier retreat and to date rock glaciers and talus slopes development. The results show that Splügenpass was ice free since  $15.8 \pm 2.6$  ka cal BP, whereas the Splügenpass rock glacier started its formation during the Lateglacial Interstadial (the minimal age of the front is of  $12.6 \pm 2.6$  ka cal BP).

In the upper Val Scaradra, R-values were measured on large boulders of the proglacial area of the Scaradra glacier composed by micaschists and paragneisses. From a Younger Dryas lateral moraine to the glacier portal, several terminal moraines were studied by SHD in order to determine the glacier fluctuation during the Holocene. Schmidt hammer R-values were calibrated thanks to historical topographic maps of the area: (1) the original relief for the Dufour Map (Topographical Map of Switzerland, sheet OA 443, Feuille XIX. Sect. 2, 1:50'000) cartographed by Hermann Siegfried in 1854; (2) the editions of the Sheet 504/Olivone of the Siegfried Map (Topographical Atlas of Switzerland, 1:50'000; the first edition is from 1872) and; (3) the editions of the Sheet 1253/Olivone of the National Map of Switzerland 1:25'000 (the first edition is from 1966).

The SHD age-calibration based on historical surfaces of known age highlights a non-linear behaviour of surface weathering from the Lateglacial to the Late Holocene. These investigations will also improve the knowledge of the potential use of SHD for numerical-age dating in alpine geomorphological studies, a field of research that is currently rapidly developing and that can be an alternative to Cosmogenic Nuclides dating in the understanding of complex glacial-periglacial-paraglacial landsystems.

P-4830

## Lichenometry of wandering blocks approaching the landslide surface velocity

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Landslides, creep slow movements and rockfalls have been widely studied from modern times by using remote sensing, which goes back up to 20 years by using GPS and INSAR and almost 100 years by using aerial photographs. The use of ancient maps and even old paintings from the 19th century allow going back up to 200 years. In this work, we introduce the use of lichenometry of wandering blocks to estimate the velocity of a landslide located at El Portalet (Central Pyrenees, Spain), by using these blocks (decametric size and limestone lithology) as time and spatial markers. To do this, we have used lichenometry to estimate the age of the blocks and determinate the runout distance traveled by the blocks detached from the source area, by geomorphologic markers. We have obtained the annual growth rate (GR) of the calcicolous lichen specie *Aspicilia calcarea* (Hoffm.) from cemeteries, historical buildings and infrastructures for the last 300 yrs. A lineal GR value of 0.45 mm/yr has been estimated. The oldest block was dated in 600 CE  $\pm$  40 yr. and the modern one in 1750 CE  $\pm$  5 yr. The analysis of aerial orthophotos and field work of the study zone reveals two N- and S-oriented chutes in which wandering blocks were located: the North path (NP) and the South path (SP). The inventory map had been carried out taking in account the wandering blocks disseminated close to 1 km in length from the source area. The lichenometry analysis yields that the block surface velocity varies from 0.3 m/yr to =0.97 m/yr for the NP and 0.2 to 0.88 m/yr for the SP. However, the behavior of both chutes is opposite. Whereas the NP accelerates during warm climate periods and decelerates in the cold ones, on the contrary, the SP velocity decelerated during Medieval Warm Period and accelerated during the Little Ice Age (LIA). Estimations of the block wandering during the Industrial Era are approximated. INSAR and GPS velocity during the last 20 yrs. shows 0.2 m/yr. Clinometers and thermometers in boreholes indicate that during the last 20 years no permafrost was detected. Instead, the rupture plane for the landslide was estimated between 13 and 14 m depth and even 25 m depth for the SP. Differential behavior of both landslides seems to be related with the presence of water, the flux-direction and the presence of natural obstacles at the foot of the landslide.

**P-4831**

### **3D mapping and geological subsurface modelling in Helsinki metropolitan area, Finland**

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Ongoing urbanization has caused profound changes in land use and construction in larger cities and increased a need for detailed 3D models for specific purposes, such as construction suitability, environmental assessments offshore infrastructure. Helsinki metropolitan area (land 770.35 km<sup>2</sup>) consist of crystalline bedrock superimposed by Quaternary deposits of glacial, glaciofluvial and glacialmarine in origin. One third of the land area is covered with fine-grained (clayey) sediments with thickness varying from 1 to 35 m. The Helsinki metropolitan area was deglaciated circa 13 000 years ago and the area has undergone lacustrine and brackish marine stages, along with other Baltic Sea basin (BSB) shoreline cities. The metropolitan area emerged from BSB 8000-2000 years ago, and the areas glacioisostatic land uplift is still about 2 mm per year relative to sea level. The urban land cover expansion is increasingly focusing on areas with fine-grained soft and unconsolidated sediments with poorer ground conditions. The need for comprehensive understanding of the engineering geological properties and 3D geometry of these fine-grained superficial deposits has increased.

The present study was carried out in collaboration with the Helsinki metropolitan area cities (Helsinki, Vantaa and Espoo) and Geological Survey of Finland. The combined use of Quaternary maps, LiDAR digital elevation models (DEM) and site-specific geophysical and sediment core investigations together with cities geological maps and geotechnical investigations provide a basis for high-resolution digital terrain characterization and 3D sediment mapping; an integrated approach by the Geological Survey of Finland. This study focuses on the distribution and characteristics of fine-grained deposits and on mapping underlying permeable glaciofluvial sand and gravel deposits and their hydrological parameters.

The fine-grained sediment case studies displayed that deposits (clay basins) consist of two different types of fine-grained units, postglacial lacustrine silty clays and sulphate-bearing brackish water muds, with different engineering-geological properties. These units are separated by an undulating erosional surface (unconformity). This unconformity is of high engineering geological significance, because the overlying organic-rich brackish water mud has a poorer bearing capacity and higher abundance of sulphide minerals. The present study provides a basis for characterization and classification of basin fill deposits by using their lithology, surface geometry, sediment thickness, lateral continuity and basin characteristics. The goal is to provide models on e.g. the distribution of greenish-grey brackish water mud and the appearance and continuity of clay-covered aquifers.

P-4832

## Challenges in assessing land systems and slope stability from a glaciated volcano: the Mount Meager Massif (BC, Canada)

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Mount Meager is a glaciated volcanic massif located in SW British Columbia, Canada. Within an area of about 225 km<sup>2</sup>, the massifs shows both modern and ancient glacial and periglacial landforms, as well as landslides characterized by high frequency and magnitude. Many studies have focused on present and past landslide activity at Mount Meager, but only few studies have investigated the role of recent deglaciation on slope stability. According to the GLIMS world Glacier Database Mount Meager Massif supports 32 alpine glaciers. No detailed studies have focused on the Mount Meager present glacier morphology and activity, nor on the effects of regional glaciation on Mount Meager volcanic activity. In this study we approached the present glacier morphology and activity at Mount Meager volcano, as well as landslide events by identifying physiographic land types, reflecting both lithology, structural and geomorphological constrains.

We applied an historical approach to digital interpretation of over 500 airphotos of the Mount Meager massif, creating 8 subset of images from 1947-2006. By using SfM software we provided high-resolution orthophotos (0.42-1.13 m/pixel) and tested the cartographic suitability of the historical datasets by comparison with a Lidar DTM acquired in 2015-2016. We performed interpretation of Lidar and orthophotos and identified landform components of Mount Meager Massif: glacier outlines, moraines, landslides deposits, scarps, and fractures. Geomorphic parameters were assessed: glacier front position from 1951 to 2016, and relative retreat of front position in 2016; glacier length and basin area; headwall height and aspect of cirque; elevations of glacial accumulation zone. The historical approach allowed interpretation of glacier fluctuations: even if with different parameters and activity, glaciers at Mount Meager Massif are generally retreating. Total cumulated retreat is about 8 km<sup>2</sup> and retreat is about 20% with respect to the 1951 glacier extension.

We recognized mutual conditions posed by present and past glaciations and hydrothermal activity to present-day volcanic massif stability and glacier morphology. We developed a conceptual model to explain the high landslide frequency and the glacial activity at Mount Meager: rocks are fractured and altered by interaction with past ice sheets and today's glaciers are mostly debris-covered and sit in collapse scars from large landslides. Climate-related deglaciation of volcanic mountains not only cause changes in ice cover, but affects regional and local hydrology, slope stability, sediment supply, hydrothermal circulations, leading to short-term and long-term consequences on the overall relief geomorphology.

**P-4833**

## **Constraining the glacial history and relict landscapes of the Cheshire Plain and south-west Pennines: ice-marginal limits, landsystems and geotechnical implications.**

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In Great Britain, numerous attempts have been made to constrain the maximum extent of the late Devensian British-Irish ice-sheet (BIIS) through the mapping of distinctive ice-marginal landforms such as end moraines and lateral meltwater channels. However, in the south-west Pennines, where the geomorphological signatures are unclear, significant uncertainty remains regarding the location of the ice margin with numerous ice limits for the Late Glacial Maximum (LGM) having been proposed by various authors.

In these circumstances, till geochemistry provides an alternative approach that can be used to determine former ice limits and ice-flow directions. This approach is routinely used in Antarctica for example to determine provenance, ice-flow patterns and paleoclimate conditions. Within the context of the UK however, the boundaries between late Devensian tills and those belonging to the Mid Pleistocene are not mapped with any certainty. In addition, little work has been undertaken on the tills found within inland locations due to the lack of natural exposures, with most work to date focussing on coastal sections. As a consequence, data concerning the location, consistency, age and depth of inland tills remains sparse, leading to great uncertainty regarding variations in local ground conditions. Ice-marginal landsystems are associated with significant spatial heterogeneities in this regard, with the associated variations in the geotechnical properties of near-surface materials posing significant engineering challenges.

This poster presentation forms part of a broader PhD project that will assess the extent to which clast provenance analysis and till geochemistry can assist in the identification of former ice limits in inland locations where the geomorphological signatures are absent or unclear. The results of preliminary analyses on samples obtained from cores along a 80km transect that traverses a former Late Devensian ice limit within the Cheshire Plain will be presented. In addition, these preliminary results are compared with an easterly transect extending into the Peak District (an area of Pre-Devensian tills) in order to assess the degree of variability in relation to both the local geology, age and ice-sheet configuration.

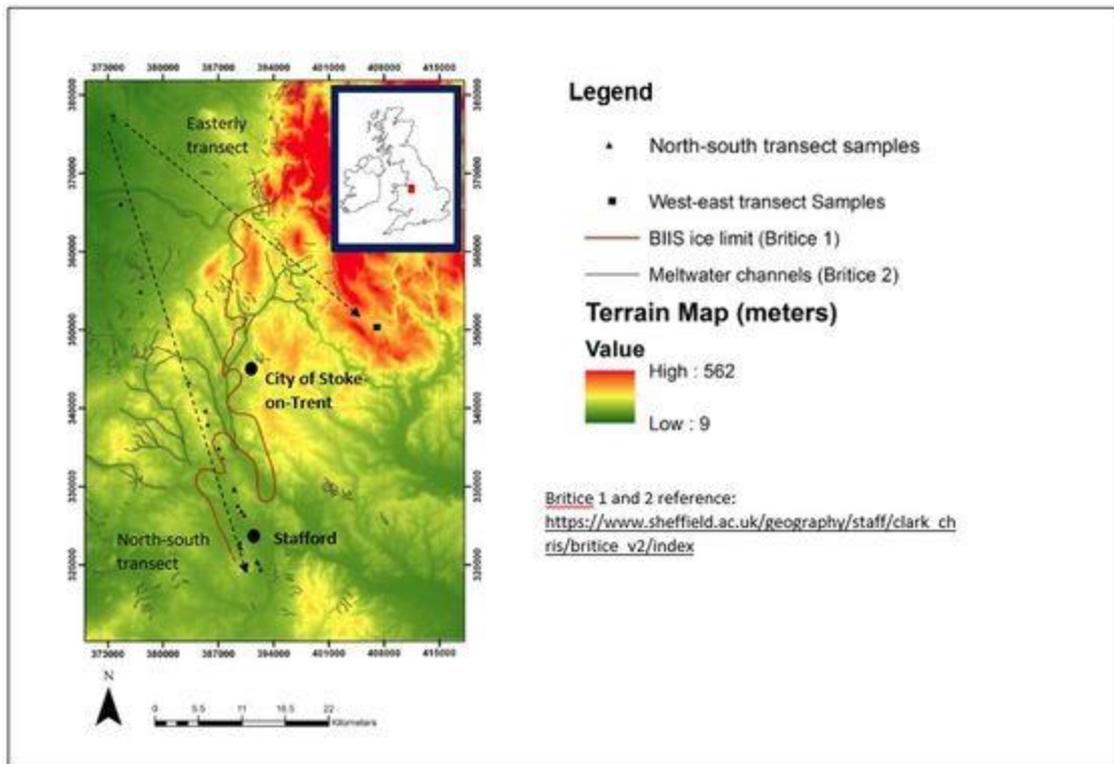


Figure 1. Sample transects and ground core locations in the Cheshire Plain and south-west Pennines.

**P-4834**

## **The impact of climate cooling on the evolution of the Middle and Late Pleistocene sedimentary environments in Central Europe**

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One of the most interesting areas where the cyclicity of climate changes is clearly pronounced is Central Europe. This area has been affected by both successive Scandinavian Ice Sheet (SIS) transgressions and the development of various terrestrial environments in periods between these transgressions. Despite the fact that periods of cooling the climate without the direct presence of an ice-sheet occupy about 70-80% of the time, the knowledge about them is the least well-known.

During long periods of the climate cooling, the area of Central Europe experienced repeated aggradation of permafrost. The timeframe of permafrost presence and its type is well recognized for the Weichselian Glaciation. However, information about the presence of permafrost from before Eemian Interglacial is few.

Selection of key areas is determined by location in the periglacial zone in cold periods of the Middle and Late Pleistocene. On this assumption, it covers Central Europe – the Central-European Lowland, i.e. Poland, east part of Germany and the west part of Ukraine. Thereby, research will cover over 1500 km latitudinal extension area. Such a large area requires an indication of test areas, where deposits of two the most typical sedimentary environments existing in the periglacial zone – fluvial and aeolian will be documented.

The main goal of the project is the reconstruction of fluvial and aeolian depositional environments in cold climate phases of the Middle and Late Pleistocene in Central Europe:

- Determination of the conditions of functioning of the fluvial and aeolian environments in cold periods of the Middle and Late Pleistocene in the studied area.
- The reconstruction of the type of permafrost, number of phases and their ages, the rate of the permafrost aggradation and degradation in the studied period, and the correlation of cryogenic horizons with Marine Isotope Stages (MIS).
- Characteristics of local conditions affecting the development of permafrost, as well as the determination of the textural and structural features of the sediments and obtaining which of them were determined by local and regional factors.
- Reconstruction of climate changes (thermal-humid and air circulation) in Central Europe in the Middle and Late Pleistocene, with particular emphasis on the features of climate continentality.
- The development of a sampling method from sandy wedges, enabling the study of their age variability (overlapping of successive generations of wedges).
- The modification of the morphoscopic method aimed at the reconstruction of various sedimentary environments and the order of their interaction on shaping the grain surface of the quartz sand fraction.

**P-4835**

## **Periglacial alluvial fan activity over the last 100 ka: insights from a study of the Eerbeek fan (The Netherlands)**

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Periglacial fans are common in NW Europe, but in the literature little attention has been given to their formation in relation to climate variations over a full glacial-interglacial cycle. We have reconstructed the evolution of a periglacial alluvial fan in the Netherlands over the past 100 ka by combining the reconstructed 3-D, stratigraphic architecture of the fan with age control of 38 samples from two sediment cores by means of optically stimulated luminescence (OSL) and <sup>14</sup>C methods. The reconstruction shows evidence of distinct phases of clastic alluvial fan aggradation, organic accumulation (peat units) and aeolian deposition. We interpret climatic changes, and in particular the existence of permafrost in combination with vegetation absence and sufficient water availability, as the driver for fan activity, as sediment transport by running water will only occur when infiltration is hampered by a permafrost layer. The age control provides a correlation with major Marine Isotope Stage transitions during the last glacial period, and shifts in the depocentre position from more proximal to distal locations reveal the build-up history of the fan. Fan aggradation rate calculations show a general increase from MIS 5d towards MIS 3, and after that a decrease towards the Holocene (MIS 1). The lower activity during MIS 2 is probably related to further aridification and the limited presence of a seasonally thawing top layer during permafrost conditions.

**P-4836**

## **Surge-induced streaming of Two Medicine Glacier, Rocky Mountains, Montana, USA in response to climate warming, topography and a weak bed**

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During the final stages of late Wisconsin glaciation after 14,500 ybp, ice from the Northern Rocky Mountain Ice Cap (NRMIC: 150,000 km<sup>2</sup>) flowed through narrow passes in the continental divide along the crest of the Rocky Mountains and terminated as outlet glaciers on the interior plains of eastern Montana. The Two Medicine Glacier was the largest forming a ~ 2000 km<sup>2</sup> piedmont lobe comparable in size to today's Malaspina Glacier of southern Alaska. The geomorphology of its well-exposed bed east of present-day Glacier National Park is exceptional compared to other lobes and shows 50 km-long flow sets of megascale glacial lineations cut into soft bentonite-rich Cretaceous shales and identifying a former ice stream. Streamlined landforms are fringed by arcuate belts of uncontrolled hummocky moraine composed of thick (< 10 m) clay-rich clast-poor till produced by subglacial erosion of subglacial bedforms and downstream advection of remolded shale. The Two Medicine Ice Stream (TMIS) is the only paleo-ice stream so far recognized in the eastern Rocky Mountains of Montana and was likely triggered by regional climate warming, enhanced accumulation and basal melting of the eastern NRMIC and downstream surging during regional deglaciation prior to c. 12,000 ybp when mountain passes became ice free. Ice streaming was facilitated by topographic forcing of confluent outlet glaciers and their flow out onto the Interior Plains across a weak bed of easily-remolded shales rich in swelling clays.

**P-4837**

## **Holocene retreat of Jakobshavn Isbræ**

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Marine terminating glaciers, such as Jakobshavn Isbræ in West Greenland, are complex systems driven by a combination of changes in oceanic and atmospheric climate. The recent retreat and speedup of Jakobshavn Isbræ is mainly attributed to oceanic warming, while the general retreat of the Greenland ice sheet since the last glacial maximum is attributed to changes in surface mass balance. However, the relative impact of atmospheric and oceanic forcing on marine terminating glaciers of the Greenland ice sheet, and the corresponding time scales of the response remain unknown. We use a thermo-mechanical 3D ice sheet model to study the retreat history of Jakobshavn Isbræ during the Holocene (9500 BP to present) and compare it with available observational data.

The glacier retreat is simulated with the Ice Sheet System Model (ISSM) in a thermo-mechanically coupled 3D setup. The resolution is enhanced in areas with complicated topography and fast flowing ice. The model is run forward with different oceanic forcings starting from a recorded margin position at 9500 a BP. The simulated evolution of the front is compared to known geomorphological evidence, such as moraines and dated boulders.

The results show that the retreat in the fjord is strongly dependent on the bathymetry of the fjord. Furthermore, our results suggest that while surface mass balance dominates the retreat of the land based sections of the glacier, the fast flowing ice stream in the fjord is dominated by oceanic forcing and the dynamic response of the marine terminating front. Thus, our results indicate that the evolution of the land based and marine based ice in the area of Jakobshavn are driven by different external forcings, and that it is critical to resolve the detailed fjord topography.

**P-4838**

## **Ice sheet extent and deglaciation on the continental shelf offshore of northeast Greenland during the LGM**

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The Northeast Greenland Ice Stream is a key sector of the Greenland Ice Sheet because it controls ice flux into the NE Atlantic and it holds a sea-level equivalent of  $\sim 1.4$  m. Recent ice shelf loss and grounding line retreat post 2010 suggest that the ice stream and this sector of the Greenland Ice Sheet are starting to respond to atmospheric/oceanic change. The aim of the project 'NEGIS' is to reconstruct the past behaviour of the Northeast Greenland Ice Stream from the LGM to the late Holocene including the past sensitivity of the ice stream to oceanographic and atmospheric forcing. The project adopts a combined approach of terrestrial and marine geological data collection which will be used to calibrate and validate numerical ice sheet models that can predict ice stream-shelf dynamics over centennial to millennial timescales. This presentation focuses on the offshore component from the continental shelf and upper slope, focusing mainly on new marine geophysical data and sediment cores collected from mid-outer Westwind and Norske Troughs, two major cross-shelf bathymetric troughs. These bathymetric troughs acted as pathways for offshore-directed ice flow across the wide NE Greenland continental shelf during the last glacial cycle. Data collection took place during two research cruises of the RV Polarstern in 2016 and 2017. The seafloor geomorphological and acoustic data reveal a range of flow parallel and flow transverse landforms in both troughs. Well-developed mega-scale glacial lineations and drumlins record former streaming flow towards the outer shelf/shelf edge. The geophysical data also imaged flow transverse landforms such as moraines and grounding-zone wedges which record episodic grounding line retreat inshore from the shelf edge/outer shelf during deglaciation. Beyond the shelf edge of Norske Trough the continental slope is characterised by glacial debris flows typical of submarine slopes offshore of shelf-edge terminating palaeo-ice streams. Sediment cores from the troughs recovered over-consolidated subglacial tills overlain by deglacial stratified glacial marine sediments recording advance and retreat of the ice stream. Radiocarbon dating of deglacial sediments in these cores indicate that deglaciation of the ice stream from the shelf edge of Norske and Westwind troughs was underway by c. 19.2-19.7 ka cal BP. Collectively these data indicate that the Northeast Ice Stream was grounded to the shelf edge and imply a much more extensive Greenland Ice Sheet in this sector during the LGM than has hitherto been demonstrated.

**P-4839**

## **Interactions between meltwater drainage, bed erosion and ice dynamics beneath terrestrial ice streams: insights from a new experimental modelling approach.**

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The interactions between subglacial drainage, bed erosion and basal sliding govern past and modern ice stream activities, thus controlling the evolution of ice sheet dynamics and mass balance. Complex landform assemblages beneath palaeo-ice stream are the result of these interactions although timing and characteristics of subglacial processes, inferred from geomorphological and sedimentological analyses, remain often poorly-constrained. If both palaeoglaciological studies and numerical modelling have provided a tantalizing glimpse on subglacial processes occurring at ice stream beds, we here present a new analog modelling approach. This approach has been underestimated in glacial sciences while having the potential to circumvent the challenge of numerically modelling interactions between ice stream dynamics, subglacial drainage and bed processes.

The subglacial bed and the ice are respectively simulated with a layer of fine sand and a layer of silicon putty. Meltwater production is simulated with a punctual injection of water within the experimental subglacial bed. The formation of subglacial drainage landforms was monitored through time, and their shapes were analyzed from digital elevation models obtained by stereo-photogrammetry. The ice dynamics was also monitored using the temporal displacement of markers placed at three different levels of the silicon putty. This initial experimental setup, developed over the past three years, has shown promising results. We managed to address the temporal relationships between (1) meltwater pocket storage/drainage (2) meltwater subglacial drainage types, (3) temporal evolution of subglacial meltwater drainage efficiency, (4) tunnel valley formation and (5) ice stream dynamics. Experimental results highlight that distributed subglacial drainage such as transient water pocket migration can trigger ice flow acceleration similar to an ice stream. The subsequent distributed-channelized transition occurring when the water pocket reaches the ice margin initiate tunnel valleys formation. Thereafter, ice stream dynamics is mainly controlled by the ability of tunnel valleys to drain all meltwater leading to modifications of ice streams directions, geometries and velocities. Ultimately, when the tunnel valleys system become efficient, ice streams can enter a stagnation phase. These experimental results reconcile several natural observations in modern ice sheets and provide some temporal constraints on the spatial coexistence of tunnel valleys and palaeo-ice streams.

Recently, significant modifications have been carried out on the initial experimental setup; we tripled its size, we added 12 meltwater injection points to simulate more complex meltwater storage and drainage patterns and we developed a new analog subglacial bed. Indeed, an analog subglacial till (scaled to natural till) has been developed in the lab using permeability and mechanical tests. We also show you some of the preliminary results of this updated experimental setup together with the new array of subglacial landforms we are able to reproduce beneath experimental ice streams (Glacial lineations, flutes, moraines).

**P-4840**

## **Mineral dispersal trains as products of hard-bedded ice streams in northern Canada**

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The identification of glacial dispersal landforms and sedimentary deposits formed by fast-flowing glaciers was important to the earliest recognition of palaeo-ice streams of the Laurentide Ice Sheet in the 1970 and 1980s. The spectacular continental-scale Dubawnt dispersal train in northern Canada was one of the first to be identified as the product of a high glacial flow rate. Subsequently, dispersal plumes of Paleozoic carbonate rocks imprinted on Precambrian Canadian Shield terrain in northern Canada were interpreted to be products of ice streams.

Smaller glacial dispersal trains emanating from point sources within larger palaeo-ice stream trunk flows have also been identified. The Strange Lake glacial dispersal train in northern Quebec and Labrador, is a remarkably linear ribbon defined by till geochemistry and airborne gamma-ray data that extends >60 km down-ice (northeast) from a mineralized rare earth element-rich peralkaline intrusion. This dispersal train formed within one of several ice streams that operated over a hard bed near the center of the Labrador Dome of the Laurentide Ice Sheet. Further north, a kimberlite indicator mineral-rich dispersal train (referred to as the Tremblay Corridor) extends 65 km down-ice (northwest) from a cluster of kimberlite intrusions on northern Melville Peninsula, Nunavut. This glacial dispersal train was also formed over a hard bed by the Gulf of Boothia Ice Stream, which originated from the Foxe Dome of the Laurentide Ice Sheet.

The geomorphic imprint of ice streams over hard-bed, higher relief areas tends to be less obvious because of thinner till cover and an absence of diagnostic geomorphic features such as shear margin moraines. Despite the relatively thin till cover in the Strange Lake, Labrador area, and on the northern Melville Peninsula, the extremely high concentrations of mineralized (exotic) debris within the till 10s of kilometres down-ice from their sources is quite remarkable. Typically, under normal ice flow conditions in areas of hard-beds on the Canadian Shield, dispersal trains formed by erosive ice are diluted over relatively short distances (<5 km) down-ice. The long (10s of km) dispersal trains of till with distinct chemical and/or mineralogical compositions, coupled with obvious erosive/depositional corridors of streamlined landforms, provide a means of identifying hard-bedded ice streams elsewhere in northern Canada.

**P-4841**

## **The Cabot Lake ice-stream: a hard-bedded palaeo-ice-stream near the Ancestral Labrador ice-divide of the Laurentide Ice Sheet's Quebec-Labrador Dome.**

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The Cabot Lake ice-stream (CLIS) is a previously unidentified east-trending ice-stream on the Canadian Shield that provides evidence for rapid basal-flow acceleration in close proximity to an ice-divide. The CLIS is located near the central-eastern border of Quebec and Newfoundland and Labrador, between two much larger ice-stream corridors. The CLIS is situated south of the Kogaluk River Ice-Stream near Strange Lake (IS #185 of Margold et al. 2015), and north of the unnamed ice-stream in the Smallwood Reservoir (herein referred to as the Smallwood ice-stream). The CLIS occupies a lowland region in the headwaters of the George River and is bounded on its onset zone and terminus by large bedrock upland regions: the Paleoproterozoic De Pas Batholith at its onset in the west and the Neoproterozoic granite and orthogneiss at its terminus in the east. The CLIS is 40 km wide at its onset, with a classic converging flow pattern and sharp lateral margins that narrows to 20 km wide near its terminus, where it abruptly ends at an intrusive bedrock upland region. The CLIS contains over 1000 streamlined landforms, many with elongation ratios of 12:1 or greater. The CLIS was relatively short-lived, given its extent, and following the ice streaming, the system shutdown with sluggish, topographically-controlled ice-flow to the northeast, which explains the high degree of preservation of the landforms and lack of a time-transgressive land system that would result from gradual glaciological changes. This younger northeastern ice-flow was oblique to the eastern-trending CLIS bedforms, as indicated by striations on nearby bedrock highlands and moderate reworking of some of the MSGs.

This ice-stream operated near a migrating dispersal saddle of the Laurentide Ice Sheet's Quebec-Labrador dome in central-eastern Quebec. The CLIS' proximity to this ice-divide suggests that ice-streams were active toward the centre of the ice-sheet during late-stage deglaciation. The timing and duration of the ice-stream remain undefined; however, it shares a similar longitude to the Happy Valley-Goose Bay ice-stream to the south (IS #186 of Margold et al. 2015), another short ice-stream that is thought to have been active at about 8.9 cal ka BP. The location of the CLIS in such close proximity to an ice-divide, in conjunction with the other ice-streams operating simultaneously along the eastern margin of the retreating Laurentide Ice Sheet (e.g., Kogaluk River, Smallwood, and Happy Valley-Goose Bay ice-streams) indicate these ice-streams had an important impact on the transportation of glacial sediments away from core-regions of the ice dispersal-centre and possibly influenced the westward migration of the ice-divide during deglaciation.

**P-4842**

## **Iceberg scouring in terrestrial eastern Sweden and implications for deglacial history**

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During mapping on detailed elevation models in eastern Sweden, large areas with morphologically chaotic till surfaces have been detected below the highest coastline. We interpreted these areas being formed as the result of iceberg scouring.

The mapping was conducted on LiDAR derived elevation models in a GIS environment. Units for these features will be incorporated in a future national glacial geomorphological database developed by the Geological Survey of Sweden to make these data openly accessible.

The mounds are circular to elongated with crater-like rims, often cross-cutting. Sizes are from semi-circular mounds of few meters up to elongated mounds more than 1 km long and 50 m across. Based on the morphology we interpret these as iceberg plough marks and pits formed by floating icebergs scouring the sea bottom. Previously, iceberg activity has been interpreted in this area based on deposits of sedimentary material which should have its provenance in the Bothnian Sea. Our study support that calving icebergs most probably was produced by and derived from the Bothnian Ice Stream.

This is, as far as we know, the first reported observations of iceberg scouring in Swedish modern terrestrial environments. Moreover, it should be noted that while screening other parts of Sweden we have also found iceberg pits in paleo-ice lakes in central Sweden and also a few mounds in south eastern Sweden.

The new finding of iceberg-grounding activity is significant for interpretations of surficial deposits and possibly an important piece to the puzzle of the Fennoscandian Ice Sheet history, for example: 1) the varve chronology from terrestrial areas displays a uniform ice-margin retreat, while the Bothnian Sea record presents an ice streaming behavior. Such an environment would produce an abundance of icebergs – this mapping clearly shows that this was the case. 2) In physical planning it is important to know where sediments have melted out from ice-beargs, as it must be considered that fine sediments might be found further down in the stratigraphy, even if there is diamicton on the surface. 3) Iceberg-scouring events are significant for paleo-environmental reconstructions at all scales, since the needed glaciological and oceanic conditions indicate past climate-ocean interactions.

**P-4843**

## **Are bedrock mega-grooves formed through ice streaming?**

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Mega-grooves are assemblages of straight and parallel troughs 100s of meters long, thought to have formed through erosion in bedrock, beneath Quaternary ice sheets. The mechanisms and palaeoglacial conditions of mega-groove formation are still to be elucidated, but most studies published in the past decades favour the hypothesis of formation through intense and focused abrasion beneath fast-flowing ice in the onset zones of ice streaming. However, the evidence for a link between mega-grooves and ice streaming is often poorly constrained and ice streaming may not be a necessary condition for groove formation. Indeed, it is likely that the duration of ice flow is also important (e.g. re-excavation through repeat glaciations), along with bedrock susceptibility to erosion. In this paper we present recent landform mapping from several sites across the world, which suggest that the mega-groove patterns as bedrock bedforms differ to those characteristic to zones of ice-streaming onset. Thus, overall, mega-grooves are parallel and sometimes even slightly divergent in planform, in the down-ice flow direction, whereas bedrock bedforms in ice-streaming onset zones have a clearly defined convergent pattern. Also, empirical observations in Assynt, Scotland in conjunction with detailed mapping on high-resolution aerial imagery identified three groove assemblages with different orientations. Two of these correspond to sets of geological fractures aligned at an angle to palaeo-ice flow direction. The third set consists of grooves and ridges aligned parallel to the palaeo-ice flow direction and also to the bedrock strike. This last group give the landscape its characteristic streamlined aspect due to their large number, length, and continuity for 100s of meters, and have been previously interpreted as the result of ice streaming. However, the presence of cross-cutting groove assemblages, and the fact that all grooves and ridges occur in close connection with geological structural lines, point to a landscape of areal scouring, likely throughout multiple glaciations, rather than streamlining through fast ice flow.

**P-4844**

## **A conceptual framework for the spatial and chronological variations in the intensity of glacial flow within the Boothia-Lancaster ice stream.**

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The history of ice flow within the Boothia-Lancaster Ice stream (BLIS) area relates to numerous datasets and important concepts, which, however sparse and geochronologically uncertain, indicates several successive ice flow patterns. Based on spatial features and chronological/stratigraphic aspects on land and underwater for the BLIS, it is possible to suggest conceptual correlations with the offshore IRD stratigraphy in Baffin Bay. The concepts of time and space involved are based on 1. Ice flow paths variations in time; 2. Glacial erosion history; 3. Stratigraphic data from which one deduces presence or absence of ice. In turn, the synthesis of those concepts could be useful for the modelling of the ice sheet behaviour.

New Arctic DEM, high definition satellite observations, multibeam echosounder, pebble counts in till, TCN analysis, stratigraphic units geochronology, field-based glaciodynamical observations and field striations measurements, help to understand in greater details the history of ice flow. Glaciodynamical mapping highlights extensive cold-based zones on several plateaus surrounding the BLIS, with important TCN inheritance measured in bedrock and till/regolith samples. A ternary diagram with relative importance of erosional factors helps to illustrate the transition between cold-based and warm-based zones. Pebbles transport half-distances are used to understand the contrast between various glaciodynamical settings. Submarine glacial geomorphology from multibeam echosounder indicate subglacial ice flow all through the Lancaster Sound, Gulf of Boothia and Committee Bay axis.

Fluctuations in the intensity of BLIS activity during the last glaciation is indicated from striae chronology on Boothia Peninsula, and recent data from the Keewatin (Hodder et al., 2016) indicates possible switch in ice flow intensity reaching as far as the Keewatin ice divide. Possible ice flow paths variations in time, however not strictly dated, can be conceptualized. During deglaciation, highly contrasted glacial geomorphology results from marked differences in ice retreat rates between the west and the eastern side of the BLIS.

Stratigraphy for pre-LGM events on Boothia Peninsula and Bylot Island indicates that ice cover and marine invasions can be traced before MIS2. Pre-LGM stratigraphic units, previously only dated with ages on shells at >35 to >41 <sup>14</sup>C ka (AMS) and with amino acid dating, are currently being dated with IRSL. On Boothia Peninsula, the Paisley River IRSL preliminary dates yield ages between 80 ka and 150 ka.

**P-4845**

## **New data about the Kileshino section - as the important section for understanding the LGM position on the Valday Upland (Russia)**

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Stratigraphic investigations of sections with organic deposits of the Mikulinian Interglacial (MIS 5e) or Early - Middle Weichselian ages (MIS 5b - MIS 3) are a reliable method for assessing the development of the Late Valdai (Weichselian) glaciation. The Kileshino section is one of the key sections for studying the Last Glacial Maximum (LGM) position in the central part of the Valday Upland. Investigations of the section were started in the late 50s XX century. Most researchers try to correlate peat observed in the section with the Mikulinian Interglacial (MIS 5e). Also, some researchers were able to detect the layer of till which covers organogenic deposits in the section; others did not find any till. The uncertainty in the section structure does not allow to reasonably show the LGM boundary in the central part of the Valday Upland.

In 2017 detailed investigations of the section in village Kileshino were carried out for the purpose of revision. The section opened the valley side of the r. Sizhina. On the base of visual structure observations, grain size, loss on ignition at 550 and 900 C, magnetic susceptibility, pollen, paleocarpology and 14C analyzes were distinguished stratigraphic horizons: alluvial deposits of the Late Valdai Age (0–2,86 m); floodplain facies of alluvial deposits of the Early Valdai Age (2,86-5,3 m); lacustrine-peat deposits of the Mikulinian Interglacial (5,3-7,0 m); lacustrine and limnoglacial sediments of the Late Moscow age (7,0-13,40 m). The stratigraphy of section allows making a correlation between boreholes along the profile line through the key section. It needs for understanding the bed position of organogenic deposits. Analysis of the profile shows that till represented by loams with the inclusion of carbonate and crystalline rocks debris, were found at the upper parts of interfluves and some boreholes. It suggests that organo-mineral deposits which studied in the section were formed in the depression between hills of the Late Moscow age. In the Late Valdai (MIS 2) the ice cover could hardly spread to the south from the section.

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P-4846

## Low-temperature permafrost and absence of ice-sheet relics – new data in respect to Northwestern Siberia's environment during the Pleistocene cryochrones

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Development of permafrost in Northwestern Siberia has been a fact that is beyond any doubt. Permafrost occupies a vast area here both at present and over the Pleistocene. At that, there is numerous evidence of very strong rock freezing formed at that area. Permafrost changed in thickness, its area fluctuated in size, but it always formed here as the main environmental attribute. Some researchers, nevertheless, suppose presence of ice sheets in Northwestern Siberia during the Pleistocene cryochrones, though to explain the combined development, at the same time and at the same area, of giant glaciers and well-expressed permafrost phenomena is impossible. In any case, at the base of ice sheets frozen grounds have to transform, whereas surface deposits occur in the region as unaffected original forms in a state of fair preservation. They reflect undergoing through only active freezing at the background of mostly river self-development resulted in different forms. Some of those forms rated, at times, as glacial relics, are not of glacial origin, and no evidence of ice sheets occurs here.

The base to suppose an ice sheet in Northwestern Siberia is distribution of stony material north of the Middle Ob' River where a low upland (less than 300 m a. s. l.) stretched along the sub-latitudinal direction and named the Siberian Uval is situated. When to look at the map, the upland likes to a moraine ridge; however, it is only in the form. Overall, the Siberian Uval represents a system of typical river terraces with a height of cliffs up to 35-40 m, and such indicator of former strong freezing as pseudomorphs after polygonal ice wedges occurs in their bodies. According to the dating carried out by different ways, the wedges at the top of the terraces formed during MIS-2, and during the cold phase of MIS-5 in the central part of the terraces. Their top deposits resemble loess-like sediments, but they contain fresh water aquatic microfossils and bear features of floodplain alluvium (see our other abstract). As to the stony material, it mostly represents basaltic fragments carried away from the right-hand bank of the Yenisei River. The terrace deposits are mostly composed of sandy alluvium, whereas the stony material is much dispersed debris embedded in sandy deposits. To our mind, it is a result of river ice-floe drift typical for self-development of many rivers in Siberia – even at present, Yenisei, during the ice drift time, can rich 30-m raising of water level, whereas thickness of ice floes can rich 2 m. It is quite enough to capture boulders by ice floes and to move them over not high water divides near the Siberian Uval. All of that confirms non-glaciated development of the studied area.

P-4847

## Loess-like deposits at the top of the high river terraces of Northwestern Siberia: floodplain alluvium or eolian sediments?

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Accumulation of loessic sediments is usually observed to the south of the margins of the Pleistocene glaciers. Within the Arctic and Subarctic zones, loess-like sediments are spread in the regions which were not covered by glaciers during the Pleistocene cryochrones. Some researchers considered Northwestern Siberia as an area of development of the Pleistocene glaciations which to the west merged with the North-European ice sheet (Grossvald, Hughes, 2002). Recently alternative concepts supposing much more modest spread of the ice sheets in Northern Eurasia were developed. Within these hypotheses West Siberia was completely free of the ice cover (Sheinkman, 2016; Sheinkman et al., 2017). At that, the paleoecological scenario supposes for West Siberia wide development of extra-arid cold ecosystems in the Late Glacial and Last Glacial Maximum (Velichko et al. 2011). Such a scenario implies activation of eolian processes which could give rise to loess accumulation.

During our study of the Quaternary sequences in the upper and middle reaches of the rivers running down from the Siberian Uval (a not high upland at the right-hand bank of the Middle Ob' River), we encountered in many exposures of the high (at a relative height of 15-20 to 35-40 m) river terraces the layers of loamy sediments that capped extensive sandy alluvial sequences. The most profound and well developed superficial loamy stratum has been found in the top exposure of the terraces. The loams consisted predominantly of silt fractions, were not laminated evidently, and showed well-developed cryogenic structure. They were severely affected by the pseudomorphs after middle-size polygonal ice wedges often outlined by thin paleosols. Set of <sup>14</sup>C determinations produced from the paleosols the ages between 10 and 20 ka BP. It attributes the loam accumulation and its cryogenic transformation to MIS-2 (the Sartan cryochrone, in Siberian schemes). So, interpretation of the loams as the floodplain alluvium met firstly certain difficulties because in this case evident thin rhythmic lamination is expected. Therefore, the alternative hypothesis of eolian accumulation of these loess-like sediments and simultaneous impact of cryogenic processes in the cold and dry landscapes was developed – which fits into the “Glacial desert model” (Velichko et al., 2011).

Nevertheless, micromorphological studies of the considered loamy deposits revealed typical features of floodplain sediments. These are: a) well-expressed microlamination, b) occurrence of organic plant fragments oriented parallel to the lamination, c) iron hypocoatings along the layers – an indicator of gleying, d) relics of fresh water aquatic microfossils – diatoms, sponge spicules. So, we suggest these facts evidence in favour of floodplain alluvium origin of the loamy sediments although incorporation of the windblown material is still not excluded. Within the floodplain hypothesis, recent tectonic uplift should be considered to explain the elevated present day position of the loams

**P-4848**

## **Late-Glacial paraglacial drainage system inferred from palaeolakes buried under the aeolian sand**

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On a distal part of the outwash plain in the several sites of Ūla River valley, South East Lithuania, the organogenic sediments (gyttja) are found at the different depth buried under the lacustrine and aeolian sand. The Late-Glacial is indicated as the sedimentation time by the results of a palaeobotanical analysis, <sup>14</sup>C and OSL dating. During the earlier studies, the origin of palaeolakes was always interpreted as glaciokarst with the subsequent postglacial sedimentation in kettle-hole lakes. Correspondingly, the area of the outwash plain was interpreted to be covered by ice during the Last Glacial Maximum and boundary of the ice sheet passing along the distal outline of the outwash. The results of a new site study and the reinvestigation of old sites supplemented with LIDAR models and ground-penetrating radar data show the existence of the paraglacial drainage system, which was late mostly covered by aeolian dunes. The moving dunes apparently dammed the surface runoff and formed the lakes inside the valleys of the drainage system. The sediment sequence structure shows the lake sedimentation interchange with the aeolian one until the lakes were filled with sand and buried completely. The study results also let to consider the position of the Last Glacial Maximum boundary up to half a hundred kilometres northwestwards. This research was funded by a grant (No. S-LL-18-2) from the Research Council of Lithuania.

**P-4849**

## **Surface morphological types and spatial distribution of fan-shaped landforms in the Arctic based on examples from Svalbard, Iceland, and Greenland**

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Landforms, which shape reassemble fans and cones, are a characteristic element of many mountain landscapes in the Arctic. In this research, we focus on small fans that developed along steep mountainsides as a result of paraglacial adjustment of topography, and which varied greatly in geomorphology and processes. We distinguished: colluvial fans - mainly formed by rockfalls and snow avalanches, alluvial fans that are dominated by debris flows, and alluvial fans that are dominated by fluvial flows. The primary purpose of this study is to provide a context for a further examination of the variability in fan shape and morphology by documenting their spatial distribution across the selected area of Svalbard (central part of Spitsbergen Island), Iceland (SE fringe of Vatnajökull) and Greenland (Zackenber area and S Disco Island).

The geomorphological features of surface morphology of fans were identified based on analysis of orthoimages (high-resolution satellite imagery and aerial photographs) combined with visualisations of DEM (shading relief with different azimuth angles of the light source) and maps of slope gradient, aspect and curvatures. Additional field geomorphological mapping and ground checking were carried out during fieldworks. Three main types of fans' surface morphology were mapped: colluvial fans, debris-flow-dominated fans, fluvial-flow-dominated fans. A classification of the surface morphology of fans was developed based on their geomorphic expression and traces of dominating processes. For example, the presence of braided channel networks on the fan's surface indicated that its morphology had been transformed mainly by fluvial-flows rather than debris-flows. The abundance of levees and lobes indicated domination of debris flows, whereas a relatively uniform surface with traces of avalanches and sporadic debris-flow channels was classified as colluvial fans. The main morphometric and morphological features of the fans and their catchments have been collected, including: fan and catchment area, relief, length, width, elevation (the lowest point at the fan toe, apex, and the highest point of the catchment boundary), fan mean plan and profile curvatures, distance from the ice margin, and fan relation to neighbouring fans.

Colluvial fans were the smallest and steepest, whereas debris-flow-dominated and alluvial-flow-dominated fans were significantly larger and characterised by a gentler slope. Moreover, the catchments of colluvial fans were much smaller in comparison to the large catchments of fluvial-flow-dominated fans. Other morphometric properties of both fans and catchments also differed according to type. The collected data will be used for further in-depth analysis of the relationship between the surface morphology of fans, dominant processes, morphometric variables and time passed since deglaciation.

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**P-4850**

## **Paleocryogenesis in the periglacial area of the West Siberian Plain**

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Below are some of the results of the study of geodynamic processes and paleocryogenesis in periglacial zone of the West Siberian plain. Sedimentary strata revealing elevated terraced surface, within the middle course of the Ob basin, can be classified into two types: 1) sedimentary strata with traces of cryometamorphic deformations; 2) sedimentary strata with the inclusion of boulder-pebble material. The study area belongs to the zone of island permafrost and intergelisol of the Arctic region and is located within 60 – 62 Parallels of Northern latitude. Appearance paleocryogenic deformations, their Genesis and sedimentation conditions in stratigraphic sequences of the middle course of the Ob is a debatable issue. Accumulation and formation of sedimentary strata occurred in the Neopleistocene time. The change of sedimentation is subject to interstage and interstadial periods. A manifestation of intense paleocryogenesis occurs during the Upper Pleistocene period. The studied sequences of the Ob valley accommodate various types of vein structures that differ in size and structure. The general trend for the studied sequences is the lower tier represented by sandy rocks with layers of iron hydroxides.

The generalizing trend of sequences is:

The second tier (at a depth of 10 – 12 m) stratigraphically lies above the first tier, represented by ice-subsoil veins. Large wedge-shaped ice-subsoil veins are fixed in the sequence of Kir'yas, smaller are fixed in the sequence of Agan's Uval.

The wedge-shaped pseudomorphs are filled by bluish gley loam (except in the sequence of Kir'yas) and banded argillite with a border of iron hydroxides.

The third tier (at a depth of 8 – 10 m), formed above the tier with wedge-shaped pseudomorphs, is represented by humus-gley paleosols with water-accumulative characteristics, the age of which correlates with MIS 3 and is 43.871 cal. BP for the Kir'yas sequence, for Agan's Uval sequence 27.300 years cal. BP.

The fourth tier (at a depth of 6 – 8 m) are presented pseudomorphs, crushed by loamy-sandy rocks.

The fifth tier (at a depth of 1 – 6 m) for the sequences of Kir'yas and Agan's Uval is represented by loess – like loam, a sequence of Mega is represented by lake-alluvial sandy loam.

This process is almost exclusively due to the elementary ice veins that fill the frost cracks.

The consequence of such genesis of veins is their correct wedge-shaped form, distinct vertical banding and clear contacts with the host rocks. Cooling, aridization of climate, in comparison with the previous epochs, led to a reduction in the level of the sea basin, which became an obstacle to the development of glaciation in the north of the West Siberian plain and this contributed to the intensive freezing of rocks. The development of paleocryogenesis and epigenetic ice in particular contributed to the wet conditions and developed extensive lake-marsh complexes.

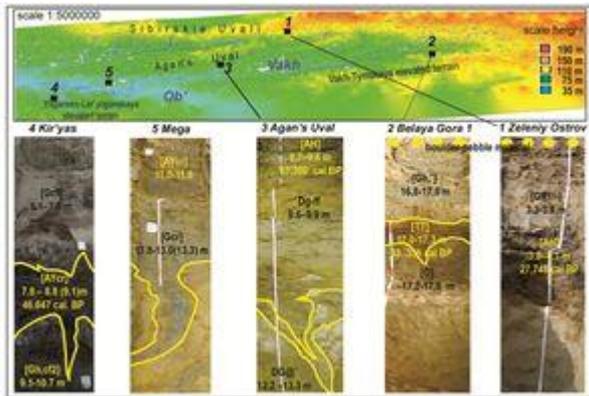


Fig. Map-scheme of geographical location.

**P-4851**

## **Geomorphology, facies variability and large-scale depositional architecture of ice-marginal deltas in glacial lake basins: a synthesis**

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During the Middle Pleistocene glaciations ice sheets repeatedly blocked the main river-drainage pathways in northern central Europe and led to the formation of extensive ice-dammed lakes along the southwestern margins of the Fennoscandian ice sheets. During deglaciation the lakes commonly increased in size and eventually drained successively towards the west and northwest. Catastrophic lake-drainage events occurred when large overspill channels were suddenly opened.

This study presents a synthesis of ice-marginal deltas controlled by rapid lake-level change. The integration of digital elevation models, outcrop, borehole, ground-penetrating radar (GPR) and high-resolution shear-wave seismic data allow to assess the role of rapid base-level change on delta morphology, sedimentary facies and the larger-scale depositional architecture and provide information about the distinct types of deltaic facies and geometries generated under different lake-level trends.

The exposed delta sediments record mainly the phase of lake-level highstand and subsequent lake drainage. The stair-stepped profiles of the delta systems reflect the progressive basinward lobe deposition during forced regression when the lakes successively drained. Depending on the rate and magnitude of lake-level fall, fan-shaped, lobate or more digitate tongue-like delta morphologies developed. Deposits of the stair-stepped transgressive delta bodies are buried, downlapped and onlapped by the younger forced regressive deposits.

The delta styles comprise both Gilbert-type deltas and shoal-water deltas. The sedimentary facies of the steep Gilbert-type delta foresets include a wide range of gravity-flow deposits. Delta deposits of the forced-regressive phase are commonly dominated by coarse-grained debris-flow deposits, indicating strong upslope erosion and cannibalization of older delta deposits. Deposits of supercritical turbidity currents are particularly common in sand-rich Gilbert-type deltas that formed during slow lake-level rise and highstand. Foreset beds consist typically of laterally and vertically stacked deposits of antidunes and cyclic steps. The trigger mechanisms for these supercritical turbidity currents were both hyperpycnal meltwater flows and slope-failure events.

Shoal-water deltas formed at low water depths during both slow lake-level rise and forced regression. Deposition occurred from tractional flows. Transgressive mouthbars form laterally extensive sand-rich delta bodies with a digitate, multi-tongue morphology. In contrast, forced regressive gravelly shoal-water deltas show a high dispersion of flow directions and form laterally overlapping delta lobes.

Deformation structures within the forced regressive ice-marginal deltas are mainly extensional features, including normal faults, small graben or half-graben structures and shear-deformation bands, which are related to i) gravitational delta tectonics; ii) post-glacial faulting during glacial-isostatic adjustment and iii) crestal-collapse above salt domes. In some cases, a neotectonic component cannot be ruled out. Dead-ice melting did not play a major role in the formation of normal faults.

**P-4852**

## **Lake Seliger (Valdai upland, Russia): hydrological history after deglaciation**

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Lake Seliger is a system of 24 semi-isolated bays (so-called Plyosy), which stretch for 60 km from north to south on the Valdai Upland. This territory is the main watershed of the East European Plain, which divides the river runoff between the basins of the Caspian and Baltic Seas. The Valdai Upland is in the margin zone of the last glaciation. This area has a typical post-glacial landscape with marginal moraines, kamas, eskers and kettle holes. The Valdai Upland gave the name to the last glacial epoch in the Russian geological systematic - the Valdai glaciation. Traditionally, the Lake Seliger is considered relict lake, which remained after degradation of a huge proglacial lake. But bottom sediments and topography previously have not been studied in sufficient detail.

In winter of 2018, the bottom sediments of Lake Seliger were drilled from ice. Drilling was carried out on 5 profiles in the southern part of the lake. Bathymetric and GPR work was also carried out for all profiles. In total, 14 boreholes were drilled. Received and delivered to the laboratory 43 m of cores. For samples from reference cores, the loss on ignition, the magnetic susceptibility and the particle size distribution were determined. 15 radiocarbon dates were obtained.

In all boreholes at the bottom of the lake, 2-3-meter, and in some cases 6-meter lake mud, have been discovered. The upper part of the mud has a dark gray color due to enrichment with organic matter (30-60%). This is the Holocene sapropel (gyttja). The lower layers of mud in many boreholes have a light gray or blue-gray color, because they contain little organic matter (3-10%). This is a sign of formation in a cold climate - at the end of the last glacial epoch. Everywhere under the mud coarse sands occur. It is deposits of a fairly fast water flow. Many bays of the lake have an elongated and meandering shape and it looks like flooded river valleys. The topography of the bottom of these bays also indicates the fluvial origin.

Based on the study of sediments and topography of the bottom and shores of the lake, the following conclusions were made:

1. Lake Seliger is a flooded system of river valleys which appeared after the retreat of the last glacier.
2. The transformation of the river system into the lake took place gradually at the end of the Late Pleistocene, during the Belling-Allred interstadial (about 14.5–12.5 ky BP).
3. The likely reason for the transformation of the river system into the lake system is the differential glacio-isostatic movements of the earth's crust which changed the surface topography.

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**P-4853**

## **The construction of a new varve thickness time series from glacial Lake Agassiz**

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A new varve time series is being constructed using lake sediments from the former Lake Agassiz basin in northern Minnesota and Ontario (United States/Canada). Our goals are to reconstruct both ice margin retreat and glacial Lake Agassiz lake levels across the period spanning the Bølling-Allerød and Younger Dryas (YD). This is the first annually resolved record from North America that details ice margin dynamics and meltwater supply from the LIS through these dynamic climate periods; therefore, this project offers the opportunity to determine the LIS response to abrupt climatic shifts. In addition, by combining the ice margin positions, tracked by varves, with a lake level record, developed from sediment cores and seismic reflection data, the hypothesis that glacial Lake Agassiz drainage triggered the YD will be tested.

Here we report on 12 cores recovered so far, which all have varves, and correlate to records described by Antevs (1951) from Steep Rock Lake and Rittenhouse (1933) from Lake Wabigoon. We expect to add data from five more sites this year. Our youngest (most northern) and oldest (most southern) series of varves cross-correlate well, but the intervening record is complicated by non-varved sections, which we attribute to lake level drops associated with ice retreat opening new, lower elevation outlets for Lake Agassiz. This interpretation is supported by abrupt contacts between varved and non-varved sections, and unconformable surfaces and associated gravity flows visible in seismic reflection data.

The thickest (and presumably longest-lasting) non-varved, lowstand section is the youngest. The lowstand ends ca. 11,500 cal yr BP, at around the YD/Holocene transition. This lowstand is well-documented elsewhere in Lake Agassiz sediments and referred to as the Moorhead Low. Our reconstructions suggest that Lake Agassiz drained to the Arctic Ocean during this lowstand, because ice covered every potential eastern outlet to the Atlantic Ocean that would have been sufficiently low enough in elevation to create the lowstand. There are two, older, non-varved sections that likely resulted from earlier drawdown events. Multiple lowstands in Lake Agassiz have been suggested, but in recent literature, only one lowstand is typically emphasized. Neither the timing, nor ice margin positions for these older drawdown events are currently well constrained.

By targeting lower elevation or more isostatically depressed sites, we should be able to recover varves that span the non-varved sections, which are critical for determining the timing and durations of the lowstands. Varves spanning part of the Moorhead Low document that the lowstand lasted at least 750 years (from 12,250 to 11,500 cal yr BP).

P-4855

## Proglacial lakes at the southeastern edge of the last Scandinavian Ice Sheet: *sic et non*

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The southeastern flank of the last Scandinavian Ice Sheet extended over the territory of Northwestern Russia, occupying the White Sea and the downstream part of the Severnaya Dvina (SD) River catchment (Svendsen et al., 2004), and thus the proglacial lakes must have been formed in the SD valley and its large tributaries Vychegda and Vaga (Fig. 1).

The idea of the LGM proglacial lake formation in the Severnaya Dvina and Pechora drainage systems was first proposed by Krasnov (1948) and then developed by Kvasov (1975). In the last decades, analysis of digital elevation models allowed to propose new LGM limits advancing farther east- and southeastwards into the valleys of Vychegda and Vaga rivers (Lysa et al., 2011; 2014; Fredin et al., 2012; Larsen et al., 2013).

Our chronostratigraphic studies of natural outcrops and river valley morphology in the SD catchment area have led us to the reconstruction of two separate proglacial lakes in Vychegda and Vaga valleys in the LGM.

In the Vychegda valley, we examined the morphological features mapped by Fredin et al. (2012) and Larsen et al. (2013) as terminal moraines that dammed the proglacial lake. According to our observations, the moraine is characterized by dense erosion network, and the breakthrough reach of Vychegda contains a staircase of relatively high terraces with alluvial bottom and aeolian cap (Zaretskaya et al., 2018). Preliminary OSL-age of higher terraces at around MIS 5 allows to propose the MIS 6 age for the moraine ridge. Vychegda MIS2 terraces are of alluvial origin with traces of ice wedge casts in the sandy layers of LGM age (Zaretskaya et al., 2014; Zaretskaya et al., in press) and do not contain specific proglacial lake sediments such as varved clays. Accumulation of this terrace had probably been promoted by the backwater effect from the proglacial lake forming downstream. The only section with well-expressed LGM-related varved-like deposits is located in the middle reaches of SD. This coincides with the reconstructions of the LGM limits just upstream the Vaga confluence (Svendsen et al., 2004).

Another situation is observed in the Vaga valley. We identified the well-expressed grayish varved clays within Vaga fluvial system with maximum thickness of 10 m. Thickness of sand and silt layers varies significantly, which indicates the unstable hydrodynamic regime characteristic for proglacial lakes within river valleys; that is a large and deep ice-dammed Vaga lake was forming during the LGM.

The proglacial lake expansion east- and southeastwards was probably limited by glacioisostatic forebulge crossing these river systems during the LGM. The absolute height of water level could reach 80 m a.s.l.

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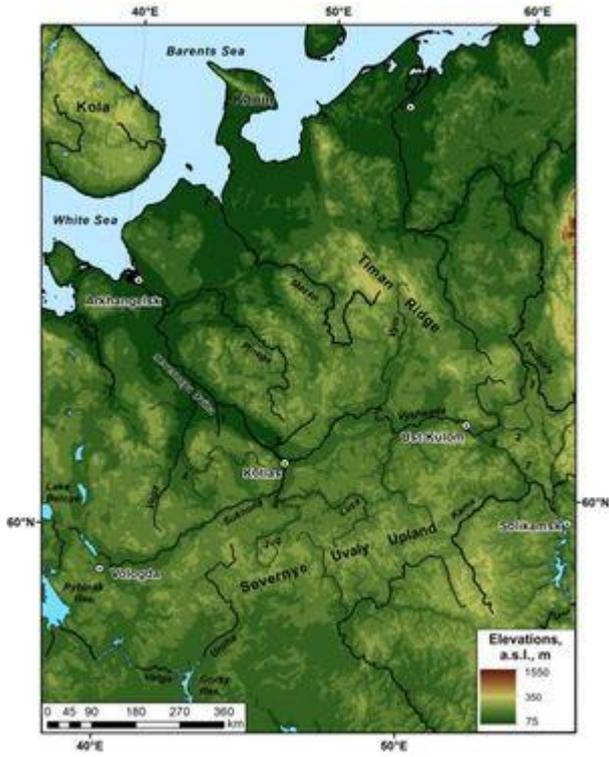


Figure 1. Study area.

**P-4856**

## **Paleoenvironmental potential of newly-formed proglacial lakes (Calluqueo Lake, Chile)**

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Proglacial lakes are widely recognised in the glacio-sedimentological community to hold accurate and high resolution records of glacier variability. However, the modern literature on proglacial lake sedimentation contains conflicting interpretations about the exact signature of glacier mass balance variations in proglacial sediments. The goal of our project is therefore to better understand how glacier variability is recorded in lake sediments. To do so, we study sediment records from glaciers in Chilean Patagonia, and compare our results to historical documentary evidence and information from satellite images. Here, we focus on Calluqueo Glacier, the largest ice mass (45.3 km<sup>2</sup>) of Monte San Lorenzo (48°S). Although a 3 km long and 1 km wide lake currently exists in front of the glacier, historical images show that in 1941 the glacier still covered the entire lake basin. It rapidly retreated between 1941 and 1985, when it became land-based. Unfortunately, information about the exact position of the ice front between 1941 and 1985 is currently lacking or too vague to interpret. Nowadays, Calluqueo Lake is divided in two sub-basins separated by a rocky sill. The sub-basins are connected via a relatively narrow (240 m) and shallow (40 m) channel, and the lake is bordered by a thick lateral moraine that contains large boulders. Our bathymetrical survey revealed that the largest and most proximal basin reached a maximum depth of 220 m, whereas the smaller distal basin reaches a depth of 50 m. Van Veen grab sampling showed that sediment was limited to the small distal basin although the entire lake has been ice free for at least three decades. The deepest proximal basin did not contain any material samplable with a grab sampler. Four short (7 – 27 cm) sediment cores, which appear to be laminated based on X-ray computed tomography images, were collected from the distal basin. Core chronologies are not yet available, but our observations suggest that the first ~30 years of the glacier's retreat are not represented in the sediments of Calluqueo Lake. We hypothesize that fine-grained sediments that are discharged into the lake immediately after its formation first start accumulating between the large boulders that compose the ablation moraine on the lake floor. These sediments only start forming a continuous stratigraphic record after the coarse moraine deposits are buried under fine-grained particles. Additionally, sediment deposition may be reduced due to fine particles by-passing the lake as a result of the temperature-related density gradient in the water column. Regardless of the explanation, our results imply that the first years/decades of Calluqueo Glacier's retreat were not recorded in the sediments of its proglacial lake, which potentially restricts the use of proglacial lake sediments to reconstruct the early stages of glacier retreat.

**P-4857**

## **Sedimentary evidence for a Younger Dryas ice-dammed lake in the Gaick, Scotland**

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Ice-marginal and proglacial glaciolacustrine sediment-landform assemblages are important geological archives, potentially providing valuable information on the style and dynamics of former glaciers. In this contribution, we present the results of sedimentological and structural-geological investigations of an assemblage of glaciolacustrine deposits identified at the northern end of a contemporary lake in the Gaick, Scotland. This sediment-landform assemblage is crucial to elucidating the extent and style of glaciation in this area, where it has long been 'generally accepted' that the most recent glacial phase was one of extensive plateau icefield glaciation during the Younger Dryas (~12.9–11.7 ka). According to this model, the valley containing the glaciolacustrine deposits would have been submerged by ice during the Younger Dryas, but we have found no geomorphological or sedimentary evidence for this configuration. Instead, our sedimentological investigations have revealed glaciolacustrine sediment-landform assemblages (a glaciotectionised grounding-line fan and a Gilbert-type delta) that document the lowering of an ice-dammed lake, which we infer to have existed during the Younger Dryas based on morphostratigraphy. The sedimentary and morphostratigraphic evidence for this ice-dammed lake and the associated glacier limits therefore contradicts the widely-accepted model of Younger Dryas glaciation in the Gaick. Thus, these findings have important implications for our understanding of glacial events in this area of the Central Grampians, Scotland.

**P-4858**

## **Assessing the ages of the Moorhead and Emerson phases of Lake Agassiz and their temporal connection to the Younger Dryas**

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The low-water Moorhead Phase of glacial Lake Agassiz has been attributed to a rapid  $\sim 90$  m drawdown in lake level contemporaneous with the onset of the Younger Dryas cold reversal ca. 12.9 cal yr BP. We examine the radiocarbon dates associated with the Moorhead and subsequent high-water Emerson Phases in the Lake Agassiz basin. We apply manual and statistical filters to vet the radiocarbon dataset, resulting in the exclusion of about one third of existing dates. A Bayesian radiocarbon calibration model applied to the filtered dataset yields modeled age ranges for the onset and demise of each lake phase. Notably, the modelled age range for the onset of the Moorhead phase post-dates the initiation of the Younger Dryas. The dataset and model do not necessarily preclude freshwater flux from Lake Agassiz drawdown during the Moorhead phase as the trigger for the Younger Dryas cold reversal, but they do indicate that this interpretation relies on only a few low-precision radiocarbon dates that are identified statistically as outliers. The lingering uncertainty in the radiocarbon chronology for Lake Agassiz, despite rigorous filtering and application of a Bayesian calibration model, strongly suggests that additional high-quality radiocarbon dates from clear depositional settings in the Lake Agassiz basin are required to further constrain lake level histories and linkages to abrupt deglacial climate change.

**P-4859**

## **Tracing the final deglaciation of the Scandinavian Ice Sheet in northwestern Sweden - ice-dammed lakes and a catastrophic glacial-lake outburst flood**

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This study presents geomorphological evidence indicating final deglaciation of the last Scandinavian Ice Sheet remnants east of the Scandinavian mountain range, northwestern Sweden, in contrast with the prevailing view of final deglaciation in the higher mountains of Sarek. High resolution (LiDAR) terrain models were used to map out a large number of previously undocumented paleoshorelines within the northern Scandinavian mountain range. The distribution of these paleoshorelines indicates a larger system of ice-dammed lakes than previously thought. Using cross-cutting relations and the altitudes of bedrock thresholds the relative ages of the different lake-stages was obtained and used to trace the ice-sheet retreat in the area. Similar to the deglaciation further to the north and south, the distribution and pattern of the ice-dammed lake deposits in this area suggests an eastward retreating ice-sheet, which dammed up lakes towards the mountains in the west.

In addition, this study presents geomorphological evidences, in the form of mega deposits and extensive erosive features, of a catastrophic glacial lake outburst flood along the Pite River valley. These features, including erosive lines found up to 50 m above present day river level, can be traced continuously for ~130 km from the mountain range and ending at the early Holocene Ancylus lake level. Based on cross-cutting relations to early Holocene raised shorelines from the Ancylus lake the age of the flood is constrained to c. 9.9-9.8 cal. ka BP.

**P-4860**

## **Rostov lowland (Yaroslavl region, Russia) - was there a gulf of proglacial lake?**

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Rostov lowland is a middle size depression (550 km<sup>2</sup>, 60-80 m deep) which situated about 170 km to the NE from Moscow. The lowland is surrounded by moraine hills of Saalian glaciation. About 10% of area of the lowland is occupied by Lake Nero. On the west bank of Lake Nero the city of Rostov is located - one of the oldest cities in Russia, founded in 862. The modern lake level is 93 m asl. From the Lake Nero flows out the Kotorosol River. The Kotorosol River flows into the Volga River near the city of Yaroslavl. On the slopes of the Rostov lowlands are situated 5-6 lake terraces. There is a discussion about the age of the terraces and the reasons of lake level fluctuations. According to Kvasov (1975) at the end of the Late Pleistocene the level of lake rose to 145 m asl and the lake had a connection with the huge system of proglacial lakes. According to Aleshinskaya and Gunova (1997), the level of Lake Nero in the late Weichselian epoch did not exceed 110 m asl and highest terraces was formed in late Saalian epoch. In many ways, this discussion is due to the weak use of dating methods in older works.

We investigated the topography of the terrace complex of the Rostov lowlands. On the basis of SRTM we identified areas with well-defined terraces. Using DGPS the height of the terraces on the eastern side of the basin was fixed: T1 - 94-95 m asl, T2 - 102-104 m asl, T3 - 108-109 m asl, T4 - 123-125 m asl, T5 - 130-134 m asl, T6 - 145 m asl. 11 boreholes were drilled on the terraces of the eastern side of the basin. A series of radiocarbon dates from terraces has been obtained. The dating results indicate that the level of Lake Nero in the Late Weichselian did not exceed 110 m asl, which refutes the model of Kvasov (1975). The terrace of 110 m is also well marked on the sides of other adjacent basins - Yaroslavl, Kostroma, Galich. This suggests the existence of a single interconnected system of glacial lakes in the Late Valdai on the territory of the Yaroslavl Volga region.

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**P-4861**

## **An alternative view of the Anglian/Elsterian (MIS 12) glaciation of southeastern England**

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Anglian/Elsterian (marine oxygen isotope stage (MIS) 12) glaciation of East Anglia has been debated for more than 150 years. Most favour a subglacial origin for the spectacularly deformed chalk-rich diamictons (CRDs) and associated sediments of the North Norfolk coast, although for the most part the CRDs are clearly waterlain. This presentation pieces together evidence from the Peterborough area with observations along the North Norfolk coast, between Weybourne and Trimmingham, in order to provide a plausible account of the Anglian glaciation of East Anglia in the context of a proglacial lake occupying the southern North Sea basin. Two subaqueous diamictic facies deposited in a proglacial lake depositional environment, as evidenced by the conspicuous presence of dropstones, dominate the Anglian sequence on the North Norfolk coast: Happisburgh diamicton (HD) and Bacton Green diamicton (BGD). The former has either folded Chalk bedrock or Chalk rafts of varying size, which are present only to the east of Sheringham. Chalk was sourced offshore from the north by erosion of a Chalk headland on the north bank of the W–E trending Ancaster river. The BGD has an influx of ferruginous fines, large pockets of sand and gravel and, to the west of Sheringham, of extremely chalk-rich diamictons. Sand and gravel appear to be sourced from a glacial portal to the north of Britons Lane/Sheringham. Extremely chalk-rich diamictons deposited by cohesive flow were probably sourced from an ice lobe associated with the Blakeney esker to the west; the ice lobe was responsible for the extensive erosion of Chalk between Weybourne and Huntingdon and represents the only demonstrable incidence of Anglian subaerial glacial overriding of East Anglia. The HD represents a deeper water setting, up to 62 m OD at Briton's Lane, relative to the BGD. Proglacial lake development extended westwards upstream in the Ancaster river catchment as demonstrated by evidence for lacustrine, deltaic and subaqueous slide and grain-flow deposits in the Peterborough area, where a deeper water phase reached up to about 70 m OD. At Norman Cross a succeeding shallower phase is recorded up to 30 m OD. The abundant evidence for subaqueous deposition of CRDs and associated sediments along the North Norfolk coast and in the Peterborough area indicates that the proglacial lake occupying the southern North Sea basin was more extensive than is normally portrayed. Recognition of the two proglacial-lake phases suggests that the two-stage opening of the Dover Strait could have occurred in MIS 12. Destruction of a Chalk headland to the north of the present North Norfolk coast supports the presence of an Ancaster river, which has implications for reconstructions of Anglian ice advances and limits, as well as the pre-Anglian drainage network of East Anglia.

**P-4862**

## **Detailed sedimentological analysis of a new 3000 varve year record from Chilean Patagonia**

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High resolution sedimentary archives, such as glaciolacustrine varve sequences formed in proglacial lakes, offer the potential for detailed reconstructions of past glacier dynamics. Specifically, a glaciolacustrine varved sequence can be utilised to investigate, at an annual resolution, the rates and/or duration of change during deglaciation of a former glacial basin. However, to robustly utilise these high resolution palaeoenvironmental archives, there is a need to understand the processes of sediment deposition.

Typically, glaciolacustrine varves are composed of two main sediment components: a coarse sediment component (very fine sand and silt) deposited during the melt season, and a fine component (very fine silt and clay) deposited during the non-melt season. At the macroscale, the couplets may appear simple, but when viewed at the microscale, the couplets may exhibit a complex range of sedimentary structures entering the proglacial environment, which can originate from the glacial margin, nival melt, precipitation and slump deposits.

We presents new varve data obtained from field exposures in Chile Chico (-46.53°S, -71.73°W) in the Lago General Carrera (Chile)/Buenos Aires (Argentina) basin in central Patagonia. Here, an ice-contact proglacial lake formed during the recession of an ice lobe of the former Patagonian Ice Sheet from its local Last Glacial Maximum position. The remodelled ages for the Fenix I moraine (i.e. the youngest of the Fenix complex and innermost before wider glacier retreat) is  $18,778 \pm 615$  to  $18,086 \pm 214$ . Sequences of laminated glaciolacustrine sediment accumulated in the palaeolake and have subsequently been exposed following lake drainage. We report on the geomorphic and sedimentological context which defines glaciolacustrine evolution at Chile Chico, present the results of detailed macro- and micro-facies analyses of the sediments recovered, and develop a process model for the formation of melt season and non-melt season components that suggest a varved origin. Using these new data, we construct a ~3000-year duration varve thickness record for Chile Chico that post-dates (<17 ka BP) the Fenix Chico Master Varve Chronology.

**P-4863**

## **Paleolake Riada, Central Ireland: Extent, Characteristics and Impact on the Recession of the Last Irish Ice Sheet.**

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Ice-contact proglacial lakes are a significant component of glacial systems as they affect the behaviour of glacier margins and influence rate and dynamics of ice retreat. They also act as sediment sinks and contain important records of ice and meltwater dynamics. Some lakes contain varved sediments, which can provide high-resolution records of ice sheet dynamics, meltwater fluxes and, in some cases, climate change.

In central Ireland, a large ice-contact proglacial lake, Paleolake Riada, is known to have existed during recession of the last Irish Ice Sheet. However, little is known about the lake - while the eastern, bedrock, lake margin has been identified, the extent of the lake at maximum has not been established, nor its final drainage route. Lake water depths, and the impact of the lake on ice margin dynamics are also poorly understood. Paleolake Riada is particularly well suited for study due to the abundance of well-preserved geomorphological landforms and widespread lake sediment deposits. The combination of these two records allows for an extremely well resolved and detailed reconstruction of ice dynamics in this region.

This poster will present new geomorphological and sedimentological evidence for the extent and characteristics of Paleolake Riada, including modelling of the maximum extent and drainage route of the lake, and evidence for changing ice-marginal dynamics during its existence. Sedimentary depositional processes within the lake and the potential for constructing a chronology based on varved sediments are also considered.

**P-4864**

## **Reconstructing Retreat Dynamics of the Irish Ice Sheet Using Proglacial Lake Sediments**

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Modern ice sheets have retreated rapidly during the last century in response to rising global air temperatures. Understanding the rate and pattern of current deglaciation relies on long-term records of ice sheet behaviour spanning several millennia. Such a record can be found in the Irish Midlands in the form of landforms and sediments preserved from the retreat and breakup of the Irish Ice Sheet (IIS) during the Last Glacial Termination (LGT, c.21-14 ka).

Existing reconstructions of the IIS are based on geomorphological mapping of landforms, which are inherently discontinuous in their distribution and preservation, and therefore provide only snapshots of glacial history. A more continuous archive is preserved in proglacial lake sediments. These lakes are sinks for glacially-derived meltwater and sediment, and enable continuous, spatially-integrated reconstructions of glacial and foreland environmental change, including annually or seasonally-resolved (varved) records that far exceed the temporal resolution of geomorphological techniques.

Thick sequences of laminated, potentially varved, proglacial lake sediments from Palaeolake Riada are well-preserved in the Irish Midlands and provide valuable insights into IIS behaviour and lake sedimentation. Their high temporal resolution provides a basis from which a new chronology of ice sheet behaviour can be constructed.

We present a new high-resolution analysis of laminated glacial lake sediment cores from Co. Offaly, close to IIS marginal landforms (moraines and eskers). A suite of physical and chemical analyses are used to reconstruct ice marginal processes and fluctuations of the IIS during the LGT. This preliminary analysis examines the value of multiproxy data to produce detailed reconstructions of the timing and dynamics of Irish Ice sheet retreat. This will produce insights into long term retreat patterns and behaviours of ice sheets during periods of climate amelioration, applicable to current and future dynamics of existing ice sheets.

**P-4865**

## **Chronology of proglacial lake overflows through the Arctic - Caspian watershed**

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The chronology of the overflow of ice-dammed lakes through the Main Continental Divide from the Vychegda valley to the Kama and then to the Volga River has been discussed since the middle of the 20th century. Krasnov (1948), Yakovlev (1956), Lavrov (1968, 1975), Kvasov (1975), Groswald (1998, 1999, 2009), Lavrov and Potapenko (2005, 2012), Lysa et al. (2011; 2014), Larsen et al. (2014) proposed that the last overflow through the Keltma pass, one of the ancient Early Quaternary valleys, occurred in the LGM. Sidorchuk et al. (1999, 2001), Mangerud et al. (2004), Zaretskaya et al. (2011, 2013, 2019) argued that there was no ice-dammed lake in the Vychegda valley and no inter-basin in the LGM. Mangerud et al. (2004) dated Lake Komi, the largest Late Pleistocene proglacial lake that occupied much of the Pechora and North Dvina basins, to 80-90 ka BP. Maslennikova and Mangerud (2001) proposed that the level of this lake was below the topographic threshold in the Keltma pass and therefore Lake Komi overflowed rather to the west into the Baltic Sea basin. If this was true, the overflow through the Keltma Pass would have never occurred in the Late Pleistocene.

To complete the discussion, we made a comprehensive study of the Keltma pass in the vicinity of the Kama-Vychegda watershed that included mechanical coring to a depth of up to 45 m, geophysical survey (electrical tomography, GPR sounding), OSL dating (vertical series of 17 dates), facial analysis (grain size and thin sections analysis, SEM analysis of quartz grain surface). The results allowed us to find the evidences of two ice-dammed lakes that existed in the Kewltma Pass in the last 150 ka. The lake dammed by the Moscovian (Late Saalian, MIS 6) ice sheet left a 20-m-thick varved silty-clayey sequence accumulated 145-140 ka BP. It is overlain by a 10-m-thick medium to coarse sand interpreted as deposit of the lake overflowed from the Vychegda Basin at 110-95 ka BP. Most probably it was the overflowing of Lake Komi that had occurred before its main stage dated by Mangerud et al. (2004) to 80-90 ka BP in the Pechora Basin. Next layer is the alluvia of local rivers deposited around 65-35 ka BP. The upper unit is 7-8-m-thick fine sand that makes a uniform cover over all topographic irregularities in the bottom and extends up the slopes of the of the Keltma hollow, which, along with microscopic features of the sediment and individual quartz grains, allows to interpret it as aeolian cover. The aeolian sand cover is dated to 30-10 ka BP, which excludes the occurrence of lacustrine environment during the whole MIS 2.

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P-4866

## Characterising hydrochemical controls on lake algal communities in proglacial lake systems from the SE ice-margins of Vatnajökull, SE Iceland.

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Arctic and subarctic regions are experiencing some of the most rapid ecological and environmental changes in response to accelerated warming. As ice-margins retreat in Arctic and subarctic regions, because of accelerated warming, multiple new proglacial lakes and aquatic ecosystems are created. There is a paucity of data relating to how the source of lake water (groundwater-fed, precipitation-fed), lake hydrochemistry, lake location (ice-marginal, isolated from ice-margin) and lake age (dependent upon glacial retreat) determine the structure of proglacial lake ecosystems. Furthermore, new proglacial lakes provide a novel opportunity to investigate the very early stages of lake development (known as ontogeny) and to test hypotheses previously based on palaeolimnological datasets and to establish whether these lakes act as carbon stores or sinks in the proglacial landsystem.

Here we present preliminary data from 23 proglacial lakes created by 5 outlet glaciers (Skaftafellsjökull, Svinafellsjökull, Kviarjökull, Fjallsjökull and Breidamerkurjökull) from the SE sector of the Vatnajökull ice-sheet, SE Iceland. The lakes comprise ice-marginal lakes fed by glacial water and precipitation, isolated lakes (isolated from the ice-margin in the last ~80 years) fed by either groundwater and or precipitation and perched moraine lakes which are fed directly by precipitation. The lakes are all between 0 – 80 years in age, based on the date the lake became directly isolated from the ice-margin, identified from satellite imagery and aerial photographs. We analysed stable oxygen isotopes ratios ( $^{16}\text{O}:^{18}\text{O}$ ) to determine lake water source; Chlorophyll *a* to measure lake biological productivity and diatom assemblages to investigate the algal ecosystems of the lakes. In addition, limnological and hydrochemical parameters were analysed in situ and at the laboratory to investigate the environmental controls on the algal lake ecosystems and to determine the type and source of organic carbon in the lakes.

Our preliminary data demonstrates that ground water may be an important driver of early lake algal ecosystems. Diatom assemblages in the majority of the lakes were characterised by high relative abundances of small benthic pioneer species (e.g., *Achnantheidium minutissimum* var. *minutissima*, *Achnantheidium minutissimum* var. *jackii*) which can tolerate turbid, low light and alkaline conditions caused by the groundwater and utilise the high concentrations of nutrients from glacial flour. *Nitzschia palea* was found in high relative abundances in some of the ground water-fed lakes possibly reflecting the high conductivity of these lakes. The precipitation-fed lakes are typically older and more distal to the ice-marginal; suggesting that the influence of groundwater on proglacial lake ecosystems may diminish over time. Early proglacial lake ecosystems are dynamic and may undergo rapid ecological changes as hydrological inputs change in proglacial areas.

**P-4867**

## **Varves, chronology and climate: progress on the re-investigation of the Swedish Timescale**

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A central research theme in the field of Quaternary Science today relates to the question of whether high-magnitude and abrupt (millennial to decadal scale) shifts in climate occurred synchronously or asynchronously across the globe. The importance of deciphering this lies in its ability to help us understand how our climate system operates.

By investigating palaeoenvironmental archives which preserve long records of past climate fluctuations, we can more accurately assess and model how our climate system is likely to respond to future changes. Polar ice-cores provide a record of past climatic change at annual resolution. These records, however, are remote from the major populated land masses, located predominantly in the temperate latitudes. Attempts to identify whether variability exists in the expression of abrupt climate change at different latitudes are hampered by uncertainties in the timing of events, as measured through traditional chronological techniques. Thus annual records of climate recorded in palaeolake basins (akin to tree rings) provide us with an opportunity to address this challenge as they are one of very few terrestrial archives of environmental change which have the ability to provide data at a resolution comparable or better than that of the polar ice cores. Consequently, they are a key archive for assessing the spatial and temporal differences in regional environmental responses to changing climates.

The Swedish Timescale (STS), a 13,300 year-long palaeoglaciolacustrine varve record which tracks deglaciation of ice following the Last Glacial Maximum, is preserved within a network of sites from south to north Sweden (De Geer, 1912; Wohlfarth et al., 1995). However, controversy surrounds the accuracy of this chronology, with authors suggesting that there may be more than 1000 years missing during the most recent glacial-interglacial transition (Younger Dryas to Holocene; e.g. Lundqvist, 1975). This poster from our ongoing research project discusses our approach which ultimately aims to unlock the true potential of these sequences, focusing predominantly on the lateglacial period. It will present new data which has been obtained from several of the original STS sites and highlights new sites that will help test, secure and refine the chronology. In addition to this, we apply high-precision analytical techniques such as  $\mu$ -XRF corescanning, x-radiography and thin section analysis allow us to test and compare our new work to the original varve counts, which were solely based on macroscale analysis of core surfaces in the field. It is anticipated that eventual refinement of this chronology will ultimately permit direct correlation and assessment of leads and lags in climate records across the North Atlantic region.



## AUTHORS INDEX

Presenting authors are underlined.

Author Name	Programme Codes
, Jérôme	O-1193
A. Catunda, Maria Carolina	<u>O-2037</u>
Abad, Manuel	O-3156, P-3056
Abakumov, Evgeny	P-3003
Abarzúa, Ana M.	<u>P-1821</u>
Abarzúa, Ana María	O-1150, P-4481
Abbasi, Hamidreza	P-3809
Abbott, Mark	<u>O-5091</u> , <u>P-2223</u>
Abbott, Peter	P-1618, <u>P-3618</u> , P-4460
Abbott, Peter M.	P-1417
Abderamane, Moussa	P-3806
Abdykanova, Aida	P-2239
Abe, Shintaro	O-2090
Abe-Ouchi, Ayako	<u>O-1085</u> , P-1411, P-1430, P-2489, P-4512
abraham, vojtech	P-4284
Abraham, Vojtěch	P-4299
Abram, Nerilie	P-4423
Abrantes, Fatima	O-2041, P-1802, P-2486
Abrantes, Fátima	O-4069, P-2484, P-2488
Abrook, Ashley M	<u>P-2271</u>
Abrook, Ashley M.	<u>P-3441</u>
Abrosimov, Konstantin	P-1865
Abstein, Michelle	O-3221
Accettella, Daniela	P-4004
Aceituno, Javier	O-5097
Achim, Brauer	P-4442
Achnopha, Yudhi	P-1623



INQUA 2019  
DUBLIN  
IRELAND

Achoundong, Gaston	O-5083
Achyuthan, Hema	<u>O-1109</u> , O-1112, <u>P-1453</u>
Adam, Ori	O-3030
Adamczyk, Aleksander	O-0049, O-2141, O-2211
Adamiec, Grzegorz	O-1191, P-1634, P-3856
Adams, Jon	O-3130
Adams, Scott	O-3013
Adamson, Kathryn	O-1056, <u>O-5085</u> , P-2458, P-3484, P-4863, P-4864
Adamu Isa, Aliyu	<u>O-1174</u>
Adatte, Thierry	P-3447
Adderley, W. Paul	P-4288
Addis, Agerie	P-3210
Adiya, Saruulzaya	P-1816
Adkins, Jess	P-4439
Adler, Dan	O-1181
Adler, Daniel	P-2615, P-4270
Adler, Lewis	P-4488
Adojoh, Onema C.	P-2002
Adolf, Carole	<u>O-2134</u> , P-2253
Adolphi, Florian	<u>O-3194</u> , O-3196, O-4008, O-4014, <u>P-4452</u> , P-4617
Adolphs, Silja	P-3010
Adrados, Luna	P-2623
Aedo, Diego	P-3034
Aeschbach, Werner	P-2469
Agarwal, Shailesh	P-4290
Agatova, Anna	O-3003
Ageby, Lucas	<u>O-4177</u>
Agnihotri, Rajesh	O-4053
Agnini, Claudia	P-3804
Agnon, Amotz	P-1034
Agrawal, Shailesh	P-1877
Aguilar Ortiz, Luis Ernesto	P-3806
Aguilar, Rigoberto	P-3224



INQUA 2019  
DUBLIN  
IRELAND

Aguirre Díaz, Gerardo	O-1042
Aguirre, Catalina	O-5052
Aguirre, Enoch	O-4125
Agusti, Jordi	P-2204
Agustí, Jordi	O-2166
Ahadi, Floriane	O-4036
Ahlborn, Marieke	P-2510
Ahmad, Khaldoun	P-1434, P-1436
Ahmady-Birgani, Hesam	O-3209, P-3404
Aichi, Masaatsu	P-1827
Aichner, Bernhard	O-2080, O-4087
Aidukas, Tomas	P-1852
Ait Brahim, Yassine	<u>O-3074</u> , <u>P-1496</u>
Aizhi, Sun	<u>P-2410</u>
Ajallooian, Fatemeh	<u>P-3418</u>
Akihiro, Yoshida	P-1009
Akkerman, Keechy	P-3446
Akpo, Orijemie E.	<u>P-2002</u>
Akpovi, AKOEGNINOU	O-5137
Aksay, Selçuk	O-1221, <u>P-1839</u>
Aksoy, Murat Ersen	P-4818
Akçar, Naki	O-1149, <u>O-2018</u> , P-2430, P-2462, P-2884, P-3001, P-3824
ALAMOU, Eric	O-0161
Alba, González-Lanchas	O-3154
Albalat, Emmanuelle	O-5064
Albani, Samuel	<u>O-0008</u> , O-0010, <u>P-2603</u>
Albarède, Francis	O-5064
Albert, Paul	O-3037, O-3042, O-4091, P-3620, P-3629
Albouy, Camille	P-3229
Alcalá-Reygosa, Jesús	<u>P-2441</u> , <u>P-2443</u>
Alcolea, Marta	P-1255, P-1872
Aldahan, Ala	P-4617
Aldeias, Vera	O-0073



INQUA 2019  
DUBLIN  
IRELAND

Aleksandrin, Mikhail	P-3606
Alekseev, Ivan	<u>P-3003</u>
ALEKSEEVA, VERONIKA	P-1413
Aleman, Julie	O-1044
Alessandri, Luca	P-1616
Alexanderson, Helena	<u>O-1052</u> , P-2452, <u>P-2457</u> , P-4510
Alexandrin, Mikhail	P-3631
Alho, Petteri	P-3825
Ali-Zwart, Sibel	P-2472
Aliev, Fuad	P-3612
Alina, Tudryn	P-3403
Alisher-Kyza, Saltanat	P-2239
Aliste, Diego	O-3172
Aliverini, Mauro	P-2510
Aliyeva, Elmira	<u>O-3050</u> , P-3402
Alizadeh, Kamaledin	P-1027, P-4289
Allaart, Lis	O-3203
Allaby, Robin	O-1103, O-4030
Allan, Estelle	P-2490
Allan, Mohammed	<u>P-1505</u>
Allan, Rob	O-0090
Allard, James	<u>O-2096</u> , P-2434
Allemand, Pascal	O-4186
Allen, Claire	P-3472
Allen, Melinda	O-5101
Allen, Peter	O-1059, O-3161, P-1282
Allen, Phillip	<u>P-1826</u>
Alliksaar, Tiiu	P-2859
Allin, Josh	P-3801
Allott, Timothy	O-1037, P-1491
Alloway, Brent	P-4499
Almond, Peter	P-4493
Alok, Apurva	<u>O-2070</u>



INQUA 2019  
DUBLIN  
IRELAND

Alonso-Garcia, Montserrat	O-2041, <u>O-4069</u> , P-2486
Alonso-García, Montserrat	O-3154, P-2471, P-2488
Alonzi, Elise	<u>O-0144</u>
Alramadan, Khalid Abdulsamad Hasan	P-2838
Alsharekh, Abdullah	P-4274
Alsos Greve, Inger	P-1201
Alsos, Inger	O-1100, O-1104, P-3204, P-3221
Alsos, Inger G.	O-0039, O-1027, O-1162, O-3025, P-1202, P-1209, P-1210, P-2218
Alsos, Inger Greve	<u>O-1105</u>
Alsouliman, Amer	O-2043, O-4201
Alt, Mio	O-2137, P-2238
Altaweel, Mark	O-1205
Altmeyer, Marina	P-3843
Altolaguirre, Yul	<u>O-2165</u> , O-4135, <u>P-4203</u>
Altınay, Onur	P-2462
Alvarez, Alajandro	O-5048
Alvarez, Claudio	O-3172
Alvarez, Denisse	O-3188
Alvarez, Nadir	P-1205
Alvarez-Solas, Jorge	<u>O-2040</u>
Alvarez-Zarikian, Carlos	O-1111
Amann, Benjamin	O-2094, O-3080, <u>O-3157</u> , <u>P-3432</u> , P-3838
Amantov, Aleksey	O-5127
Amaral-Zettler, Linda A	O-3174
Ambili, Anoop	O-1120, P-3452, P-3454
Ambrosi, Christian	<u>P-1842</u> , P-4829
Ames, Christopher	<u>O-2043</u> , O-4201, <u>P-2235</u>
Amesbury, Matt J.	P-4604
Amesbury, Matthew	<u>O-2051</u> , O-2133, O-2202, P-2853, <u>P-2872</u>
Amigo, Gonzalo	P-4477
Amini, Hamideh	<u>P-4809</u>



Amirnezhad-Mozhdehi, Sahar	O-3081, O-5124
Amirov, Elnur	O-3050
Amon, Leeli	P-2859
Amorós, Gabriela	P-2202
An, Chengbang	<u>P-2413</u> , P-3420
An, Wenling	<u>P-1422</u>
An, Zhisheng	O-0025, P-1444, P-1498, P-1515, P-2500, P-2836
Anadón, Pere	P-3804
Anand, Pallavi	O-1121
Ancin-Murguzur, Francisco Javier	P-1202
Andačić, Natalija	P-2818
Anderberg, Emma	P-4617
Andersen, Jane L.	P-1483, P-3485
Andersen, Morten	O-4037
ANDERSEN, NILS	O-2118
Andersen, Nils	O-3071, P-1457, P-1458
Anderson, Agnes	O-1080, P-1007
Anderson, Brian	O-2098, O-4020, P-3466
Anderson, John	O-5057, P-2258
Anderson, Leif S.	<u>O-2017</u> , <u>P-2817</u>
Anderson, Lesleigh	<u>O-1231</u> , O-5091, <u>P-2876</u>
Anderson, Patricia	P-1273
Anderson, R. Scott	O-3023, O-3151, O-5029, P-3493
Anderson, Romario	<u>P-1037</u>
Anderson, Scott	O-3214, P-2212
Andrade, César	P-4022
Andrade, Claudia	P-1017
Andrade, César	O-3088, O-4107, P-3052, P-3062, P-4024
Andre, Berger	P-2476
Andreassen, Karin	O-2143, O-5129, O-5131
Andreev, Andrei	O-1045
Andreev, Pavel	P-1909, P-3854
Andrei, Krivoshapkin	P-2231



INQUA 2019  
DUBLIN  
IRELAND

Andresen, Katrine Juul	O-0005
Andreu-Hayles, Laia	O-3195
Andreucci, Stefano	O-1153
Andrews, Luke	<u>P-2209</u>
Andrič, Maja	P-2262, <u>P-4240</u>
Andrés, Miriam	P-2808
Andrés, Nuria	P-1486
Andueza, Luis	P-1265
Andy, Wheeler	P-1404
Angeletti, Lorenzo	P-4029
Anghelinu, Mircea	P-4445
Anglos, Demetrios	P-1510
Anguilano, Lorna	O-0158
Anjar, Johanna	<u>P-3824</u>
Ankit, Ankit	<u>P-3454</u>
Ankor, Martin	<u>O-5053</u>
Anma, Ryo	O-1006
Anoikin, Anton	O-0056, O-0135
Anschutz, Pierre	P-1802
Anselmetti, Flavio	<u>O-3085</u> , P-3042
Anselmetti, Flavio S.	P-1471, P-1897, P-2907
Antigüedad, Iñaki	P-4474
Antinao, Jose Luis	P-2454, P-4496
Antipov, Mikhail	O-3205
Antoine, Pierre	O-1193, P-1409, P-1634, P-1869, P-3875, P-4443
ANTOINE, Pierre	<u>O-5115</u> , <u>P-1874</u>
Antolin, Ferran	<u>O-1093</u> , O-5009
Antón, Loreto	P-2883
Anupama, K.	O-5013, <u>O-5014</u>
Anupama, Krishnamurthy	O-2158, P-1457, P-1458
Anyanwu, Chiamaka	<u>O-5139</u>
Anzalone, Erlisiana	P-2892
Anzidei, Marco	P-3021



INQUA 2019  
DUBLIN  
IRELAND

Ao, Hong	P-3212
Aouadi-Abdeljaouad, Nabiha	O-5023
Aouraghe, Hassan	O-5025
Aoustin, David	P-4632
Aoyama, Kazuo	O-2161
Appel, Erwin	P-3434
Appelt, Oona	O-3036
Aquino Lopez, Marco Antonio	<u>O-4153</u>
Aquino-Alfoso, Olga	O-3060
Aradóttir, Nína	O-4128, <u>P-1894</u>
Aragón-Moreno, Alejandro A.	O-1083
Arai, Ryoyu	O-2090
Arakelyan, Dimitri	O-2100, P-1601
Arakelyan, Dmitri	P-2615
Aranbarri, Josu	O-1139, <u>P-1255</u> , <u>P-1872</u> , P-4284
Aranburu, Arantza	P-4451
Araneda, Alberto	O-3188
Araos, José	O-4164
aratman, cihan	<u>O-1210</u>
Araujo, Gael	P-3224
Aravena, Juan Carlos	O-4019, P-2518
Aravena, Juan-Carlos	<u>P-4477</u>
Araújo, Ana Cristina	O-4107
Arbelaez-Moreno, Lina	P-4836
Archer, Claire	P-3431
Archer, Stuart	O-5058
Arcusa, Stephanie	<u>O-0011</u> , O-1126
Ardelean, Adrian	P-2845
Ardelean, Florina	P-2845
Arenas, Concha	P-1872
Arias, Pablo	O-4107
Arienzo, Ilenia	P-3810
Arienzo, Monica	<u>O-1049</u>



INQUA 2019  
DUBLIN  
IRELAND

Ariztegui, Daniel	P-3060, P-3442
Armitage, Philip	P-2809
Armitage, Simon	O-3107, P-4456
Armon, Moshe	O-3030
Armstrong McKay, David I.	<u>O-2058</u> , <u>P-2255</u>
Arnardóttir, Erna Ósk	<u>O-1188</u>
Arnaud, Fabien	O-1024, O-4006, P-1214, P-2262, P-4240
Arnaud-Fassetta, Gilles	P-1016
Arnold, David	<u>P-3217</u>
Arnold, Lee	O-3035, O-5025, O-5032, P-1513, P-2604, P-2899
Arnold, Lee J.	P-4627
Arnold, Neil S.	O-0045, P-1843
Arnuk, James	O-3013
AROUNA, Ousseni	<u>O-0161</u>
Arppe, Laura	<u>O-0146</u> , <u>P-1229</u> , P-4214
Arrighi, Simona	O-3224
Arrington, Eric	P-1619
Arriolabengoa, Martin	P-4451
Arrison, Thomas	P-4428
Arroyo-Kalin, Manuel	O-4002
Arruda Rangel, Carlos Marclei	<u>P-1042</u>
Arslan, Sebnem	<u>P-2463</u>
Arslanov, Khikmat	P-1058
Arthaud, Florent	P-1212
Arici, Mehmet	O-3210
Asch, Kristine	<u>O-2190</u>
Aschenbrenner, Simone	O-4048
Ascough, Philippa	O-2078, O-4013, P-1055
Ascough, Philippa L.	P-2494
Asena, Quinn	<u>O-2136</u>
Ashe, Erica	O-0081, <u>O-4152</u> , P-1061
Ashworth, Allan	<u>O-0042</u>
Asioli, Alessandra	O-5041



INQUA 2019  
DUBLIN  
IRELAND

Asrat, Asfawossen	O-1036, O-3031, <u>O-3098</u> , O-4173, O-4174, P-2421, P-3805, P-4272, P-4273
Astakhov, Valery	<u>O-5037</u> , P-2622
Astley, Sean	P-2860
Aswan, A	P-1610
Atanackov, Jure	O-4188
Atkinson, Nigel	O-5119, P-4823
Atkinson, Tim	O-4010, <u>P-4462</u>
Attig, John	P-1853
Atwood, Alyssa R.	O-5100
Auderset, Alexandra	P-1428
Audin, Laurence	O-4125
AUGUSTE, Patrick	P-1874
Augustijns, Femke	P-2862
Augustinus, Paul	O-3145, O-4012, O-5103, P-1475, P-3423, P-3463, P-3470, P-4492, P-4493
Augustinus, Paul C.	O-4116, P-1470
Ault, Toby	O-0011, P-1499
Aumaitre, Georges	P-4617
Aumaître, Georges	O-1053, O-1151, P-2457, P-3409
Aurice, TOSSA DOGNON	O-5137
Ausin, Blanca	P-4454
Austermann, Jacqueline	P-1066
Austin, Bill	P-4460
Austin, William	O-3190
Autret, Ronan	O-3165
Avery, Rachael	<u>O-1051</u>
Avirmed, Dashtseren	P-1816
Avni, Yoav	<u>O-4198</u> , O-4199, <u>P-2248</u>
Avriel-Avni, Noa	P-2248
Axford, Yarrow	O-0125
Ayalon, Avner	O-0050
Aydemir, Eda	O-3210



Aytaç, Ahmet Serdar	<u>O-1060</u> , <u>P-1279</u>
Azanza, Beatriz	P-2207
Aze, Tracy	O-2180
Azevedo, Allana	P-4007
AZIBEIRO, LUCIA	O-2118
Azibeiro, Lucía A.	O-3071, O-3076, <u>O-3154</u>
Aznarte, Jose	P-2259
Azuma, Takashi	P-4803, <u>P-4814</u>
Aðalgeirsdóttir, Guðfinna	O-2017
B.R., Ramesh	P-2219
B.Wormull, Juan L.	P-1266
Babonneau, Nathalie	P-3490
Baccolo, Giovanni	O-0013, O-0095, O-2015
Bachmanov, Dmitriy	P-3037
Bachtsevanidou Strantzali, Ioanna	P-3230
Bacon, Anne-Marie	P-1452
Bacon, Karen	O-2197
Badal, Ernestina	P-1255
Bader, Juergen	O-1035
Bader, Jürgen	P-4434
Badino, Federica	O-1097, O-1168, <u>O-3224</u> , <u>P-3430</u>
Badura, Janusz	P-3873
Badura, Monika	O-4083
Badyukov, Danila	<u>P-2227</u> , <u>P-3002</u>
Badyukova, Ekaterina	<u>P-3601</u>
Bagge, Meike	P-3018
Baggio, Jacopo	O-3170
Baghel, Pankaj	O-1013
Bahdasarau, Maksim	P-4641
Bahr, Andre	O-3071
BAHR, ANDRE	O-2118
Bahr, André	<u>O-0028</u> , O-2037, P-2482
Bahrour, Sonya	O-4078



INQUA 2019  
DUBLIN  
IRELAND

Baichtal, James	O-2074
Baig, Irfan	<u>O-0004</u>
Baigusheva, Vera	O-5107
Baika, Kalliopi	O-4029
Bailey, Richard M.	P-2606
Baillie, Michael	O-4205
Baioni, Marco	O-1097
Baird, Andy	P-2863
Baisch, Christopher	O-3048, P-1836
Baisden, Troy	P-2872
Baize, Stephane	O-4122, O-4187
Baize, Stéphane	<u>O-4125</u> , <u>P-4803</u>
Bajard, Manon	O-1024, <u>O-4006</u> , <u>P-4433</u> , P-4435
Bajo, Petra	O-3075, P-3488, P-4486
Baker, Andy	O-3098, O-4092, P-2507, P-4488
Baker, Patrick	O-1046
Baker, Victor R	P-1617
Bakke, Jostein	O-1226, O-3114, <u>O-3186</u> , O-4051, <u>P-3453</u> , P-3484, P-3822, P-3853, P-4433, P-4435
Bakken Thastrup, Mads	P-3628
Bakker, Marcel	O-2193
Bakker, Pepijn	<u>P-1406</u>
Bakran-Petricioli, Tatjana	O-0084
Bakulina, Nadezhda	P-4636
Bakumenko, Varvara	P-4300
Balakauskas, Lauras	P-2487, P-4216
Balasz, J. Carles	O-3004, <u>P-3846</u>
Balascio, Nicholas	O-3023
Baldini, Lisa	P-2507
Baldock, Jeff	O-5032
Balk, Joshua	O-0159
Balkanski, Yves	O-0008, P-2603
Ballantyne, Colin	O-1055, O-3230



Ballantyne, Colin J.	O-5063
Ballard, HollyNoelle	O-4175
Ballesteros, Daniel	O-1151, <u>O-2072</u> , <u>P-1488</u>
Ballo, Eirik	P-4433, <u>P-4435</u>
Balme, Jane	<u>O-5095</u>
Balme, Matt R.	O-0045, P-1843
Balme, Matthew R.	O-5000
Baltrūnas, Valentinas	P-2912
Balážovičová, Lenka	P-2448
Bamford, Marion	O-4159, P-2235
Bandou, Dimitri	P-1898, P-4511
Banner, JAy	P-2507
Bannister, Wayne	O-1023, <u>O-5076</u> , P-4251
Bao, Kunshan	O-2210, P-1431, <u>P-4243</u>
Bao, Roberto	O-3174, O-4106, P-1495, P-4024
Baptista Neto, José Antonio	P-1042
Baptiste, Julien	P-1833
Bar-Yosef, Ofer	P-4456
Baranov, Dmitry	P-4845
Barbante, Carlo	O-1186
Barbara, Delmonte	<u>O-0013</u>
Barberena, Ramiro	<u>O-0143</u>
Barbería, Laura	O-3080
Barbieri, Giulia	O-1082
Barbosa, Ana C.C.	O-3195
Barbujani, Guido	O-1026
Bard, Edouard	O-2120, O-3190, P-3225, P-4617
Bardají, Teresa	<u>P-3497</u> , <u>P-4531</u> , P-4804
Barešić, Jadranka	O-0084
Barham, Lawrence	P-4624
Barker, Graeme	O-2044
Barker, Louise	O-0150, P-1033
Barker, Philip	<u>O-2109</u>



INQUA 2019  
DUBLIN  
IRELAND

Barker, Stephen	O-1087, P-1478, P-1856
Barker, Steve	P-3618
Barlow, Axel	P-1231, P-1238
Barlow, Dr Natasha	O-1200, P-1047
Barlow, Natasha	O-0003, O-0078, O-0116, P-1056, P-1064, P-1072, P-1903, <u>P-2005</u> , P-4631
Barnett, Peter J.	O-0029
Barnett, Robert L.	<u>O-1161</u> , <u>P-1067</u>
Baroni, Carlo	O-0013, P-1887
Baroni, Mélanie	O-0013, P-3468
Barr, Cameron	O-3184, O-4094, O-5032, <u>P-1513</u> , P-3413, P-4489
Barr, Iestyn	O-0046, O-0047, O-4033, P-1884, P-2439
Barratt, Phil	O-1213, P-4287
Barratt, Philip	O-3099, O-4060
Barrell, David	O-3145, <u>O-4021</u>
Barrera González, Matias	P-2442
Barrett, Kevin	<u>P-2875</u>
Barrett, Maire-Therese	O-4205
Barrett, Phil	O-3101
Barriandos, Mariano	O-3004, O-3079, P-3846
Barroso-Medina, Cecilia	O-1026
Barroso-Ruiz, Cecilio	O-1026
Barrows, Timothy	<u>O-3068</u> , O-3142, P-1831, P-3501, P-4493
Barry, James	O-0150, O-4034
Barsky, Deborah	O-2166, P-2204
Barta, Gabriella	O-1194, O-1195, P-1629, P-1870, P-2614, P-3625
Bartlein, Patrick	O-3214, P-1273, P-1824, <u>P-2514</u>
Bartlett, Marie	O-3013, <u>P-3035</u>
Bartmann, Phillipp	P-4473
Bartmiński, Piotr	P-4224
Bartolome, Miguel	P-2507, P-4451
Bartolomé, Miguel	P-1226, P-1266, P-1872, P-2841
Barton, Nick	O-5023



INQUA 2019  
DUBLIN  
IRELAND

Bartoszek, Krzysztof	<u>P-1492</u>
Bartowitz, Kristina	O-0021
Bartrolí, Raül	O-5025
Bartz, Melanie	<u>O-4114</u> , P-4627
Baryshnikov, Gennady	P-3856
Basell, Laura	<u>O-3095</u> , P-2232, <u>P-2809</u> , P-4220
Bassetti, Maria-Angela	O-1111
Bassetti, Michele	O-3078
Bassi, Magdalena	P-4017
Bassinot, Franck	P-1449, P-1802, P-2470, P-4490, P-4515
Bassis, Jeremy	<u>O-3225</u>
Basso, Daniela	P-4029
Basu, Sayak	O-1120, <u>P-3452</u>
Bataille, Clement	O-0062, O-0063
Bataille, Clement P.	<u>O-0058</u>
Batchelor, Christine	O-0007, <u>O-1237</u> , O-4127
Batchelor, Robert	<u>P-1272</u>
Bateman, Mark	O-0080, O-1055, O-1127, O-3230, O-5128, O-5130, P-1485, P-2492, P-2837, <u>P-3038</u>
Bateman, Mark D.	O-5042, P-2625
Bateman, Rebecca	P-3038
Bates, Martin	O-0078, O-4030, P-1036, P-1048
Bates, Richard	O-4030, P-1048
Batliner, Andreas	O-4109
Batmunkh, Tsogtbaatar	O-0136
Bauch, Henning	P-4516
Bauch, Henning A.	<u>O-4214</u> , <u>P-1479</u> , P-3004
Baum, Timan	O-5009
Baumer, Marlene	O-5019
Bauska, Thomas	O-2148, P-3412, P-4498
Bavec, Miloš	<u>O-4188</u>
Baykal, Yunus	O-1191, <u>P-1425</u>
Bayliss, Alex	O-1213, O-3190, P-3614



INQUA 2019  
DUBLIN  
IRELAND

Bayon, Germain	P-1405, P-4401
Bayrakdar, Cihan	<u>P-2462</u>
Bazarradnaa, Enkhtuya	P-3480
Bazin, Lucie	O-2039, <u>P-4515</u>
Beach, Timothy	<u>O-3138</u> , O-3215, O-4052, P-3237
Bechtel, Achim	P-3428
Beck, Kristen	<u>O-4097</u> , <u>P-4252</u>
Becker, Lukas	O-4129
Beckett, Frances	P-1620
Beer, Jürg	P-4452, P-4617
Beerten, Koen	O-1065, P-1242
Beeton, Jared	<u>P-3222</u>
Beets, Christiaan J.	O-3125
Behling, Hermann	O-2205, O-3061, O-3136, P-1027, <u>P-1232</u> , P-1623, <u>P-2247</u> , P-4289, P-4461
behling, hermann	P-2856, P-4212
Beilinson, Elisa	<u>P-4524</u>
Beilman, David	<u>P-2864</u>
Bejar-Pizarro, Marta	P-4830
Bekele, Tamrat	P-3207, P-3210
Bekker, Matt	P-1263
Belcher, Claire	P-1807
Belfoul, Alaeddine	P-2898
Belhouchet, Lotfi	O-5023
Belknap, Daniel	O-2088, P-2004, P-2007
Bell, Benjamin	<u>O-3148</u> , <u>P-2268</u>
Bell, Trevor	O-5062
Bella, Domenico	O-4044
Bella, Pavel	P-2806
Bellanova, Piero	<u>P-3053</u> , <u>P-3054</u>
Bellier, Olivier	O-2100
Bellucci, Luca	O-3153
Bellwald, Benjamin	<u>O-4129</u>



INQUA 2019  
DUBLIN  
IRELAND

Belmaker, Miriam	<u>O-4175</u>
Belmar, Carolina	<u>P-1262</u>
Belmonte-Ribas, Ánchel	P-1226
Belousova, Natalia	<u>O-0134</u>
Belousova, Natalia E.	<u>P-1278</u>
Belozerova, Ksenya	P-2874
Belt, Simon	<u>O-1183</u> , O-1189, O-4073, P-1443
Belyaev, Vladimir	O-3054, O-4191, P-1639, P-1909, <u>P-1911</u> , P-3608, <u>P-3854</u> , P-4860
Belyaev, Yuri	O-4191
Belyanina, Nina I.	P-1058
Belzyt, Szymon	O-1128, <u>P-1879</u> , <u>P-2822</u> , P-2824, P-2827
Ben Dor, Yoav	O-2219, O-3030, P-3436
Ben Nasser, Atef	P-4421
Benavente, Carlos	O-4125
Benavente-Marín, Mario	O-3174, P-1495
Benazzi, Stefano	O-3224
Bender, Maren	P-3014
Bendle, Jacob	<u>O-3144</u>
Bendle, Jacob M.	P-4862
Benedetti, Michael	O-1016, <u>P-2807</u> , <u>P-3410</u>
Benediktsson, Ívar Örn	O-1188, O-4128, P-1866
Benetti, Sara	<u>O-1055</u> , O-3230, O-5060, O-5062, O-5063, P-2431, P-2497
Beniamino, Mecozzi	P-2208
Benito, Blas M.	P-2253
Benito, Gerardo	<u>O-3079</u> , P-3848, <u>P-3850</u>
Benito, Xavier	<u>O-2060</u>
Benito-Calvo, Alfonso	O-5025, P-2880
Benkaddour, Abdelfattah	O-3073
Bennett, Hannah	O-4111
Bennike, Ole	O-1159, <u>P-1071</u>
Bensa, Aleksandra	P-2818
Bentley, Michael	O-4133, P-4005



INQUA 2019  
DUBLIN  
IRELAND

Bentley, Michael J	P-4479
Bentley, Mike	<u>O-0113</u> , O-3228, P-2435
Benítez, Anahí	O-0143
Beranova, Jana	O-2207
Berben, Sarah M. P.	<u>P-1417</u>
Berben, Sarah M.P.	O-3114
Berclaz, Christophe	O-0093
Berdnikova, Alina	<u>P-3604</u>
Bereiter, Bernhard	O-1088
Berenguer, José	O-3172
Berg, Edward	O-5029
Berg, Sonja	P-1635
Berg, Stefanie	O-2024, P-1835, P-3208
Berger, André	P-2215, P-2478, P-2485
Berger, Jean-François	O-3077, P-1868
Bergeron, Yves	O-0016
Berglund, Olof	P-1004, P-1045
Bergson, Bergur	O-3202
Berkelhammer, Max	O-2201
Berlioz, Emilie	<u>O-2164</u>
Bermingham, Adam	O-2107, <u>O-3173</u>
Bernal Wormull, Juan Luis	<u>P-3048</u> , <u>P-4451</u>
Bernal, Dario C.	P-4819
Bernales, Jorge	<u>P-1420</u> , P-1483, P-3485
Bernard, Loup	O-4056
Bernasconi, Stefano	O-1093
Bernatchez, Pascal	P-1067
Berndt, Christian	P-1073
Berndt, Jan Ole	O-4135, <u>O-4136</u> , <u>P-4204</u>
Berndt, Jan-Ole	O-4134
Bernhardt, Nadine	O-1102
Berrío, Juan-Carlos	P-3235
Bersezio, Riccardo	P-1906



INQUA 2019  
DUBLIN  
IRELAND

Berthier, Etienne	O-1142
Bertini, Adele	P-2477
Bertler, Nancy	O-1088
Bertoni, Duccio	P-1013
Bertran, Pascal	P-3885
Bertrand, Sebastien	O-2094, O-2095, O-3157, P-3838, P-4856
Bertrand, Sébastien	O-1077, O-4055, P-3840, P-3847
Bertuletti, Paolo	O-1168, O-3224
Best, Louise	O-0116, O-0132
Betancort, Juan F.	P-2605
Bethke, Ingo	P-2505
Bettencourt, Ana MS	O-1026
Bettinger, Robert	O-2104
Bettis III, Elmer Arther	O-0033
Bettis, Arthur	P-2902
Bevan, Andrew	P-4427
Bevan, Andy	O-5078
Beverley, Emily	P-4270
Bevington, Joe	P-1819
Bevis, Michael	O-4185
Bewley, Robert	P-1264
Bezděk, Ales	O-5109
Bezgodov, Konstantin	P-4417
Bhagwat, Shonil	O-1121, O-1134
Bhattacharyya, Amalava	P-4290, P-4534
Biagioni, Siria	O-3136, P-1623
biagioni, siria	P-2856, P-4212
Bianchini, Paula	P-2425
Biasi, Christina	P-2857
Bicho, Nuno	O-1016
Bickert, Torsten	O-4071
Bierman, Paul R.	P-3823
BIETTE, Melody	<u>O-2016</u>



INQUA 2019  
DUBLIN  
IRELAND

Biette, Mélody	P-2458
Bigelow, Nancy H.	P-1210
Bigg, Grant	O-0080, O-3230, O-5058, P-1407, P-2492
Bigler, Matthias	O-4008
Bigus, Katarzyna	<u>P-1043</u>
Bihari, Árpád	P-4299
Bijaksana, Satria	O-3057, P-1471
Bilintoh, Thomas	P-1836
Biller, Nicole	O-2117
Billingsley, Anne	O-4169
Billy, Isabelle	O-5102, P-2495
Billy, Julie	P-3011
Biln, Libby	P-2617
Bindler, Richard	O-1084, O-2083, O-2127, O-2131, O-2198, <u>O-3102</u> , P-4438
Bingham, Robert G.	P-2439
Bini, Monica	P-1013, P-1607, P-3488, <u>P-3810</u> , <u>P-4013</u>
Binnie, Steven A	P-4479
Birch, Leah	O-0032
Bird, Darcy	O-3170
Bird, Michael	O-0103, O-1046, O-1047, O-2112, O-3065, P-1065, P-1811
Birkel, Sean	O-4164
Birks, H. John B.	O-2029, O-4213, P-3235
Birks, Hilary H.	O-2031
Birner, Benjamin	O-1088
Bisbal-Chinesta, Josep Francesc	O-2167
Bischoff, Jim	P-2429
Bishop, Rosie	O-5009
Bishop-Taylor, Robbi	P-3043
Bisht, Dr. Pinkey	<u>P-2461</u>
Biskaborn, Boris	O-5021
Bista, Diksha	<u>O-0061</u>
Bitinas, Albertas	O-1128, P-1035, <u>P-1050</u> , P-1879, P-2822, P-2824, <u>P-2825</u> , P-2827



INQUA 2019  
DUBLIN  
IRELAND

Bittmann, Felix	O-0006
Bittner, Lucas	O-3021, O-3096, P-2253, P-3207, P-3480, <u>P-4505</u>
Bjarnadottir, Lilja	O-5059
Bjarnadóttir, Lilja R.	O-5131
Bjarnadóttir, Lilja Rún	<u>P-4006</u>
Bjune, Anne E.	O-2029
Bjune, Anne Elisabeth	<u>O-1162</u>
Björn, Erik	P-4438
Blaauw, Maarten	O-1154, <u>O-1179</u> , O-3191, O-4097, O-4153, P-4494
Black, Andrew	O-3202
Black, Heather	O-1111
Black, Stuart	O-3135
Blackford, Jeff	O-1037
Blackwell, Bonnie A.B.	O-3131
Blackwell, Paul	O-3190, O-3191
Blaikie, James	P-4475
Blain, Hugues-Alexandre	O-2166, <u>O-2167</u> , <u>P-2204</u>
Blais, Jules M.	P-4248
Blakeley, Adam	O-3108
Blakie, James	O-1157
Blanchet, Cecile	<u>O-3093</u> , <u>P-3839</u>
Blanchet, Claire	<u>O-1024</u>
Blankholm, Hans P.	O-3025
Blankholm, Hans Peter	<u>O-3022</u>
Blanton, Chelsea	O-4043
Blanz, Thomas	P-1457, P-1458
Blarquez, Olivier	O-1125, P-1809, P-1817, <u>P-1820</u>
Blasco, Ruth	P-2202, P-2808
Blaus, Ansis	O-2029, <u>P-2859</u>
Blauvelt, David	O-0048, P-1844
Blewitt, Geoffrey	O-4151
Bliedtner, Marcel	P-3480, P-4505, P-4530
Blinkhorn, J	<u>O-1106</u> , <u>P-4266</u>



INQUA 2019  
DUBLIN  
IRELAND

Blinnikov, Mikhail	P-4300
Blockley, Simon	<u>O-1181</u> , O-3041, O-4195, P-1601, P-2416, P-2424, P-3217, P-4270, <u>P-4456</u>
Blockley, Simon P.E.	P-3449
Bloemendal, Jan	P-3878
Bloemsma, Menno	O-1076
Blois, Jessica	<u>O-0101</u> , <u>P-3218</u>
Blomdin, Robin	P-1483, P-3485
BLOND, Ninon	<u>O-3094</u>
Blondel, Cécile	O-2164
Blue, Lucy	P-1264
Blum, Joel	O-5027
Blumetti, Anna Maria	O-4044, O-4123
Blunier, Thomas	O-2015, O-4014
Bluszcz, Andrzej	P-1634
Blyakharchuk, Tatiana	O-3219, <u>P-1257</u> , <u>P-2420</u>
Boaretto, Elisabetta	O-0050
Bobak, Dariusz	P-3873
Bobek, Premysl	P-3627
Bober, Aleksandra	O-1165, <u>P-2407</u>
Bobkov, Roman	P-3888
BOBOYE, Olugbenga	<u>P-4527</u>
Boboye, Olugbenga A.	<u>O-5135</u>
Bobrovsky, Maxim	P-1812, P-1825
Bobrowsky, Peter	P-3035
Bobrowski, Przemysław	O-1020
Bocherens, Hervé	O-0123, P-1229, P-1231, P-4214
Bodin, Xavier	P-2453, P-2455
Boechat Albernaz, Marcio	O-1078
Boehnert, Sandy	P-2246
Boers, Niklas	P-1409
Boes, Evelien	<u>O-3087</u>
Boes, Robert	O-3085



INQUA 2019  
DUBLIN  
IRELAND

Boesken, Janina	P-1635
Boesl, Fabian	<u>P-3049</u>
Bogotá-Angel, Giovanni R.	P-3235
Bogucki, Andryi	P-2885, P-4633
Boisserie, Jean-Renaud	P-4529
Bokhari Friberg, Yasmin	O-2185
Boles, Oli	O-5009
Bolge, Louise	O-3046
Bolikhovskaya, Nataliya	O-3053
Bolin, Viviane	O-5024
Bolland, Alexander	<u>O-4089</u>
Bolorbat, Tsedendorj	O-5094
Bolton, Matthew	<u>P-3619</u>
Bolus, Michael	O-4134, P-1246
Bona, Fabio	O-5108
Bonachea, Jaime	P-4256
Boncio, Paolo	P-4803
Bond, Jeffery	O-2212
Bond, Jeffrey	<u>P-1481</u> , <u>P-2890</u>
Bondarev, Alexey A.	O-3132
Bonetto, Jacopo	P-1267
Bonfiglio, Laura	P-2810
Bonk, Alicja	O-4086
Bonneville, Steeve	O-0093
Bonnin, Jérôme	P-1802
Bonomo, Sergio	P-1013
Boom, Arnoud	O-2152
Boomer, Ian	O-3098
Booth, Adam	O-0047, O-2127, P-2438, P-3822
Booth, Dr Adam	O-1200, P-1047
Bordonau, Jaume	P-2243
Bordoni, Simona	O-1035
Borek, Aleksandra	P-2265



Borges, Rebecca	P-2246
Borisova, Olga	O-3054, O-3207, <u>O-5018</u>
Borja, Adelina	O-5076
Borodavko, Pavel	P-3826
Borodin, Aleksandr	<u>O-5110</u> , P-1224, <u>P-2811</u> , P-4417
Borrero, Luis	O-3028, P-4476
Borrero, Luis A.	P-4264
Borsuk, Oleg	P-2227
Bortolini, Eugenio	O-3224
Borówka, Ryszard Krzysztof	P-2422, P-4640
Bos, Johanna	<u>P-4227</u>
Bosch, Marjolein	O-0074
Bosnic, Ivana	O-3088
Boso, Domenico	O-4044
Bosomworth, Matt	<u>O-1205</u>
Bosq, Mathieu	P-1405, P-3885
Bostock, Helen	O-3145, O-4020, P-4492, P-4499, <u>Plen04</u>
Boston, Clare	<u>O-0047</u> , O-3198, O-3200, P-2436, P-3816, <u>P-3820</u> , P-3822, P-4857
Boswell, Steven	P-1405, P-4401
Boswijk, Gretel	O-4204
Bosák, Pavel	O-1204, O-2071, P-2806, P-4523
Botha, Greg A.	O-4178
Bothe, Oliver	P-4423
Bouchaou, Lhoussaine	O-3074, P-1496
Boucher, Étienne	O-0086
Boudad, Larbi	P-1868
Bouillon, Steven	P-3236
Boujelben, Karim	O-3077
Bouloubassi, Ioanna	O-3109
Boulton, Chris A.	O-2058
Boulton, Geoffrey	<u>O-3211</u> , <u>P-1840</u>
Boulton, Sarah	P-2898



Bourgeois, Olivier	P-4839
Bourillet, Jean-François	P-1405
Bourke, Mary	P-3857
Bourlès, Didier	O-1053, O-1151, P-3409
Bourlès, Didier L.	P-2457, P-4617
Bourman, Robert P.	P-1060
Bourne, Anna	O-3042, <u>O-3117</u> , <u>P-1618</u> , P-4460
Bouttes, Nathaëlle	<u>O-2038</u> , O-2042
Bouvet de la Maisonneuve, Caroline	P-1615
Bouvet de Maisonneuve, Caroline	O-1118
Bowen, Mark	<u>P-2602</u>
Bowker, Matt	P-3819
Bowman, David	O-2062
Boyd, Meighan	<u>O-4010</u> , P-4462
Boyden, Patrick	<u>P-3015</u>
Boyes, Benjamin	<u>O-5118</u> , <u>P-1883</u>
Boyle, J.F.	O-2128
Boyle, John	O-5003, P-2221, P-4246
Boynagryan, Vladimir	P-3606
Bracchi, Valentina Alice	<u>P-4029</u>
Braconnot, Pascale	O-0008, P-2470, P-4424, P-4509
Bradak, Balazs	<u>P-2612</u>
Bradley, Sarah	O-2222, O-3230, P-3483
Bradley, Sarah L.	O-1161
Bradley, Sarah Louise	<u>O-3227</u> , <u>P-1059</u>
Bradshaw, Corey	<u>O-0103</u>
Bradshaw, Richard	<u>O-1176</u> , P-1289
Bradshaw, Richard H.W.	O-1125
Bradtmilller, Louisa	O-1086
Bradwell, Tom	O-2078, O-3202, O-3230, O-5130, P-1403, P-3821, P-4002
Brady, Esther C	O-0010
Bradák, Balázs	O-1195, P-1629, P-1870, P-2614, P-3625
Branas, Manuel	P-1265



INQUA 2019  
DUBLIN  
IRELAND

Branch, Nicholas	O-3171
Branch, Nick	O-2110
Brand, Michael	P-1811
Brandes, Arno F. N.	O-3195
Brandes, Christian	<u>O-4189</u> , P-3863, P-4851
Brandolese, Sara	<u>O-3066</u>
Brandolini, Filippo	O-2124
Brandon, Zinsious	O-1016
Braucher, Regis	O-1142, O-2020, P-2459
Braucher, Régis	P-1862, P-1912, P-2818
BRAUER, Achim	P-4448
Brauer, Achim	O-1076, O-1212, O-1228, O-2080, O-2161, O-3106, O-3193, O-4086, O-5034, P-3417, P-3436, P-3438, P-3439, P- 3839, P-4444, P-4449
Braun, David	O-4159, P-1878
Braun, Kerstin	P-3807
Braun, Mihály	P-3451
Brauser, Alexander	O-1212
Brazier, Vanessa	<u>O-1058</u> , <u>P-1283</u>
Breckenridge, Andrew	O-1235
Breckenridge, Andy	<u>O-3199</u> , <u>P-4853</u>
Breecker, Daniel	P-1873
Breen, Colin	P-1264
Breeze, Paul	O-4022, <u>O-5028</u>
Breitenbach, Sebastian	O-4078, P-1506
Bremond, Laurent	O-3061
Brendryen, Jo	<u>O-1011</u> , <u>P-3615</u>
Brennand, Tracy	O-1131, O-5088, P-1848
Brenner, Mark	O-2107, O-3221, P-3412
Bretzke, Knut	P-1246
Brewer, Simon	O-2007, O-5125, P-4420
Brian, Huntley	P-4442
Briant, Becky	O-1219



INQUA 2019  
DUBLIN  
IRELAND

Briant, Rebecca	<u>O-1220</u> , <u>P-1036</u> , <u>P-4601</u>
Briceag, Andrei	O-2011, <u>O-3127</u>
Bricheva, Svetlana	O-5020, P-4852
Briddon, Charlotte	P-2221, P-4246, <u>P-4251</u>
Bridge, Jon	P-3819
Bridgham, Scott	O-2055
Bridgland, David	O-1019, <u>O-1059</u> , O-1217, P-1271, P-1279, P-1280, P-1282, P-1290, <u>P-2878</u>
Bridgland, David R.	O-3161
Brierley, Chris	O-5124, P-4539
Bright, Jordon	O-3151
Brill, Dominik	O-2153, <u>O-3166</u> , O-4114, O-4118, O-4177, P-3053, <u>P-4610</u>
Briner, Jason	O-0115, P-1892
Brink, James S.	P-4277
Brisset, Elodie	P-4231
Bristow, Charlie	P-2838, P-3057
Brittingham, Alexander	O-2100
Britton, Kate	O-0073, <u>O-0141</u> , O-0142, <u>P-3214</u>
Brkojewitsch, Gaël	O-2120
Broadman, Ellie	<u>O-5029</u>
Brochmann, Christian	P-1204
Brock, Andrea	O-1138
Brock, Fiona	P-4601
Brocklehurst, Simon	O-5058
Broderick, Ciaran	O-0091
Broggy, Teresa	O-3072
Brohan, Philip	O-0090
Bromfield, Samantha S.	O-5116
Bromley, Gordon	<u>O-1087</u> , <u>P-1856</u>
Bromm, Tobias	O-2102
Bronikowska, Malgorzata	<u>P-3864</u>
Bronk Ramsey, Christopher	O-3190, O-3191, <u>O-3193</u> , O-3196, O-4091, O-4173, O-4174, O-4210, P-3805, P-4272, P-4273



BRONK RAMSEY, Christopher	P-4448
Brook, Barry	P-1823, P-3216
Brook, Edward	O-0109, O-1088
Brooke, Brendan	<u>O-2008</u>
Brooks, Gregg	O-1002
Brooks, Harriet	P-1407
Brooks, Stephen	O-0125
Brooks, Steve	O-2078
Broothaerts, Nils	<u>O-2049</u> , O-2200, P-1242, P-2862, P-2868, <u>P-3236</u>
Brosens, Liesa	P-3236
Brouard, Etienne	<u>O-5132</u> , <u>P-2496</u>
Brouard, Étienne	O-5087, P-1832
Brown, Antony	O-1100
Brown, Antony G.	O-1027, O-3025, P-1202, P-1209
Brown, David	<u>O-4205</u> , P-3614
Brown, David M.	O-2027
Brown, Eleanor	<u>P-1280</u> , P-1282
Brown, Erik	O-3111
Brown, Lauren	P-4010
Brown, Michael	P-4827
Brown, Sabrina	P-2238
Brown, Tom	O-4041
Brown, Tony	O-1104, <u>O-3099</u> , O-3100, O-3101, O-4050, P-1052, <u>P-1269</u> , P-1485, P-3204
Brown, Tony Gavin	O-1105
Browne, Margaret A.	<u>P-3496</u>
Brozio, Jan Piet	P-1249
Broś, Ewelina	<u>P-2448</u>
Bruce McFadgen, Bruce	P-4465
Bruch, Angela	<u>O-2162</u> , O-4134, P-1246
Bruch, Angela A.	O-2165, P-4203
Brueckner, Helmut	P-1635
Brugal, Jean-Philip	<u>O-4171</u> , <u>P-3491</u>



INQUA 2019  
DUBLIN  
IRELAND

Brummer, Geert-Jan	O-0092
Brun, Fanny	O-1142
Bruneau, Margot	O-3077
Brunelle, Andrea	O-3214, O-5091, P-1263
Brunetti, Michele	P-2210, P-3430
Brunetto, Ernesto	O-3005
Brunori, Carlo Alberto	O-4123
Bruschi, Viola	P-4256
Brush, Jade	O-3110
Brushett, Denise	<u>P-1837</u>
Brussel, Thomas	<u>O-5125</u>
Bryant, Charlotte	O-3193
BRYANT, Charlotte	P-4448
Bryant, Rob	O-4145
Bryce, Jordan	P-2617
Brynjólfsson, Skafti	O-3203, O-4128, O-5016
Brázdil, Rudolf	O-0085
Bråthen, Kari A.	O-3025, P-1209
Bråthen, Kari Anne	O-1027, O-1105, O-2033
Brønner, Marco	P-1068
Brückmann, Warner	O-3093
Brückner, Helmut	O-0002, O-1228, O-3106, O-3166, O-4114, O-4177, P-1006, P-3049, P-3053, P-4009, P-4014, P-4610
Brügger, Sandra	<u>O-2209</u> , <u>P-2264</u>
Bubadue, Jamile	P-2234
Bubenzer, Olaf	O-2153, O-3019, O-3020
Buchaca, Teresa	P-2010
Buchanan, Casey	O-5048
Buck, Caitlin	P-4403
Buck, Lucy	<u>P-3057</u>
Buckland, Hannah	O-1113
Buckland, Philip	<u>O-5120</u> , P-4418
Buckley, Francis	O-5058



INQUA 2019  
DUBLIN  
IRELAND

Buckley, Michael	<u>P-3220</u>
Buczek, Krzysztof	P-2265
Budahn, James R.	P-2605
Budanov, Leonid	O-5127, P-1032, P-3005
Buechi, Marius W.	P-1897, <u>P-2907</u>
Buettel, Jessie	P-3216
Bugalhão, Jacinta	P-4022
Buhay, Bill	P-2224
Buizert, Christo	O-0109, <u>O-1088</u> , O-4014
Bujak, Łukasz	O-1128
Bunce, Michael	O-1099
Bungenstock, Friederike	O-0002
Bunin, Elizabeth	<u>O-4202</u>
Bunn, Andrew	P-4440
Bunny Lejju, Julius	<u>P-4222</u>
Bunting, Jane	O-1213, O-4058, O-4060, P-1048
Bunting, M Jane	O-4063
Bunting, M. Jane	O-2171, O-4059, <u>O-4061</u> , O-5082, <u>P-2214</u> , P-4283, P-4287
Burge, Olivia R	O-2054
Burghele, Bety	O-1207
Burjachs, Francesc	P-4231
Burke, Andrea	<u>O-1008</u> , O-1086, O-4072, P-1402, <u>P-4439</u>
Burke, Bianca	P-1895
Burke, Kevin	<u>O-2007</u>
Burke, Matt	O-1055, O-5128
Burke, Matthew	O-1127, O-3230
Burkhalter, Reto	O-2191
Burn, Michael	<u>O-1156</u> , O-3089, P-1037, P-1467
Burningham, Helene	<u>O-4032</u> , <u>P-4020</u>
Burns, Stephen J.	O-1108
Burow, Christoph	O-4118, P-4610
Burrough, Sallie	O-3033, O-4143, <u>O-4145</u> , P-3475, <u>P-3801</u>
Burrough, Sallie L.	O-5026



INQUA 2019  
DUBLIN  
IRELAND

Burrows, Mark	O-1030, <u>O-1031</u> , P-2406
Bursik, Marcus	<u>P-1612</u>
Burunda, Alejandra	O-2015
Buryak, Serhiy	O-1115
Buró, Botond	<u>P-2616</u> , P-3451
Busfield, Marie	<u>O-0129</u> , O-2146, <u>P-2909</u>
Bush, Mark	O-0100, P-2223
Busnur, Manjunatha	<u>P-3815</u>
Buss de Souza, Ronald	P-3465
Busschers, Freek	<u>O-4212</u> , P-1064
Busschers, Freek S.	O-0001
Butcher, Frances E. G.	<u>O-5000</u>
Butcher, Frances E.G.	<u>O-0045</u> , <u>P-1843</u>
Butler, Paul G.	P-2494
Butuzova, Elizaveta	<u>P-3610</u>
Butz, Christoph	O-3183, P-4249
Butzin, Martin	O-3190, <u>O-3192</u>
Buvit, Ian	O-4028
Buxel, Heiko	O-3202
Buxton, Joshua	O-2058
Buylaert, Jan-Pieter	O-3161, O-4040, P-1639, P-2440, P-2883, P-2889, P-4626
buylaert, jan-pieter	<u>O-4176</u>
Byambaa, Gunchinsuren	O-0136
Byrne, Olivia	P-2860
Bárcena, María Ángeles	O-3076
Bödeker, Oliver	O-3020
Börner, Nicole	P-2423
Börner, Andreas	O-1166, P-1879, P-2427, P-2816
Börner, Nicole	P-2415
Böse, Margot	<u>O-5038</u> , P-2886
Bösken, Janina	P-1614, <u>P-2813</u>
Böttner, Christoph	P-1073
Błaszczyk, Marcin	O-1204, P-2805, P-4501



INQUA 2019  
DUBLIN  
IRELAND

Błaszkiwicz, Mirosław	O-4086, P-4449
C.C. Viana, João	O-3109
Cabaitan, Patrick	O-2010
Cabero, Ana	P-3497, P-4531
Cabral, João	P-2883
Cacho, Isabel	O-3153, O-3154, O-3222, P-3048, P-3494, P-3495
Cachão, Mário	P-4024
Caciagli, Marco	O-4123
Cadd, Haidee	O-2062, <u>O-5032</u> , P-1513, <u>P-3501</u> , P-3503
Cadillo-Quiroz, Hinsby	O-2055
Caf, Nina	<u>P-2262</u>
Caffee, Marc	O-0114, O-1141, P-1410
Caffee, Marc W	O-1070
Caffee, Marc W.	P-1483, P-3823
Caffee, Marc. W	P-3485
Cahill, Niamh	O-3013, O-4148, P-3035, <u>P-4406</u>
Cahnbley, Mirjam	P-3010
Cai, Merry	O-3046
Cai, Yanjun	O-4011, P-1418, P-1503
Cailhol, Didier	P-4450
Caissie, Beth	O-0038
Calandra, Ivan	O-2100
CALDARA, Massimo	<u>P-3492</u>
Calero, Miquel Angel	<u>O-3007</u>
Caley, Thibaut	O-2113, O-5102, <u>P-1449</u>
Callard, Louise	O-1055, O-3230, O-4133, O-5060, O-5128, O-5130
Callard, S. Louise	O-2088, <u>O-5061</u> , O-5063, P-2004, <u>P-2007</u> , P-4838
Calle, Mikel	O-3079
CALLOT, Yann	O-3094
Calzas, Michel	<u>P-2520</u>
Camejo, Adriana	O-3060
Cameron, Gordon	O-1081
Camidge, Kevin	O-1161



Campbell, David	P-2872
Campbell, Janet	O-0030, O-4131, P-1881
Camperio, Giorgia	<u>O-5099</u> , <u>P-3209</u>
Campforts, Benjamin	P-3236
Campisano, Christopher	O-4169
Campos, Néstor	P-2443
Camuera, Jon	<u>O-3151</u> , P-3493
Canals, Antoni	O-5025
Canals, Miquel	O-3154
Candaş, Adem	P-1889, P-2447
Candel, Jasper	<u>O-3159</u> , <u>P-3858</u>
Candy, Ian	O-3107, O-4088, O-5023, P-1239, P-2271, P-2416, P-3441, P-3445, P-4274
Cantalapiedra, Juan	O-2166
Canti, Matthew	P-1287
Cantillep, Ace Matthew	P-3058
Canuel, Elizabeth	O-1007
Cao, Xianyong	O-5008, O-5012, P-4292, <u>P-4296</u>
Capo, Eric	P-4245
Caporn, Simon	P-2209
Capotondi, Lucilla	O-3154
Capron, Emilie	O-4008, O-4009, O-4014, P-4506, P-4515
Carabias, Diego	P-4017
Caracuta, Valentina	O-0050, O-1093
Caragnano, Annalisa	P-4029
Carayon, Nicolas	P-4620
Carballeira, Rafael	O-4106, P-1495
Carcaillet, Christopher	O-1125
Carcaillet, Julien	P-2437, P-2453, P-2455
Carden, Ruth	P-2234
Cardone, Frine	P-4029
Carling, Paul	<u>O-5117</u> , P-3826
Carlson, Anders	P-1410



INQUA 2019  
DUBLIN  
IRELAND

Carney, Matthew	O-5085, P-4863, <u>P-4864</u>
Carney, Sally	O-2220
Caron, Lambert	<u>O-4151</u>
Carr, Andrew	<u>O-3034</u> , <u>P-2835</u>
Carr, Andrew S.	O-2152
Carracedo-Plumed, Ana	O-3092
Carrasco, Rosa M.	P-1885, <u>P-2851</u>
Carrasco, Rosa María	P-1486
Carrasqueira, Igor	P-3234
Carretier, Sébastien	P-3505
Carrillo, Carlos	O-0011
Carrion, Jose S.	O-2032
Carrivick, Jonathan	O-0003, O-1144, O-5086, P-1854, P-1903, <u>P-2847</u> , <u>P-3816</u>
Carrión, José	O-3151, P-2202, P-2212
Carrión, José S.	P-3493, P-4019
Carta, Cristina	P-4820
Cartajena, Isabel	O-4017, <u>O-4161</u> , P-4017
Cartelle, Victor	P-2005
Cartelle, Víctor	P-2491
Carter, John	P-4465
Carter, Vachel	<u>O-3214</u> , <u>P-1263</u>
Carter, Vachel A.	O-2206
Carter-Champion, Alice	<u>O-4085</u> , <u>P-1472</u>
Cartier, Rosine	<u>O-5030</u>
Caruso, Antonio	P-3495
CARVALHAL-GOMES, Sinda Beatriz Vianna	P-2011
Carvalho, Filipe	<u>O-2028</u> , O-3080, O-3083
Carvalho, Milena	O-1016
Casado, Marta	P-3499
Casarosa, Nicola	P-1013
Cascalheira, João	O-1016
Cascella, Antonio	P-1013



INQUA 2019  
DUBLIN  
IRELAND

Casella, Elisa	P-3015
Cashman, Katharine	<u>O-1113</u> , P-1620
CASTANET, Cyril	P-4229
Castelltort, F. Xavier	<u>O-3004</u>
Castelltort, Xavier	P-3846
Castillo, Olegario	O-3079
Catalan, Jordi	O-2030
Català, Albert	O-3153
Cater, John	O-5058
Cattaneo, Antonio	P-3490
Cattle, Stephen	O-3045
Caulfield, Seamas	O-2023
Cavallotto, José Luis	P-4256
Cavers, Graeme	O-1104, O-3100
Cazaunau, Mathieu	P-1435
Cañas, Verónica	O-2195
Cearreta, Alejandro	P-1011
Cederstrøm, Jan Magne	<u>O-3114</u>
Celia, Martin-Puertas	<u>P-4442</u>
Celis, Freddy	P-4017
Cendrero, Antonio	P-4256
Cendón, Dioni	O-4092
CHA, LINA	P-3811
Chabangborn, Akkaneewut	P-1514
Chacon, M. Gema	<u>O-5025</u>
Chadwick, Oliver	O-0096
Chagué, Catherine	P-3040
Chahal, Poonam	O-4053
Chaimanee, Yaowalak	O-0123
Chalie, Françoise	P-3401
Chamberlayne, Briony	O-1005
Chambers, Paul	P-4632
Champenois, Johann	P-4803



INQUA 2019  
DUBLIN  
IRELAND

Chan, Wing-Le	O-1085
Chandan, Deepak	O-1009
Chandler, Benjamin	<u>O-3200</u> , <u>P-4857</u>
Chandrajith, Rohana	O-2158
Chang, Hong	P-1424
Chang, Melanie	O-1017
Chang, Tae Soo	<u>P-4016</u>
Chang, Yuan-Pin	O-0107, O-1074
CHANTREAU, Yoann	P-2895
Chapkanski, Stoil	P-3849
Chapligin, Bernhard	O-5035
Chapman, Henry	O-1213, O-4060, P-4287
Chapman, Mark	P-4460
Chapot, Melissa	O-4174, P-4272
Chapot, Melissa S.	O-4173, P-3805, P-4273
Chapron, Emmanuel	P-3060
Chaput, Amélie	P-1435
Chaput, Michelle	O-5008
Charidemou, Miros	<u>P-1473</u>
Charman, Dan	O-2052
Charman, Dan J.	O-1161, P-1067, P-4604
Charman, Daniel	O-2133, P-2872
Charnley, Gina	O-5072
Charrieau, Laurie M.	P-1030
Charrier, Reynaldo	P-3505
Chartier, Daniel	O-0086
Chase, Brian	O-3034, O-4015
Chase, Brian M.	O-1214, <u>O-2152</u>
Chaste, Emeline	<u>O-0016</u>
Chatterjee, Anirban	<u>O-2123</u>
Chatterjee, Debolina	<u>P-4510</u>
Chattova, Barbora	P-3627
Chauhan, Parth	O-2067



Chauhan, Parth R	P-1288
Chauhan, Parth R.	O-2068
Chauvel, Catherine	O-2203
Chawchai, Sakonvan	O-0025, P-1514
Chazan, Michael	O-4144
Chea, Vincent	P-1504
Checa, Helena	<u>P-3494</u>
Chellman, Nathan	O-1049, P-2238
Chen, Chen-Yin	P-3215
Chen, Christine	O-3110, P-2223
Chen, Chunzhu	<u>O-4200</u>
Chen, Cong	P-2852
Chen, Fahu	<u>P-3479</u>
Chen, Fuyou	P-3205
Chen, Guangjie	P-2269, P-4221, <u>P-4248</u>
Chen, Guihua	<u>P-4811</u>
Chen, Hongjun	P-1005, P-3406
Chen, Hongyun	P-1424
Chen, Honjing	O-4131
Chen, Jia-Hong	P-1905, <u>P-2882</u>
Chen, Jianhui	P-3479
Chen, Jianyao	P-2464, P-2465, P-2466, <u>P-2467</u>
Chen, Kefan	O-5070, <u>P-4431</u>
Chen, Qinqin	<u>O-0089</u>
Chen, Qiong	<u>O-4081</u>
Chen, Qu	P-3411
CHEN, Qu	P-3435, <u>P-4518</u>
CHEN, Rong	<u>P-3426</u>
Chen, Shengqian	P-3479
chen, Wei	<u>O-4080</u>
Chen, Wentao	O-4006
Chen, Xianglong	O-0145
Chen, Xiaoshuai	P-2911



Chen, Xiaoyun	P-2215
Chen, Xu	P-4259
Chen, Xuemei	O-2157, <u>P-1451</u>
Chen, Yue-Gau	O-0027
Chen, Yupeng	P-3205
Chen, Zhongyuan	P-3486
Chen, Zuoling	<u>P-4503</u>
CHENET, Marie	O-2016
Cheng, Hai	O-2075, O-3074, O-3190, O-3222, O-4011, P-1418, P-1496, P-2480, P-2819, P-4451, P-4457, P-4473
Cheng, Linjing	O-5073
Cheng, Peng	P-2836
Cheng, Xing	O-4011, <u>P-1418</u>
CHENG, Yan	P-4613
Cheng, Zhongjing	<u>P-1250</u>
Cheon, Youngbeom	<u>P-4805</u>
Cheong, Albert Chang-sik	<u>P-4801</u> , P-4816
Cheong, Daekyo	P-1606
Cheron, Sandrine	P-4402
Chevalier, Manuel	<u>O-1214</u> , O-2152, O-4143, O-5121
Chi, Zhenqing	O-4065
Chiba, Takashi	O-4183, <u>P-3036</u>
Chiba, Tatsuro	P-4808
Chichinadze, Maia	<u>P-1245</u>
Chidiebere, Christabel	O-5135, P-4527
Chiessi, Christiano M.	O-0028
Chiessi, Cristiano Mazur	P-4461
Chillen, Barrie	O-0021
Chin, Hahjung	O-2062
Chinthala, Bency David	P-4534
Chipman, Jonathan	O-2098
Chipman, Melissa	<u>O-2138</u>
Chique, Carlos	O-4160



Chivas, Allan	P-2498
Chiverrell, R.C.	O-2128
Chiverrell, Richard	<u>O-1127</u> , O-1222, O-2207, O-3230, O-4062, O-4167, O-5003, O-5060, O-5101, O-5128, O-5130, P-2445, P-3429
Chiverrell, Richard C.	O-1055, O-5063, P-4611
Chodorowski, Jacek	P-1243, P-4224
Choi, Han Woo	P-1002
Choi, Jeong-Heon	O-2012, P-4801, <u>P-4816</u>
Choi, Jin-Hyuck	P-4817
Choi, Jin-Hyuk	P-2830
Choi, Jinhyuck	P-3027
Choi, Jooah	P-1606
Choi, Sung-Ja	<u>P-3027</u>
Choi, Sung-ja	P-2830
Choi, Yire	<u>P-4810</u>
Choler, Philippe	P-2453
Chong, Feng	P-2877
Chou, Yu-Chen	P-3033
Choudhury, Dipayan	<u>P-1401</u>
Chouteau, Michel	O-4131
Chowdhury, Arindam	O-1013
Christiansen, Cristina Fasting	P-2490
Christie, Duncan	<u>O-3172</u>
Christl, Marcus	O-1065, O-2018, P-2448, P-2844, P-2884, P-3001, P-4617
Chu, Guoqiang	<u>O-2006</u> , P-2409, P-2411, P-3408
Chua, Stephen	<u>P-1065</u>
Chuang, Chih-Kai	P-3215
Chuang, Ming-Lin	P-1834
Chueng, Karina	P-3232
Chun, Jong-Hwa	P-1610
Chun, Seung Soo	P-4016
Chunga, Kervin	O-3014, P-4806
Chunmei, Ma	P-2877



INQUA 2019  
DUBLIN  
IRELAND

Church, Michelle	P-1836
Churchman, Jock	O-1117
Chuyko, Margarita	P-2622
Chyi, Shyh-Jeng	P-2882
Chyi, Shyi-Jeng	P-1905
Chételat, John	P-1809
Cibin, Giannantonio	O-0095
Cid, Cristina	P-2841
Cinti, Francesca	P-4803
Ciochon, Russell	O-0121, P-1218
Cipriano, Giulia	P-3023
Cisneros, Mercè	P-3048
Cisneros-Dozal, Malu	O-5101
Cisternas, Marco	P-3020, P-3032
Civico, Riccardo	P-4803
Clague, John	O-5088
Clark, Chris	O-1127, O-2222, O-3227, <u>O-3230</u> , O-5060, O-5118, O-5128, O-5130, P-1059, P-1849, P-1884, P-3483
Clark, Chris D.	O-0043, O-1055, O-4132, O-5063
Clark, Christopher	O-3231, P-1403
Clark, Douglas	O-1037
Clark, Peter	P-2431
Clark, Peter U.	O-1010
Clark-Wilson, Richard	<u>O-3107</u>
Clarke, Charlotte	O-1100, O-5101
Clarke, Charlotte L.	<u>O-0039</u> , O-1027, O-1162, P-1202, <u>P-1210</u>
Clarke, Peter	O-0113
Clarkson, Chris	O-0103
Claro, Sheinna May	<u>O-3163</u> , P-3058
Clason, Caroline	P-1831
Clausen, Ole Rønø	O-0005
Claussen, Martin	O-3016
Clear, Jennifer	O-1125, O-4062, P-1813



Clear, Jennifer L.	O-2207
Clemens, Steve	O-1111
Clemens, Steven	O-2115
Clement, Alastair	<u>O-0082</u> , <u>P-1051</u>
Cleveland Stout, Rebecca	<u>P-1066</u>
Cleymans, Sam	O-2049
Cline, K. Michael	O-4188
Cline, Michael Logan	O-4188
Cloete, Gert	P-3850
Cloke, Hannah L.	O-3206
Cloke-Hayes, Angela	<u>O-3072</u> , P-3496
Clément, Charlotte	P-1457
Clò, Eleonora	O-2124
Coates, Kadane	<u>P-1467</u>
Cochrane, Allan Alexander	<u>O-2078</u>
Cochrane, Leise	O-5007
Cockburn, Jaclyn	P-3432
Cocker, Scott	<u>P-1206</u>
Cocquyt, Christine	P-2250
Codding, Brian	P-1263
Coe, Heloisa Helena	<u>P-3232</u> , <u>P-3233</u>
Cogbill, Charles V.	O-5081
Cohen, Andrew	<u>O-4169</u> , O-4174, P-3805, P-4272, P-4278
Cohen, Andrew S.	P-4273
Cohen, Denis	<u>O-3229</u> , P-1482
Cohen, Kim	O-1220, O-3082, O-4212, <u>P-1064</u> , P-1910, P-3852
Cohen, Kim M.	<u>O-0001</u> , P-1604, P-3845
Cohen, Marcelo	P-4007, <u>P-4026</u>
Cohen, Marcelo C.L.	O-1083
Cohen, Tim	O-1046, O-3065, O-3066, O-3160
Cohen, Timothy	<u>O-3035</u> , P-3501
Cohuo-Durán, Sergio	O-3221
Coichon, Russell	P-1610



INQUA 2019  
DUBLIN  
IRELAND

Coissac, Eric	P-1204
Colarossi, Debra	<u>O-4178</u> , <u>P-4615</u>
Cole, Lydia	<u>O-1134</u> , P-1265
Colizza, Ester	P-1476
Collings, Adrian	<u>O-5113</u>
Collins, Benjamin	P-2235
Collins, Daniel	P-1022
Collins, James	O-4087
Collins, Matthew	P-4236
Collins, Philip	O-0158, P-3040
Collins, Philip E.F.	O-5116
Collins, Shawn	P-2224, P-2812
Colombaroli, Daniele	O-2032, <u>O-2106</u> , O-2140, P-1806, <u>P-1822</u> , P-2212
Coltorti, Mauro	P-3810, P-4622
Colucci, Renato Roberto	P-2842
Columbu, Andrea	O-3075
Comas Bru, Laia	P-1493
Comas-Bru, Laia	<u>O-5124</u> , P-1495, <u>P-2507</u> , P-4410
Combourieu-Nebout, Nathalie	P-2477, P-3490
Comerci, Valerio	O-4123
Comley, Rainy	P-1811
community members, Chiba composite section	O-0118
Comolli, Roberto	O-1097
Conciatori, France	P-4440
Condon, Dan	O-4037
Conedera, Marco	P-4291
Conley, Daniel J.	O-1003, O-5030
Connor, Simon	P-2212
CONNOR, SIMON	P-4282
Conroy, Jessica L.	O-5100
Consortium, BRITICE-CHRONO	O-2222
Constantin, Silviu	<u>P-1502</u>



INQUA 2019  
DUBLIN  
IRELAND

Constantine, Mark	O-1046
Conti, Martina	<u>O-0078</u> , P-4618
Conway, Susan J.	O-0045, O-5000, P-1843
Cook, Eliza	O-3042, O-4014, P-1417, P-4455, P-4460
Cook, Simon	O-1144
Cooley, Sarah	O-4097, P-4494
Cooper, Andrew	O-2088, P-2004, P-2006, P-2007
Cooper, Claire	<u>O-3115</u>
Cooper, Emma	<u>P-4472</u>
Cooper, Rhys	O-1198, P-1025
Copes-Gerbitz, Kelsey	O-0106
Copley, Alex	O-4125
Copons, Ramon	P-4241
Corbett, Lee B.	P-3823
Corcoran, Derek	O-0102
Corcoran, Jane	P-1285
Cordier, Stephane	O-1220
Cordova, Carlos	O-2043, <u>O-4201</u> , P-2235
Corella, Juan Pablo	P-2841, P-3848, P-4254
Cormier, Marc-Andre	O-4087
Cormier, Marc-André	O-4074
Cornachione, Harriet	<u>P-1438</u>
Cornejo, Luis	O-0143
Cornelissen, Henk	O-1048, O-3148
Cornford, Stephen	O-3231
Corns, Anthony	O-0150, P-1033
Cornu, Sophie	P-3885
Cornwell, David	O-2143, O-5058, P-1846
Correa-Metrio, Alexander	O-3221
Correggiari, Annamaria	O-2009, P-3017
Corrick, Ellen	<u>O-4009</u> , <u>P-4450</u>
Corrò, Elisa	P-3844
Corsells, Cesare	P-4029



Cortegoso, Valeria	O-0143
Cortese, Guiseppe	P-4492
Cortina, Aleix	O-3154, <u>P-3499</u>
Cortizas Martinez, Antonio	O-2131
Cosgrove, Richard	<u>O-5096</u>
Costa, Ana Maria	<u>O-4107</u> , <u>P-4022</u>
Costa, Antonio	O-1042
Costa, Carlos	P-4803
Costa, Pedro	P-3045, P-3047
Costa, Pedro J.M.	P-3062, P-4022
Costa, Pedro José Miranda	<u>O-3088</u> , <u>P-3052</u>
Costas, Susana	O-4106
Cote, Susanne	O-0072
Cotterill, Carol	O-0003, O-5130, P-1069, P-1070, P-1903
Couchoud, Isabelle	O-4009, P-2480, P-4450
Coughlan, Mark	<u>O-2013</u>
Coughlan, Tim	O-2025
Coulsen, Sheila	P-3801
Coulson, Sheila	O-5026
Coulthard, Thomas	O-1222
Cousins, Mags	O-5003
Coussin, Vincent	<u>P-3490</u>
Coutard, Sylvie	P-3875
Couwenberg, John	O-5080, P-2216
Cova, Andrea	P-4004
Cowling, Richard	O-4015
Cox, Rónadh	<u>O-3164</u>
Crann, Carley	O-4209
Craven, Kieran	O-0150, <u>O-4034</u> , P-1033, P-4001
Crawhall, Nigel	P-2218
Cremaschi, Mauro	O-2124, O-3121, P-1887
Cresswell, Alan	P-2837
Creyts, Timothy	P-4401



INQUA 2019  
DUBLIN  
IRELAND

Cribdon, Becky	O-1103, O-4030
Cripps, Jonathan	<u>O-1131</u>
Crisci, Carolina	P-3460
Crisp, Molly	P-4618
Croke, Jacky	<u>O-3081</u>
Cromb�, Philippe	O-1215, P-4227
Crone, Anne	O-1104, O-3100
Cronin, Shane	O-3117
Cronmiller, Derek	O-2212, P-1481
Costa, Xavier	O-1184, O-2038, O-3189
Croudace, Ian	O-1075, O-5101, P-4467, P-4468, P-4469
Crouvi, Onn	O-0050, <u>O-1206</u> , O-3121, P-1859
Crouzet, Christian	O-4006
Crowhurst, Simon	O-1073, O-4211, P-2433
Crowley, Brooke	<u>O-0057</u> , <u>O-0059</u>
Crowley, Brooke E.	O-0058, O-0060
Cruceru, Nicolae	O-1207
Cruces, Anabela	P-4024
Crucifix, Michel	P-1505, P-2478
Crump, Sarah	<u>O-1099</u>
Cruz Jr, Francisco	O-5097
Cruz, Francisco W.	O-0028, O-3074, P-1496
Cr�py, Ma�l	<u>O-2126</u>
Cr�t�, Lucile	<u>P-4529</u>
Csonka, Di�na	O-1194, O-1195, <u>P-1629</u> , P-2614, P-3625
Cs�k, Attila	P-3451
Cs�ll�g, G�bor	P-4299
Cudennec, Jean-Fran�ois	<u>P-1029</u>
Cuevas, Carlos Alberto	P-4254
Cuffey, Kurt M.	O-0076
Cui, Linlin	O-2176, O-2177
Cui, Qiaoyu	<u>P-4280</u>
Culioli, Camille	<u>P-1016</u>



INQUA 2019  
DUBLIN  
IRELAND

Cullen, Sean	O-0150, O-4034
Cumming, Brian	O-2111, O-5074
Cunanan, Melandro	P-4251
Cunha, Ana	P-4024
Cunha, Pedro	O-1059
Cunha, Pedro P.	<u>O-3161</u> , <u>P-2883</u> , P-2889, P-2896
Cunha, Pedro-Proença	P-2440
Cunha-Ribeiro, João Pedro	P-2899
Cunningham, Alastair	<u>P-2456</u> , P-2460, <u>P-4626</u>
Cunningham, Laura	O-1123, P-1818
Cupper, Matt	<u>P-1012</u>
Curran, Mark	P-3468
Curras, Andrés	O-2120
Curry, B. Brandon	P-1851
Curry, Ben	<u>O-2214</u>
Curry, Brandon	P-2454
Currás, Andrés	P-4022
Curtin, Lorelei	O-2188
Curtis, Jason	O-3221, P-3412
Cuthbert, Mark	P-2504, P-2507
Cutler, Nick	O-1119
Cutmore, Anna	<u>P-4454</u>
Cyr Gervais, ETENE	<u>P-4258</u>
Cytrynbaum, Jacob	O-3164
Czerski, Dorota	P-1842, <u>P-3447</u>
Czerwiński, Sambor	<u>P-1256</u> , <u>P-2865</u> , P-2867
Czubla, Piotr	P-4638
Czuppon, György	P-2469
Czymzik, Markus	O-1003
Cárdenas, Joseph	P-3224
Cílek, Václav	O-5109
Córdoba, Francisco	P-3438
Côté, Steeve	O-0142, P-3214



D'Agostino, Roberta	<u>O-1035</u> , <u>P-1432</u>
D'Andrea, Catherine	P-4288
D'Andrea, William	O-2188, O-3023
d'Errico, Franscesco	O-1018
D, Padmalal	<u>P-4027</u>
D. Heintzman, Peter	P-1203
da Cruz, Francisco William	O-3109
Dabengwa, Abraham	<u>O-1122</u>
Dabkowski, Julie	O-1208, <u>O-1209</u> , <u>P-1868</u>
Dabrio, Cristino	P-3497
Dabrio, Cristino J.	P-4531
Dadson, Simon	O-3033
Daehling, Kira	<u>P-3476</u>
Daems, Dries	O-2049
Daëron, Mathieu	P-2480
Dahl-Jensen, Dorthé	O-1186, O-4014
Dai, Lu	<u>P-4012</u>
Dalaiden, Quentin	<u>O-3185</u> , P-4409
Dale, Luke	O-1019, <u>O-1217</u> , P-1271, <u>P-1290</u>
Dalla Pozza, Ramona	O-3081
Dalton, April	O-1237, P-2435
Dalton, April S.	<u>O-0029</u> , <u>P-4623</u>
Dalton, Catherine	<u>O-5077</u>
Daly, Christopher	P-3015
Dambrine, Etienne	O-4006
Damušytė, Aldona	P-1035, P-1879
Dan, Anca	P-2230
Dangendorf, Soenke	P-1056
Dangendorf, Sönke	P-1049
Danhara, Tohru	P-3457
Daniau, Anne-Laure	O-5102, P-1802, P-1810, P-1824, <u>P-2470</u>
Danilov, Kencheeri	P-3006
Daniëls, Teun	P-2868



Danukalova, Guzel	O-5036, <u>O-5039</u> , P-4632
Darin, Andrey	P-3631
Darvasi, Yaniv	P-1034
Darvill, Chris	O-4133
Darvill, Christopher	<u>O-0114</u> , <u>P-2814</u> , P-4471
Das, Kaushik	O-2070
Das, Supriyo K.	P-1454
Dasgupta, Utsha	<u>O-1082</u>
DASGUPTA, UTSHA	P-1028
Dash, Chinmay	P-4008
Dashzeveg, Bukhchuluun	O-4025
Daumantas, Liudas	<u>P-4216</u>
Daut, Gerhard	O-3061
Dauverné, Armando	P-1259
Davaadorj, Davaasuren	P-1277
Davaagatan, Tuyagerel	P-2419
Davaakhuu, Odsuren	O-4025
Dave, Aditi	O-3044, O-4066, P-1428, P-4443
Dave, Aditi Krishna	<u>O-2218</u>
David, Fernand	O-4006
David, Thomas	P-3801
Davies, Althea	<u>O-1136</u> , P-1265, P-2214
Davies, Bethan	<u>O-0131</u> , P-2911, <u>P-4471</u> , P-4472
Davies, Bethan J.	O-4166
Davies, Caroline	<u>P-1434</u> , P-1436
Davies, D.	O-4042
Davies, Darren	O-4210
Davies, Fabienne M.	P-2002
Davies, Kim	O-1104, O-1213, O-3099, O-4060, P-4287
Davies, Kimberley	O-3100, <u>O-3101</u> , <u>P-1273</u>
Davies, Lauren	<u>O-3118</u> , <u>P-1609</u>
Davies, Marissa	<u>O-2199</u>
Davies, Sarah	O-1160, O-3021, O-4174, P-1033, P-2421



INQUA 2019  
DUBLIN  
IRELAND

Davies, Sarah J.	<u>O-0150</u> , <u>P-3805</u>
Davies, Siwan	<u>O-3042</u> , P-1618, P-2870, P-3624, <u>P-4460</u>
Davis, Basil A. S.	O-5121
Davis, Basil A.S.	O-1125, O-1214
Davis, Loren G.	P-1003
Davis, P. Thompson	P-3823
Davis, Stephen	O-0133, O-1056
Davis, Steve	P-1048
Dawid Adam, Iurino	P-2208
Dawson, Andria	O-1211, <u>O-5008</u> , O-5081
Dawson, Sue	O-3162, P-1048, P-3045, P-3052
Dawson, Timothy	P-4803
Daxer, Christoph	<u>O-4046</u> , P-1464, P-2272, P-2273, <u>P-3862</u>
Daňhelka, Jan	O-3155
de Andrés Herrero, María	O-5024
De Andrés, Nuria	P-2443
De Batist, Marc	O-3011, O-3087, P-2828, P-3028, P-3619
De Beaulieu, Jacques-Louis	O-4006
De Becker, Piet	P-1242
de Boer, Bas	P-1478
de Boer, Erik	P-1495
de Boer, Erik J	<u>O-3174</u>
de Boer, Hugo	P-2513
De Carli, Elyssa	<u>O-0157</u>
de Coninck, Arnaud S.	P-3432
De Cort, Gijs	<u>O-4143</u>
De Deckker, Patrick	P-4490
de Fleurian, Basile	P-4837
de Garidel-Thoron, Thibault	<u>O-2174</u> , <u>P-3219</u>
De Giosa, Francesco	P-3023
de Haas, Tjalling	O-1078
De Haller, Antoine	P-3442
De Jonge, Cindy	<u>P-3455</u>



de la Fuente, Maria	P-3495
de Lombera, Arturo	O-5025
De Martini, Paolo Marco	P-3040
de Munnik, Nicolas	P-4281, P-4294
de Pol-Holz, Ricardo	O-1157
De Pol-Holz, Ricardo	O-3195, O-4004
de Porras, Maria Eugenia	<u>O-4017</u> , O-4161, P-4496
de Porras, María Eugenia	O-0026, O-4156, P-4218
de Regt, Rick	O-0100
De Santis, Vincenzo	P-3492
De Schepper, Stijn	P-1442
De Smedt, Philippe	P-4227
de Souza, Patricio	O-4161
de Vernal, Anne	O-0086, <u>O-1187</u> , O-2186, O-4068, P-1439, P-2490, P-4409
de Vicente, Gerardo	P-2883
De Vleeschouwer, David	O-1111
De Vleeschouwer, Francois	P-1433
De Vleeschouwer, François	O-0094, P-1431
de Wet, Gregory	O-1099
de Wit, Michiel (Mike)	P-1859
de-Pol, Ricardo	O-3172
Dean, Jonathan	O-4174, P-3805, P-4272
Dearing, John	O-1222, O-2057, P-2256
Dearing, John A.	P-2255
Debnath, Manasi	<u>O-1013</u>
Debret, Maxime	P-1409, P-4402
Decker, Valeska	<u>P-3022</u>
DeConto, Robert	O-1236
Dee, Michael	O-1042
Dee, Sylvia	O-2098
DeFelipe, Irene	P-1488
Degenhart, Gerald	P-2828
Degering, Detlev	O-2043



INQUA 2019  
DUBLIN  
IRELAND

Deiningger, Michael	P-1496, <u>P-1519</u>
Deino, Alan	O-1036, O-4174, P-3805, P-4272, P-4273
Deino, Alan L.	O-4173
Dekens, Petra S.	P-1454
Del Carlo, Paola	P-1476
del Puy Papi-Isaba, Maria	O-4046
Del Siro, Chantal	P-4829
Delahaie, Amicie	O-5099
Delaney, Cathy	<u>O-1056</u> , O-5085, <u>P-4863</u> , P-4864
Delcroix, Thierry	O-5102
Delfino, Massimo	O-2167
Delgado, Fabrizio	O-4125
Deline, Philip	P-2453, P-2455, P-4482
Delmonte, Barbara	O-0008, O-0095, O-1168, O-2015, P-2603
Deloffre, Julien	P-4402
Delpech, Guillaume	O-4036
Delunel, Romain	P-2437
Delvigne, Vincent	O-0052
Demarchi, Beatrice	P-4618
DeMarchi, Beatrice	P-4601
Demaree, Gaston	O-5068
Demeter, Fabrice	P-1452
Demezhko, Dmitry	P-4607
Demiddele, Hendrik	P-4227
DeMiguel, Daniel	<u>P-2207</u>
Demir, Tuncer	O-1060, P-1038, P-1279
Demory, Francois	P-3401
Demoulin, Alain	O-1220
Demuro, Martina	P-2899, P-4627
Deng, Chenglong	P-3878, P-4267, P-4522, P-4526
Denis, Vianney	O-1071
Denisenko, Ivan	O-4049
Dennell, Robin	O-2163



INQUA 2019  
DUBLIN  
IRELAND

Dennielou, Bernard	P-1405
Dennison, Andrew	O-3199, P-4853
Denniston, Rhawn	P-2807
Dente, Elad	O-3030
Dentith, Jennifer	O-4072
Denton, George	O-4021
Denvil, Sébastien	P-4421
Deocampo, Daniel M.	P-4273
Deole, Geetanjali	P-2812
Deplazes, Gaudenz	P-1897, P-2907
DeRose, Justin	P-1263
des Lauriers, Matt	P-1003
Deschamps, Pierre	P-1876, P-3806
Descombes, Patrice	P-3229
Desprat, Stephanie	O-2041, <u>P-1457</u> , P-2488
Desprat, Stéphanie	P-1458, P-2471
Deswal, Sanjay	P-1858
Detlef, Henrieka	<u>O-1189</u> , O-2189
Dettman, David	O-2161
Dev, Maha	O-4179, P-1213, P-3834
Develle, Anne-Lise	O-4006
Deverchere, Jacques	P-3490
Devine, Rachel	<u>O-5015</u> , <u>P-1468</u> , P-4867
Dewar, Genevieve	O-5027
DeWitt, Regina	P-4005
Deza-Araujo, Mara	<u>P-4291</u>
Dhaoui, Zahra	<u>P-2468</u>
Di Biagio, Claudia	P-1435
Di Lorenzo, Halinka	P-1267
Di Manna, Pio	O-4044, O-4123
Di Rita, Federico	<u>P-1039</u> , P-3498
Di Roberto, Alessio	P-1476
Diao, Xianmin	P-3201



Dias, Frederic	O-3164
Dias, Raphaella	P-3233
Diaz, Nathalie	P-1876
Dickinson, Marc	<u>O-4115</u> , P-4236, P-4618
Dickson, Bianca	P-2274, <u>P-2802</u>
Didier, David	O-3165
Didier, Julien	P-1214
Diekmann, Bernhard	<u>O-5021</u> , P-1058, P-3477
Dieleman, Catharina	<u>P-2884</u>
Diersche, Volker	O-1154
Dietre, Benjamin	P-2270, P-2272, P-2273
Dietrich, Fabienne	P-1876
Dietrich, Peter	O-2024, P-1835, P-3208
Dietrich, Pierre	O-2146, P-2909
Dietze, Elisabeth	<u>O-1045</u> , P-3803
Dietze, Michael	P-2831
Dietze, Volker	O-0093
Ding, Guoqiang	O-4065
Ding, Zhiyong	<u>P-1437</u>
Ding, Zhongli	O-2176, O-2177, O-4064, P-4503
Dinies, Michèle	O-1228, <u>O-3016</u> , O-3106
Diniz, Mariana	O-4107
Dinney, Meaghan	<u>P-1848</u>
Dise, Nancy	P-2209
Ditchfield, Amber	P-3423, P-3463
Ditchfield, Peter	P-2234
Divine, Dmitry	O-3189
Dix, Justin	O-3130
Dixit, Yama	O-2148
Dixon, Bronwyn	<u>O-4095</u> , <u>P-1507</u>
Dobre, Mihaela	P-4260
Dobrotin, Nikita	P-4848
Dobrovolný, Petr	O-0085



INQUA 2019  
DUBLIN  
IRELAND

Dobrowolski, Radosław	P-1243, P-4224
Doctor, Ma. Angelique	O-2010
Dodson, John	O-1030, <u>O-1034</u>
Doerfler, Walter	<u>P-3444</u>
Doi, Koichiro	P-2444
Dokken, Trond M.	P-1417
Dolman, Andrew	<u>O-2181</u> , O-4013
Dolák, Lukáš	<u>O-0085</u>
Domingo, Dario	P-4506
Domingo, Soledad	O-2166
Dominguez, Gabriela	P-2429
Dominguez, José	O-2091
Domínguez-Cuesta, María José	O-1151
Domínguez-Villar, David	<u>O-2075</u> , P-2818, P-2819
Donald, Alex	P-1829
Donato, Paola	P-3804
Doncaster, C. Patrick	P-2255
Doncaster, Patrick	O-2057, P-2256
Donders, Timme	<u>P-1509</u> , <u>P-2477</u>
Donders, Timme H.	P-3845
Dong, Jibao	<u>P-2500</u> , P-2501
Dong, Linyao	P-2464
Dong, Weimiao	<u>O-2103</u>
Dong, Xinxin	P-4503
Dong, Xuhui	<u>P-4242</u>
Dong, Yajie	<u>P-1222</u> , P-2215
Donkova, Yordanka	P-3865
Donnelly, Jeffrey P.	P-1037
Donner, Reik V.	<u>P-4407</u>
Donou, Blaise	P-4257
Doole, Jennifer	O-3230
Doorenbosch, Marieke	P-1616
Dorador, Javier	P-2471



Dorale, Jeffrey	O-2074, O-2214, <u>P-4521</u>
Dorioz, Jean-Marcel	O-4006
Dorn, Mario	O-1212
Dorschel, Boris	O-5061, P-4838
Dortch, Jason	P-2434
Dosseto, Anthony	O-2012, O-2043, <u>O-2220</u> , O-3150, <u>P-3879</u>
Dougherty, Amy	<u>O-2012</u>
Doughty, Alice	<u>O-2098</u> , O-4141, <u>P-2516</u>
Douillet, Guilhem	P-4511
Douillet, Guilhem A.	P-1898
Dourado, Francisco	O-3088
Doussin, Jean-François	P-1435
Dove, Dayton	<u>O-1198</u> , O-3230, O-5130, P-4004
Dowdeswell, Julian	O-0007, O-4127
Dowling, Llsa	P-4492
Dowling, Lisa	P-3466
Doyen, Elise	P-1214
Doyle, Rebecca	<u>O-5006</u>
Doğan, Turhan	P-4818
Doğan, Uğur	P-2430
Drake, Nick	O-4022, <u>O-5023</u> , O-5028
Draper, Frederick	O-2055
Dredge, Lynda	O-0030
Dreibrodt, Stefan	O-1041, P-1249, P-3444
Drescher-Schneider, Ruth	P-2451, P-2843
Dreslerová, Dagmar	O-5009
Driessen, Tessa	<u>P-4255</u>
Drinnan, Andrew	O-3069
Driver, Toby	O-0150, P-1033
Drohan, Patrick	P-4826
Dron, Oleg	P-3005
Druckenmiller, Patrick	O-0063
Drucker, Dorothée	P-4214



INQUA 2019  
DUBLIN  
IRELAND

Drucker, Dorothée G.	P-1229, P-1231
Drury, Anna-Joy	P-4490
Drysdale, Russell	O-0075, O-2076, O-3067, O-4009, O-4093, O-4095, O-4211, P-1404, P-1507, P-2472, P-2480, P-2498, P-3487, P- 4450, P-4486
Drysdale, Russell N.	O-3075, P-3488
Drysdale, Russell Neil	O-1163
Drzymulska, Danuta	<u>P-2848</u>
Dräger, Nadine	O-1228, O-3106, O-5034
Drăgușin, Virgil	<u>O-1207</u>
Du, Xiaojing	O-3111
Duan, Chenxi	O-2047
Duan, Fucai	P-3033
Duan, Wuhui	O-3098, P-2507
Duangthongchit, Somoh	P-1452
Dubis, Lidiya	P-4834
Dublyansky, Yuri	O-4146
Dubois, Nathalie	O-3011, O-5099, O-5103, P-1475, P-3209, P-3418
Dubova, Nadezhda	P-4234
Dubé-Loubert, Hugo	O-5087, P-1832, P-1882, P-2496
Ducos, Salomé	P-1605
Duerrast, Helmut	P-1514
Duesing, Walter	P-4273
Dufaure, Olivier	O-3204
DuFrane, S. Andrew	P-1610
Dugmore, Andrew	O-1040, <u>O-1119</u> , O-3119, P-2869, <u>P-3861</u> , P-4425
Dulfer, Helen E.	<u>P-1890</u>
Duller, Geoff	O-1127, O-5128, P-2445
Duller, Geoff A T	P-1617
Duller, Geoff A.T.	O-4178, P-4277, P-4615, P-4624
Duller, Geoffrey	O-1160, O-3230
Duller, Geoffrey A. T.	O-0150
Duller, Geoffrey A.T.	<u>P-4611</u>



INQUA 2019  
DUBLIN  
IRELAND

Duller, Robert A.	P-2002
Dumalagan Jr., Edwin	O-2010
Dumas, Christophe	O-1014
Dumoulin, Jean-Pascal	O-1039
Dunbar, Gavin	P-4499
Dunlop, Paul	O-5062, O-5087, <u>P-1882</u> , P-2431
Dunne, Julie	<u>O-4022</u>
Dunseth, Zachary C.	O-2122, P-1254
Dura, Tina	O-3008, P-3020
Durcan, Julie	<u>O-2151</u> , O-3122, P-1626, P-2839
Duringer, Philippe	P-1452
Durán, Víctor A.	O-0143
DUSSOL, Lydie	P-4229
Duval, Mathieu	O-4113, O-4114, O-5025, <u>P-4276</u> , <u>P-4627</u>
Dux, Florian	O-3067, P-2480, P-2498
Duțu, Florin	O-2011
Dworkin, Steve	P-4219
Dworsky, Cyril	P-2273
Dyke, James G.	P-2255
Dymlind, Robin	P-1025
Dyuzhova, Kristina	O-3055
Dzieduszyńska, Danuta	O-1152
Dávila Harris, Pablo	O-1042
Dätwyler, Christoph	O-3183
Díaz Balocchi, Luis	P-2610
Díaz Reyes, Yoal	P-2442
Díez-del-Molino, David	O-1026
Dörfler, Walter	O-1041, <u>O-1169</u> , <u>P-1249</u>
Düsing, Walter	O-4174
Dąbrowski, Michał	O-0049
Džeriņš, Pēteris	P-2906
Eastwood, Warren J	O-1126
Eaton, Stephen	<u>P-1072</u>



Eaves, Shaun	O-3145, O-3187, <u>O-4020</u> , <u>P-3466</u> , P-4492, P-4493
Ebert, Karin	O-1070
Echeverria Galindo, Paula	P-2423
Echeverria Galindo, Paula Gabriela	<u>P-2415</u>
Echeverria-Moreno, Anna	P-2851
Echeverría, Marcos E.	P-2254
Eckardt, Frank	<u>O-3043</u> , O-4145
Ecker, Linda	P-2273
Ecker, Michaela	<u>O-4140</u>
Eco, Rodrigo C.	P-3049
Edo, Manuel	O-1093
Edwards, Ceiridwen	P-2234
Edwards, Jon	<u>O-0109</u>
Edwards, Kevin	P-1275
Edwards, Kevin J	<u>O-1177</u> , O-3027
Edwards, Larry	P-4473
Edwards, Lawrence	O-2074, P-4507
Edwards, Lawrence R.	P-2819
Edwards, Mary	O-1100, O-1162, O-3063, <u>O-4058</u> , O-4058, O-5008, <u>P-1204</u> , P-1273, P-4466
Edwards, Mary E	O-1105
Edwards, Mary E.	O-0039, O-1027, P-1202, P-1210
Edwards, R Lawrence	O-3190
Edwards, R. Lawrence	O-2075, O-3222, O-4011, O-4216, P-1418, P-2480
Edwards, Robin	O-2088, P-1059, P-2004, P-2007, P-2497
Edwards, Robin J.	O-4071
Edwards, Ross	O-2015
Edwards, Tamsin	O-4150
Egan, Joanne	<u>O-1037</u> , P-1465, <u>P-1491</u> , P-3046
Egerer, Sabine	P-1432
Egger, Gerald	P-2273
Eggleston, Sarah	P-4423
Egholm, David	O-1145, O-2221, O-3201, P-2903



INQUA 2019  
DUBLIN  
IRELAND

Egholm, David Lundbek	O-1054
Eglinton, Timothy	P-3455, P-4454
Ehlers, Jürgen	O-1238
Ehrich, Dorothee	O-0039, O-1105, P-1209
Ehrlén, Johan	P-2217
Ehrmann, Werner	O-3093
Eichhorn, Barbara	O-3097
Eichstädter, Rene	O-3019
Eiler, John	P-2500
Eiríksson, Jón	O-1188
Eisele, Steffen	O-1118, <u>P-1615</u>
Ejarque, Ana	P-2212
Ekblom Johansson, Fanny	<u>O-4051</u>
El bani Altuna, Naima	<u>O-4075</u>
El Bchari, Fatima	<u>O-0160</u>
El Hammouti, Kamal	O-5025
Elashvili, Mikheil	P-1006
Elez, Javier	P-4802, P-4804
Elison Timm, Oliver	P-2864
Elleder, Libor	<u>O-3155</u>
Ellen, Rachael	P-1069, P-1070
Ellerton, Daniel	P-2601, P-2607
Ellery, Frahm	O-2100
Elliot, Sarah	O-4001
Elliott Smith, Emma A.	O-3176
Ellis, Grace	O-1016
Ellis, Michael	P-2237
Ellouz-Zimmermann, Nadine	P-1449
Ellwood, Brooks	P-2807
Elnegaard Hansen, Katrine	<u>P-2495</u>
Elofsson, Ann	<u>P-1026</u>
Elorza, Javier	P-1427
Ely, Jeremy	<u>O-2222</u> , O-3227, O-3230, O-3231, P-1059, P-1403, P-1849,



P-1884, P-3483

Ely, Lisa	P-3020
Elyashiv, Hadar	P-2246
Emde, Kurt	O-4029
Emery, Andrew	<u>P-1903</u>
Emery, Andy	<u>O-0003</u>
Emson, Dave	P-1233
Enevold, Renee	P-3628
Enevold, Renée	<u>O-1173</u>
Engel, Max	O-0002, O-1228, O-3106, O-3162, <u>P-3045</u> , P-3049, <u>P-3059</u>
Engel, Zbynek	P-1891
Engel, Zbyněk	P-1890
Engelhart, Simon	O-3013
Engels, Stefan	O-0034, <u>O-0125</u> , O-4087, O-4088, P-1469, P-2221, P-2417, P-2510, P-3433, P-3445, P-4246, P-4458
English, Nathan B	O-2108
Engström Johansson, Alexandra	O-1191, <u>P-1428</u> , P-4281, P-4443
Enrique, Rosa	O-4184
Enters, Dirk	O-0006, P-1474
Entin, Andrei	P-4825
Enya, Takafumi	P-2001
Enzel, Yehouda	<u>O-3030</u> , P-3436, P-3850
Enăchescu, Mihaela	P-2459
Epifanio, Jenna	O-0109
Epp, Laura	P-4245
Epp, Laura S.	<u>O-1022</u> , O-1028, O-1102, <u>P-1208</u> , P-1215, P-2218
Erb, Michael	P-1499
Ercan, Fabian	<u>P-2263</u>
Erdal, Ozan	P-4205
Erel, Yigal	P-1859
Erhardt, Tobias	<u>O-4008</u> , O-4014, P-4452, P-4455
Erickson, Gregory	O-0063
Erik, Brown	P-3412



INQUA 2019  
DUBLIN  
IRELAND

Eriş, Kürşad Kadir	O-3208
Erkens, Gilles	O-0001
Erlendsson, Egill	<u>O-2208</u> , P-1260
Ersek, Vasile	O-1207, O-2203, P-1506
Ershova, Ekaterina	<u>P-4300</u>
Ersmark, Erik	P-2234
Ersoy, Orkun	O-1069
Erséus, Christer	O-1100
Ertlen, Damien	O-4056, P-3849
Erturaç, Mehmet Korhan	<u>O-3129</u> , P-3833, <u>P-3842</u> , P-4205
Erzsébet, Horváth	<u>O-1195</u>
Esch, John	<u>P-1851</u>
Escobar, Jaime	P-3412
Escobar-Torrez, Katerine	<u>P-3462</u>
Eshetu, Zewdu	P-4288, P-4537
Esteban, Sagredo	O-4019
Estelle, Allan	<u>O-2186</u>
Esteves, Mariana	<u>O-5131</u>
Estrella-Martínez, Juan	<u>P-2494</u>
Etheridge, David	O-1088
Etienne, David	O-1024, O-4006, P-1214
Etienne, Samuel	O-3165
Etourneau, Johan	O-3109, O-4073
Ettel, Peter	P-1835
Etu-Sihvola, Heli	O-0146, <u>P-4214</u>
Evans, Dave JA	P-4843
Evans, David	O-0046, O-0131, O-3230, <u>O-5043</u> , O-5045, O-5047, O-5119, O-5128, O-5130, P-1830, P-1854, P-3818, P-4823
Evans, Gianna	<u>P-3423</u> , <u>P-3463</u>
Evans, Krista	<u>O-5065</u>
Evans, Lucas	O-1148
Evans, Michael Neil	P-4409
Evelpidou, Niki	<u>P-3064</u>



INQUA 2019  
DUBLIN  
IRELAND

Evenstar, Laura	O-1218, P-3872
Everest, Jeremy	<u>P-3821</u>
Everest, Jez	<u>O-3202</u>
Everett, Rosie	<u>O-1103</u> , O-4030
Evershed, Richard	O-4022
Ewertowski, Marek	O-0046, <u>P-1830</u> , <u>P-1850</u> , P-3231, P-3819, P-4849
Ewertowski, Wojciech	P-1830
Extier, Thomas	<u>O-2039</u>
Eyles, Nick	O-1202, P-1841, P-4836
Eynaud, Frederique	P-4401
Eynaud, Frédérique	<u>O-4077</u> , P-1016, P-1605, P-1802
Ezat, Mohamed	O-4075
Ezquerro, Lope	O-1139
F. Prado, Luciana	O-3109
Fabel, Derek	O-1055, O-1143, O-3230, <u>O-4038</u> , O-4163, O-5063, O-5128, O-5130, P-1483, P-3485, P-4447, P-4476, P-4482
Fabiani, Fabio	P-4013
Facchin, Lorenzo	P-4004
Faeh, Donat	O-3085
Fagel, Nathalie	<u>O-3188</u> , P-1505
Fago, Paola	P-3023
Fagoaga, Ana	O-2167
Fahl, Kirsten	P-1439
Fahrni, Simon	P-4617
Faina, Peterson	O-1108
Faivre, Sanja	<u>O-0084</u>
Falabella, Fernanda	O-0143
Falcini, Francesca	<u>O-4130</u>
Faleide, Jan Inge	O-0004
Falkenroth, Michaela	<u>P-3010</u>
Falkowska, Ewa	<u>P-1240</u>
Fallah, Bijan	O-5055
Fallick, Anthony	O-4211



Fallick, Anthony E.	P-3488
Fallon, Stewart	O-3137
Falster, Georgina	<u>O-3067</u> , <u>P-2498</u>
Fan, Baoshuo	P-4279
Fan, Jiawei	O-2084, P-2403
Fan, Tianlai	O-3168
FAN, Xuechun	P-4613
Fang, Xiaomin	P-1804, <u>P-2515</u> , P-3425
Fang, Xiuqi	<u>P-4293</u>
Fang, Yiman	<u>O-5082</u>
Fanget, Anne-Sophie	O-2185
Fanget, Bernard	P-1214
Fantozzi, Pier Lorenzo	O-5036
Fard, Elizabeth	<u>P-4010</u>
Farebrother, Will	P-4485
Faria, Sérgio	P-2841
Faria, Sérgio H.	P-4474
Farkaš, Juraj	O-1005
Farnsworth, Wesley	<u>O-3203</u>
Farnsworth, Wesley Randall	O-5016
Farooqui, Anjum	<u>P-1450</u> , <u>P-1455</u> , P-1456, P-2432, P-3419
farooqui, shazi	<u>P-3841</u>
Farr, Lucy	O-2044
Farrell, Aisling	P-3218
Farrell, Aisling B.	P-1227
Farrell, Amirah	P-3500
Farrell, Michelle	<u>O-1213</u> , O-4058, O-4060, O-4061, P-1048, P-4283, P-4287
Fastovich, David	<u>O-2184</u> , P-1819
Fatela, Francisco	P-4024
Fattahi, Morteza	P-4809
Fauchereau, Nicolas	O-0090
Faulkner, Douglas	O-3048
Faulkner, Trevor	<u>P-2801</u>



INQUA 2019  
DUBLIN  
IRELAND

Faundes, Wilfredo	O-4161
Faust, Dominik	O-3032, <u>O-3124</u> , O-3223, P-1602, P-2815
Favre, Anne-Catherine	P-3848
Feakins, Sarah	O-3110
Fealy, Rowan	O-0091
Feathers, James	O-5090
Fediuk, Annika	O-4031
Fedje, D.W.	P-3203
Fedorchenko, Alexander Yu.	P-1278
Fedorowicz, Stanisław	P-4638
Feeley, Kenneth	O-0100
Feeser, Ingo	O-1041, P-1249, P-3444
Feigin, Alexander	<u>P-2473</u> , P-2475
Feist, Lisa	P-3053
Felde, Vivian	O-2204
Felde, Vivian A.	<u>O-2031</u> , O-4213, P-3235
Feldpausch, Ted	O-3135
Felip, Marisol	P-4241
Felja, Igor	P-3017
Feng, Han	P-3812
Feng, Yuexing	O-4093
Fengquan, Li	P-4021, P-4230
Fenn, Kaja	<u>O-3122</u> , <u>P-1626</u>
Fercovic, Emilia	O-4165
Fergus, Alex	O-2054
Fernandez, Philippe	P-3491
Fernandez-Lopez de Pablo, Javier	<u>P-4231</u>
Fernàndez, Pere Roc	O-2132
Fernández López de Pablo, Javier	O-2048
Fernández Martín-Consuegra, Aitor	<u>P-1011</u>
Fernández Peris, Josep	P-2202
Fernández, Santiago	P-2202
Fernández-Fernández, José María	O-3147, P-1486



Fernández-Lozano, Javier	P-4256
Fernández-Merodo, José A.	P-4830
Ferrario, Francesca	P-4806
Ferrario, Maria Francesca	O-4044
Ferreira, Carla	<u>O-1172</u> , <u>P-1247</u>
Ferreira, David	O-1035
Ferrer, Carlos	O-2048
Ferrero, María E.	O-3195
Ferretti, Patrizia	P-2471
Ferri, Lidia	O-2095, P-4478
Festi, Daniela	O-4216
Feuser, Stefan	P-4014
Fewster, Richard	<u>P-2849</u> , P-2860
Ficetola, Francesco	O-4006
Fichaut, Bernard	O-3165
Fiebig, Markus	O-5036, <u>O-5112</u>
Fiedler, Stephanie	P-1432
Field, Michael	P-1616
Fifield, Keith	O-2110, O-3068, O-3142
Figueiredo, Silvério	O-1059
Figus, Carla	O-3224
Filipovic, Dragana	O-1095, O-5009, P-2233
Filipsson, Helena	O-2185, P-1004, P-1026
Filipsson, Helena L.	<u>P-1030</u>
Fink, David	O-2096, <u>O-3146</u> , O-4116, P-1484, P-1485, <u>P-1487</u> , P-2517
Finke, Peter	P-3880
Finkelstein, Israel	O-2122, P-1254
Finkelstein, Sarah	O-2199, O-4144
Finkelstein, Sarah A.	O-0029, <u>O-2129</u>
Finlayson, Andrew	O-3202, O-5049
Finney, Bruce F.	O-1231
Finsinger, Walter	O-1121, O-2007, P-3462, P-4420
Fioraso, Gianfranco	P-2624



INQUA 2019  
DUBLIN  
IRELAND

Fiorentino, Girolamo	O-5009
Fiorillo, Denis	P-1868
Firestone, Richard	P-2429
Firth, Callum	<u>P-1886</u>
Firth, Callum R.	O-5116
Fis, Marjorie	<u>O-1075</u> , <u>P-4468</u>
Fischer, Hubertus	O-4008, O-4014, P-4452
Fischer, Julia	O-4109
Fischer, Markus L.	O-3031
Fischer, Peter	O-4029, O-4031, P-1628, P-3039
Fischer, Tomáš	P-3865
Fischer, Urs H.	O-3229, P-2905, P-2908
Fisher, Daniel	O-0041
Fisher, Daniel C.	O-0060
Fitch, Simon	O-4030
Fitchett, Jennifer	<u>O-3141</u> , <u>O-4142</u> , P-3502, P-3504
Fitzgibbon, Barry	P-2234
Fitzpatrick, Matthew	O-0101
Fitzsimmons, Kathryn	O-2218, <u>O-3044</u> , O-4066, P-1428, <u>P-1628</u> , P-1869, P-4281, P-4294, <u>P-4443</u>
Fitzsimmons, Kathryn E.	O-4116
Fiřoc, Magdalena	O-2211, <u>P-2401</u> , P-2848
Flantua, Suzette G.A.	<u>O-4213</u> , <u>P-3235</u>
Flaux, Clément	P-4620
Flařarová, Kristýna	<u>P-1630</u>
Flecker, Rachel	O-0061
Fleischer, Peter	O-2207
Fleitmann, Dominik	O-1205, O-4009
Fleming, Ciara	P-3857
Fletcher, Florin	P-1272
Fletcher, Michael-Shawn	<u>O-2062</u> , O-4097, P-1021, <u>P-2274</u> , P-4252, <u>P-4494</u>
FLETCHER, MICHAEL-SHAWN	P-4282
Fletcher, William	<u>O-0106</u> , O-1037, O-3073, O-3148, P-1221, P-1491, P-2268,



P-2484, P-3803

Flett, Verity	O-3202
Florenzano, Assunta	O-2124
Flores, Eliseo	O-4193
Flores, Felipe	O-3172
FLORES, JOSE A.	O-2118
Flores, José - Abel	O-3076
Flores, José A.	O-3071, O-3154
Flores, José Abel	O-4069
Flores-Aqueveque, Valentina	<u>O-5052</u> , <u>P-4017</u>
Florian, Christopher R.	O-1099
Florindo, Fabio	P-3431
Flower, Lucy	<u>O-0037</u> , <u>P-1282</u>
Flowers, Gwenn E.	O-2017
Flowers, Katy	O-3039
Fluck, Hannah	P-1285, P-1287
Flynn, Amy	<u>O-0158</u>
Foerster, Verena	O-1036, O-4174, P-4272
Foerster, Verena E.	O-3031, O-4173, P-3805, <u>P-4273</u>
Fogel, Marilyn	P-4288
Fogt, Ryan	O-0090
Fogwill, Chris	P-3464
Fogwill, Christopher J.	O-1010
Fogwill, Eleanor	P-4866
Fomenko, Igor	P-3870
Fondevilla, Victor	P-3804
Fong, Letisha	O-1023, O-5076
Fontana, Alessandro	O-2009, <u>O-3078</u> , <u>P-3017</u> , P-3845
Fontana, Sonia	O-2205
Fontes, Luis	O-1172
Fontes, Neuza	P-4007
Fontijn, Karen	O-1114
Fonville, Thierry	<u>O-1104</u> , O-3099, O-3100, O-3101, O-4058, O-5101, <u>P-3204</u>



INQUA 2019  
DUBLIN  
IRELAND

forbes, matt	<u>O-3065</u>
Ford, Derek	O-2117
Forget Brisson, Laurence	<u>O-4005</u> , <u>P-2820</u> , P-4625
Forman, Steven	O-3049
Forman, Steven L.	O-0029, O-3129, P-2610
Formenti, Paola	P-1435
Foroushani, Mansour Ahmadi	P-3809
Forrest, Matthew	O-0105
Forte, Luis María	P-4256
Fortelius, Mikael	O-2166
Forti, Luca	P-3836
Fortin, David	P-3619
Forwick, Matthias	O-5016
Foster, David R.	O-5081
Foster, Ian	O-5005
Fourcade, Tiffanie	<u>O-1018</u>
Fourel, François	P-1869
Fowell, Sarah	O-2074
Fowler, Anthony	O-4204
Fox, Beth	P-1506
Fox, Nathaniel	P-3218
Fraile, Miguel Ángel	O-1139
Francesco, Gentile	O-1024
Franchetti, Fernando	P-1259
Francis, Christopher	O-3039
Francis, Christopher P.	<u>O-4088</u> , <u>P-3445</u>
Francke, Alexander	O-1137, O-2220, <u>O-3150</u> , P-2477, P-3879
Francus, Pierre	P-2495, P-3432
Frank, Martin	O-3093, P-3839
Frank, Norbert	O-3019
Frank, Sebastian	P-3053
Franke, Jasper G.	P-4407
França, Marlon	<u>P-4007</u>



INQUA 2019  
DUBLIN  
IRELAND

François, Louis	O-2039
Frassine, Matteo	O-3078
Frechen, Manfred	P-1870, P-2886, P-3611, P-3863, P-4622
Fredin, Ola	P-1483, P-3001, P-3485
Freeman, Jacob	<u>O-3170</u> , O-3175, O-4003
Frei, Robert	O-2015
Freire, Paula	P-1040
Freitas, Maria C	P-4024
Freitas, Maria da Conceição	O-4107, P-4022
French, Amanda	P-1506
Frendo, Cristina	O-5075
Frenken, Mike	P-3054
Frenzel, Peter	O-0002, O-1228, O-3106, P-2415, P-4014
Freschi, Stefano	P-4832
Friday, Mattie	O-3112
Friedl, Lukas	O-1016, P-2807
Friedrich, Michael	O-3190, O-3194
Friedrich, Oliver	O-2037
Friedrich, Ronny	<u>P-3613</u>
Friedrich, Tobias	O-0024, O-0103
Friele, Pierre	P-4832
Frigola, Jaime	P-3048, P-3494
Frigolé, Cecilia	O-0143
Frings, Patrick J.	O-1003
Fritz, Sherilyn C.	O-2060, O-5030
Froese, Duane	O-1025, O-1115, O-2097, O-2212, <u>O-2213</u> , O-3118, O-5048, P-1206, P-1845, P-2218, P-4858, Plen02
Frogley, Mick	O-1164
Frolov, Pavel	O-3128, O-5040, P-3612
Frolov, Pavel D.	<u>O-3132</u>
Frolova, Larisa	<u>P-3458</u>
Frontasyeva, Marina	P-2266
Frouin, Marine	O-4040



INQUA 2019  
DUBLIN  
IRELAND

Frugone, Matias	O-4004
Frugone-Álvarez, Matías	O-4158
Frye, James	P-1619
Fryirs, Kirstie	P-4485
Fu, Shuqing	P-3009
Fu, Xiao	O-3035, <u>O-3160</u>
Fu, Yu	<u>P-3621</u> , P-3812, P-3878
Fuchs, Markus	O-2122, P-1254, P-1409, P-1602, P-1908, P-2815, <u>P-2831</u> , P-2887, P-4228, P-4612
Fucks, Enrique	P-4023
Fuentealba, María Magdalena	O-4158
Fuhrmann, Florian	P-1518
Fujiki, Toshiyuki	O-2161
Fujino, Shigehiro	O-3090, P-3029
Fujioka, Toshiyuki	O-3146, O-4116
Fujita, Hiroko	P-4629
Fujiwara, Osamu	O-3008, <u>O-3086</u> , O-3087
Fukumoto, Yu	P-2260
Fulop, Reka-H	P-3501
Funck, Juliette	O-0058, <u>O-0062</u>
Furió, Marc	P-2204
Furlan, Guido	P-1267
Furlanetto, Giulia	<u>O-1097</u> , O-1168, P-1235, <u>P-2210</u> , P-3430, P-3498
Furlani, Stefano	P-3017
Furmanek, Mirosław	P-4224
Furuhashi, Takuya	O-4045
Furze, Mark	O-3203
Fusswinkel, Tobias	O-3125
Fyfe, Ralph	O-3039, O-5008, O-5010, O-5078, <u>O-5079</u> , P-1272, P-1831
Fyfe, Ralph M.	O-1161
Færseth, Lars Martin	O-1130
Fülling, Alexander	O-3124
G'meiner, Anna Agosta	P-2224



G. Alsos, Inger	P-1203
Gaboriau, Théo	P-3229
Gabrielyan, Ivan	O-2162, P-3606
Gachev, Emil	P-2845
Gadd, Patrica	O-1031
Gadd, Patricia	O-3064, O-3184, O-4097, P-1021, P-1463, <u>P-1469</u> , P-3423, P-3463, P-4252, P-4494
Gadd, Patricia S	O-2108
Gafeira, Joana	O-1198
Gaffney, Vince	O-1103, O-4030
Gaillard, Marie-Jose	O-5009, O-5013, O-5014, <u>O-5083</u>
Gaillard, Marie-José	O-5008, O-5010, O-5012, P-4296
Gaillard-Lemdahl, Marie-Jose	O-4058
Gajewski, Konrad	O-5008
Gal, Jong-Ku	O-4073
Galang, Jam A.	P-3049
Galindo, Inés	O-2195
Galka, Mariuz	P-2860
Gallagher, Colman	O-0045, O-5000, P-1843
Gallagher, Michael	P-1807
Gallagher, Stephen	<u>O-1111</u> , <u>P-1404</u>
Gallagher, Vincent	O-1057
Gallardo, Laura	O-4157
Gallego Sala, Angela	O-2198
Gallego-Sala, Angela	O-2050, O-2051, O-2052, O-2202, P-2853
Gallerani, Andrea	P-1476
Galloway, Jennifer	O-2130
Galofre, Marcel	P-4241
Gammon, Paul	O-0077
Gandy, Niall	O-2222, O-3230, <u>O-3231</u> , O-5086, <u>P-1403</u>
Ganopolski, Andrey	<u>O-2036</u> , P-1429, P-1478
Ganzev, Larisa	P-1058
Gao, Feng	O-2101



INQUA 2019  
DUBLIN  
IRELAND

Gao, Fuyuan	O-0022
Gao, Qiang	P-4223
Gao, Shangyu	O-2047
Gao, Xinbo	P-3621, <u>P-3878</u>
Gao, Xing	O-0056, <u>O-0137</u> , O-0139, P-4267
Garankina, Ekaterina	<u>O-4191</u> , <u>P-1909</u>
Garankina, Katerina	P-1911, P-3854
Garces Pastor, Sandra	O-1105
Garcia Morabito, Ezequiel	P-2446
Garcia, Adriana	O-4110
Garcia, Briant	O-4125
Garcia, Juan Luis	O-4019
Garcia, Juan-Luis	<u>O-2095</u> , <u>P-4479</u>
Garcia, Marta	O-2120, O-3060, P-3225
Garcia-Molina, Marta	P-3806
Garcin, Yannick	P-1034
Garcés Pastor, Sandra	O-1027, <u>P-1203</u>
García, Juan L	P-4478
García, Juan Luis	O-1150
García-Alix, Antonio	O-3151, P-3493, P-4447
García-Davalillo, Juan C.	P-4830
García-Gil, Soledad	P-2491
García-Huidobro, Valentina	P-4264
García-Mayordomo, Julian	P-2623
García-Medrano, Paola	O-4135
García-Moreiras, Iria	P-1220, P-2491
García-Orellana, Jordi	P-2841
García-Prieto, Eduardo	P-4284
García-Rodríguez, Felipe	P-3460
García-Ruiz, José María	P-1486
García-Sansegundo, Joaquín	O-2072
García-Solano, José	O-2166
García-Vázquez, Ana	O-0040, <u>P-1236</u> , <u>P-1238</u>



INQUA 2019  
DUBLIN  
IRELAND

Gardner, Elizabeth	P-4020
Garduño Monroy, V. H.	P-3063
Garduño-Monroy, Víctor H.	P-4806
Garland, Carey	P-1251
Garneau, Michelle	O-2051, P-1067, P-2853
Garner, Andra	O-3213
GARNIER, Aline	P-4229
Garnier, Jeremie	P-2425
Garova, Elena	P-3604
Garozzo, Lorena	O-1097, P-1235, P-2210
Garrett, Ed	O-3087, O-3162, <u>P-3020</u> , <u>P-3032</u> , P-3034
Garton, Daryl	P-2241
Garvey, Jillian	O-5096
Gasco, Alejandra	O-0143
Gasmi, Nabil	O-5023
Gasparik, Mihály	O-0122
Gasparyan, Boris	P-2615, P-4270
Gaspryan, Boris	O-2100, P-1601
Gasson, Edward	O-2222, O-3230, <u>P-3483</u>
Gatley, Sarah	O-1057
Gautheron, Cécile	O-4036
Gauthier, Michelle	O-2142
Gautier, Elsa	O-5064
Gavin, Daniel	O-0042
Gavin, Daniel G.	O-0015
Gavrilov, Andrey	P-2473, P-2475
Gavrilov, Milivoj	P-1423
Gayantha, Kasun	<u>O-2158</u>
Gayo, Eugenia	O-4003, O-4004, O-4155, <u>O-4157</u>
Gayó, Eugenia	O-4158
Gazis, Iason Zois	O-2095
Gałecka, Izabela	P-3486
Gałka, Mariusz	O-2130, O-2140, P-1256, P-1806, P-2213, P-2265, P-2863,



INQUA 2019  
DUBLIN  
IRELAND

	P-2865, P-2866, P-2867
Ge, Junyi	P-3205, P-3878, <u>P-4267</u> , P-4605
Gearey, Ben	O-1213, O-4060, P-4287
Gearey, Benjamin	O-1135, <u>O-4030</u> , O-5001
Gebhardt, Catalina	O-1114
Gebhardt, Holger	O-1086
Gebhart, Anne	O-4056
Gebregeorgis, Eyob	P-4537
Gedminienė, Laura	P-2487
Geertsema, Marten	O-5088
Gegg, Lukas	<u>P-1897</u>
Gehrels, Maria	O-3039, P-2209
Gehrels, Maria J.	P-4604
Gehrels, Roland	O-0080, P-1049, <u>P-1056</u> , P-2492, P-4631
Gehrels, W. Roland	O-1161
Gehrmann, Anna	<u>O-1129</u>
Geiger, Alessa	O-4167, P-4482
Geiger, Alessa J	O-2095, P-4478
Geiger, Alessa J.	<u>O-4163</u>
Geirsdóttir, Áslaug	O-0115, O-2017, O-2188, P-1622
Gelfenbaum, Guy	O-3088
Gell, Peter	<u>P-4239</u>
Genet, Marion	<u>P-1802</u>
Geng, Junyan	P-3812
Gennaretti, Fabio	O-4206
Genty, Dominique	P-2507
George, Jessie	<u>P-1227</u>
Georgiadis, Eleanor	P-2495
Geppert, Philipp	O-0028
Gerasimenko, Natalia	<u>O-2121</u> , <u>P-4634</u>
Gerasimov, Dmitry	P-1032
Gert Jan, Weltje	O-1076
Gertisser, Ralf	O-3036



GHALEB, Bassam	P-1874
Gheorghiu, Delia	O-0131, P-3484
Ghienne, Jean-Francois	P-2909
Ghiglione, Matías	O-4186
Ghil, Michael	P-1409
Ghilardi, Matthieu	<u>O-2120</u>
Ghim, Yong Sik	P-2826, P-3027
Ghinassi, Massimiliano	P-3804
GHOSH, ANUPAM	<u>P-1028</u>
Ghosh, Anupam	O-1082, P-4510
Ghukasyan, Robert	O-2100
Giaccio, Biagio	O-1163, P-1607, P-2472
Giannecchini, Roberto	P-4013
Gianotti, Franco	P-2624, P-2844
Giardina, Miguel	P-1259
Giardini, Marco	O-1138
Giardino, Marco	<u>P-4832</u>
Gibbard, Phil L.	<u>P-1604</u>
Gibbard, Philip	O-1237, O-1238, P-1485
GIBBARD, Philip	<u>P-2626</u>
Gibbard, Philip L.	O-5042, P-2625, P-4484
Gibbs, Kevin	<u>O-4024</u>
Gibert, Luis	O-2165
Gibert-Brunet, Elisabeth	O-3209
Gibson, Sebastian	O-5113
Gibson, Sebastian M.	<u>O-5042</u> , <u>P-2625</u>
Gielly, Ludovic	O-0039, O-1024, O-1100, O-1105, O-1162, P-1204, P-1212, P-1214
Gierz, Paul	<u>P-1419</u> , P-3482
Giesche, Alena	<u>O-2148</u>
Giesecke, Thomas	O-2007, O-2029, <u>O-2139</u> , O-2205, O-5122, P-4295, <u>P-4420</u>
Giesen, Rianne	P-3822
Giglio, Cristiana	<u>O-5062</u>



Giglio, Federico	P-1476
Giguet Covex, Charline	P-1203
Giguet-Covex, Charline	O-1024, O-4006, P-1214
Giguet-covex, Charline	P-1212
Gihm, Yongsik	<u>P-2830</u>
Gil, Adolfo	<u>O-3175</u> , <u>P-1259</u>
Gil, Isabelle	O-4069
Gil, Luis	O-2032
Gil-Guirado, Salvador	O-5054
Gil-Romera, Graciela	O-1022, O-1139, O-3021, <u>O-3096</u> , O-3149, P-1226, P-1266, P-1810, P-2212, <u>P-2253</u> , P-4284, P-4420, P-4505
Giles, David	<u>O-5045</u>
Gilgannon, Sean M.	<u>P-1900</u>
Gili, Stefania	O-0093, <u>P-1435</u>
Gill, Jacquelyn	<u>O-0120</u> , O-3178, P-1819, P-3218
Gillanders, Bronwyn	O-1005
Gillespie, Jo	O-1092
Gillespie, Josephine	P-1284
Gilli, Adrian	O-4084
Gillikin, David P.	P-1505
Gilson, Gaëlle	<u>P-4409</u>
Ginat, Hanan	O-4199
Ginau, Andreas	P-3843
Giner-Robles, Jorge L.	P-4802, P-4804
Gingerich, Travis	<u>P-2617</u>
Giralt, Santiago	O-2072, O-3174, P-1495
Girardclos, Stéphanie	O-3085, P-3042
Girardin, Martin	O-0016, <u>O-0018</u>
Giraudeau, Jacques	P-2495
Girault, Igor	P-4264, P-4476
Girdland Flink, Linus	P-2234
Giri, Kattel	P-4239
Girininkas, Algirdas	P-1035



INQUA 2019  
DUBLIN  
IRELAND

Girma Tekelemariam, Minassie	O-2102
Githumbi, Esther	<u>O-5010</u> , O-5083
Giustini, Francesca	O-5108
Gjesfjeld, Erik	<u>O-4101</u>
Gkinis, Vasileios	O-2015, O-4014
Gladkov, Andrei	O-4049
Gladkov, Anton	O-4049
Gladyshev, Vyacheslav	O-5019
Glais, Arthur	<u>P-1261</u>
Glanville, Helen	P-4866
Glaser, Bruno	O-2102, P-3207, P-3210, P-3480, P-4505
Glasser, Neil	O-4167, P-1280, P-2517, <u>P-2903</u> , P-4471
Glasser, Neil F.	P-1483, P-3485, P-4474, P-4611
Glasser, Neil Frank	O-4163
Glauberman, Phil	O-2100, P-1601
Gleason, James	O-5027
Gleeson, Patrick	P-3204
Gleixner, Gerd	O-1228, O-2158, O-3106
Gliganic, Luke	P-2235
Glover, Katherine	P-3218
Gobet, Erika	<u>O-0099</u> , O-2209, O-4084, O-5004, P-2264, P-4217, P-4511
Godbout, Pierre-Marc	P-1881
Goder-Goldberger, Mae	<u>O-0050</u>
Goderis, Steven	O-0093
Godfrey, Laurie	O-0059
Godfrey, Laurie R.	O-1108
Godfrey, Michael	P-1504
Godhe, Anna	P-1004, P-1045
Godoi Millan, Maria A.	<u>P-4484</u>
Godon, Martin	O-1039
Godoy Aguirre, Carolina	<u>O-4158</u>
Goehring, Brent	O-0114, P-2814
Goehring, Brent M.	P-3823



Goldberg, Paul	O-0073
Goldstein, Steven	O-3046
Golledge, Nicholas R.	O-1010
Golovachev, Mikhail	O-5107
Gomes, Alberto	O-3092, P-2883, <u>P-2896</u> , <u>P-2899</u>
Gomes, Sandra	<u>P-2484</u>
Gomez, Natalya	O-1236, <u>O-3226</u> , P-3484
Gomez-Novell, Octavi	O-4187
Gonda, Regina	O-4001
Gondet, Sébastien	P-3855
Gong, Rouyan	<u>P-2465</u>
Gong, Xun	<u>P-1408</u>
Gontz, Allen	O-1158, O-4043, P-2601, <u>P-2607</u> , <u>P-3413</u>
Gonzalez, Humberto E.	P-3838
Gonzalez, Juan	<u>P-2226</u>
Gonzalez, Silvia	P-2429
Gonzalo, Lia A.	P-3049
González - Sampériz, Penélope	O-1139
González Sampériz, Pénélope	P-2212
González, Charles	O-5052, <u>P-1433</u>
González, Karina	P-1017
González, Mauro E.	P-1821
González, Zaire	P-3235
González-Díaz, Benjamín	O-3147
González-Díez, Alberto	P-4256
González-Fortes, Gloria	O-0040, <u>O-1026</u> , P-1236
González-Lanchas, Alba	<u>O-3076</u>
González-Lemos, Saúl	O-1151, P-3409
González-Sampériz, Penélope	O-3149, P-1226, P-1255, P-1266, P-1810, P-1872, P-4284
González-Villanueva, Rita	<u>O-4106</u>
Gonçalves, Célia	P-2486
Gonçalves, Vítor	P-1495
Gonçalves, Vítor	O-3174



Goodfellow, Bradley W	O-1070
Goodwin, Ian	P-1507
Goosse, Hugues	O-3185, O-4206, P-1499, P-4409, P-4441
Gorbey, Devon	O-1099
Gorbunov, Aleksey O. Gorbunov	P-1058
Gorczyńska, Aneta	P-4011
Gordon, Jamie	P-3819
Gordon, Jay	O-2076
Gordon, John	P-1283
Gordon, John E	O-1058
Gordon-Smith, Debbie-Ann	P-1467
Goring, Simon	<u>O-1211</u> , O-5008, O-5122
Gornostaeva, Anastasiia	<u>P-4607</u>
Goseberg, Nils	P-3825
Goslar, Tomasz	O-3025, P-1204
Gosling, Will	O-3140
Gosling, William	O-0100, <u>O-1048</u> , O-3134, O-5101, P-1509
Gosse, John	O-1066, O-1067, O-2212, O-5047, P-1481, P-1861
Goswami, Kartika	O-4179, P-1213, <u>P-3834</u>
GOSWAMI, KARTIKA	<u>P-1904</u>
GOTANDA, Katsuya	P-4448
Gotanda, Katsuya	O-2161
Gottschalk, Julia	P-3618
Gouramanis, Chris	O-0089
Gouw-Bouman, Marjolein	<u>O-1098</u> , <u>P-2417</u>
Govers, Gerard	P-3236
Govin, Aline	O-2038, P-4515
Gowan, Evan	P-1053, P-3481
Gowan, Evan J.	<u>O-1235</u>
Goy, José L.	P-3497, P-4531
Goyal, Kanva	P-3883
Gozález-Delgado, Angel	P-4531
GPWG, Global Paleofire Working	P-1822



Group

Grady, David	<u>O-3021</u> , <u>P-2421</u> , P-4505
Grady, David A.	O-3096, P-2253
Gradziński, Michał	P-2806
Graf, Andreas	O-1132
Graf, Kelly	O-4005
Graham, Romaine	O-1224
Granato-Souza, Daniela	O-3195
Grandal d'Anglade, Aurora	P-1238
Grandal-d'Anglade, Aurora	<u>O-0040</u> , O-1026, P-1236
Grande, Valentina	P-4029
Grant, Helen	O-3148
Grant, Katharine	O-3036, O-3067
Grant, Michael	O-1123, <u>O-3130</u> , <u>P-1274</u> , P-4283
Grant, Rhia	O-2092
Grasemann, Bernhard	P-2909
Grasset, Sebastián	O-3169
Grau, Oriol	O-2132
Grawe DeSantis, Larisa	O-3180
Gray, Amy	<u>P-4018</u>
Gray, Sarah C.	<u>O-1002</u>
Gray, Will	O-1086
Grazioli, Sandra	P-2905
Grebennikova, Tatiana	P-1058
Green, Andrew	<u>O-2089</u> , <u>P-2006</u>
Green, Daniel R.	O-0071, <u>O-0072</u>
Green, Sophie	P-2863
Greenbaum, Noam	O-3079, <u>P-2618</u>
Greenbuam, Noam	P-2837
Greenop, Rosanna	O-1008
Greenslade, Mark	P-4421
Greenwood, Sarah	O-1051, O-5059, P-1884
Greer, Jacinta	<u>P-4489</u>



INQUA 2019  
DUBLIN  
IRELAND

Gregoire, Lauren	O-2197, O-2222, O-3230, O-3231, O-4072, <u>O-4150</u> , P-1402, P-1403, P-1412, <u>P-1415</u>
Gregory, Andrew	P-1844
Gresina, Fruzsina	P-2609
Gribenski, Natacha	<u>P-1860</u> , P-2437
Griffiths, Alan	O-3183, O-4092, P-4488
Griffiths, Howard	O-2133, P-2872
Griffiths, Hywel	O-0150, O-1160, <u>P-1033</u> , <u>P-2244</u>
Griffiths, James	O-1218
Grimalt, Joan	O-4211
Grimalt, Joan O.	O-3076, O-3154, P-2488, P-3499
Grimes, Vaughan	O-0142, P-3214
Grimm, Eric	O-1211, P-4420
Grimm, Eric C.	<u>O-1178</u> , O-5122
Grinsted, Aslak	O-2015
Grodek, Tamir	P-3850
Groenendijk, Peter	O-3195
Groeneveld, Jeroen	O-2181, O-2185, O-4071
Groff, Dulcinea	<u>O-3178</u>
Grohgan, Madleen	O-1154
Groll, Michael	P-3809
Grondin, Pierre	O-1044
Groos, Alexander	O-2102, P-3884
Groos, Alexander Raphael	<u>O-1149</u>
Grootes, Pieter	O-3190
Grootes, Pieter M.	P-2521
Grosjean, Martin	O-3183, O-4084, O-5002, P-3450, P-4249, P-4619
Grossey, Tim	O-1200, P-1047
Grosvenor, Mark	<u>P-1807</u>
Groucutt, Huw	<u>O-5092</u>
Grove, Matt	O-4174, P-3805
Groves, Pam	O-0063
Grudzinska-Elsberga, Ieva	<u>O-5004</u> , <u>P-3439</u>



Gruetzner, Christoph	<u>O-4048</u>
Grunwald, Theresa	<u>O-2080</u>
Gröbner, Marie	O-2153
Grønnow, Bjarne	O-3026
Grün, Rainer	<u>O-4113</u> , P-4277
Gu, Fang	<u>P-1027</u> , <u>P-4461</u>
Gu, Zhaoyan	P-2228
Guan, Ying	<u>P-2236</u>
Guarino, Maria	P-4513
Guenter, Christina	P-4273
GUERIN, Gilles	O-5115
Guerra, Lucía	<u>P-3442</u>
Guerrieri, Luca	O-4044, <u>O-4123</u> , P-4803, <u>P-4820</u>
Gugerli, Felix	P-1205
Gugliotta, Marcello	O-1079
GUGLIOTTA, Marcello	P-1010
Guild, Ailsa	<u>P-3818</u>
Guilderson, Thomas	O-3190
Guillemot, Typhaine	P-3428
Guillou, Valery	P-3409
Guilou, Valery	O-1053
Guimarães, Tasso	O-2004
Guiot, Joel	O-4206
Gunchinsuren, Byambaa	O-0056, O-5094
Gunn, John	O-3098
Gunnarsdóttir, Sigurveig	O-2188
Guo, Fei	P-1503, <u>P-2483</u>
Guo, Jialong	O-0139
Guo, Yun	P-2402
Guo, Zhengtang	<u>O-2116</u> , O-5011, P-1422, P-2476, P-3621, P-3878, P-4526
Guo, Zhentang	P-1423
Gupta, Sanjeev	O-2151
Gur- ArieH, Shira	P-1601



INQUA 2019  
DUBLIN  
IRELAND

Guralnik, Benny	O-4117, P-1860
Gurinov, Artem	P-1911
Gurusamy, Raman	O-4179
Gusev, Yevgeny	P-2622
Gutiérrez, Eduardo	O-1042
Gutiérrez, Felipe	O-3169
Guzowski, Piotr	P-1256, P-2266, P-2865, P-2867
Guérin, Gilles	P-3875
Guðmundsdóttir, Esther Ruth	O-1188, O-3040, P-3623
Guðmundsdóttir, Lísabet	O-2208
Gyllencreutz, Richard	O-1071, O-1084, O-1130, O-2127, O-5019, P-3481
Gázquez, Fernando	O-2148
Gísladóttir, Guðrún	O-2208, P-1260
Gómez Puche, Magdalena	O-2048
Gómez-Arozamena, José Ezequiel	P-4256
Gómez-Bolea, Antonio	O-3080
Gómez-García, Daniel	P-1226
Gómez-Navaroo, Juan José	O-5054
Gómez-Navarro, Juan José	<u>P-4415</u>
Gómez-Orellana Rodríguez, Luis	P-1220
Gómez-Puche, Magdalena	P-4231
Gómez-Szmulewicz, Gabriel	<u>O-1150</u>
Görüm, Tolga	P-2897
Gümüş, Burçin Aşkim	P-4205
Günther, Anke	P-2216
Gürbüz, Alper	P-3842
Gürel, Ali	O-1039
Gąbka, Maciej	P-1256, P-2865, P-2866, P-2867
Gąsiorowski, Michał	O-1204, P-2805, <u>P-2806</u> , P-4238
Gębica, Piotr	O-1152
H.V., Manjunatha	P-3815
Haaga, Kristian Agasøster	O-1011, P-3615
Haas, Jean Nicolas	<u>P-2270</u> , <u>P-2272</u> , <u>P-2273</u>



INQUA 2019  
DUBLIN  
IRELAND

Haas, Mischa	P-3418
Haberle, Simon	O-1031, O-2062, O-3059, O-3065, <u>O-3137</u> , O-4096, P-1218, P-1463, P-1823, P-3216, <u>P-4528</u>
HABERLE, SIMON	P-4282
Haberle, Simon G.	P-2406
Haberzettl, Torsten	P-2510, P-4530
Habicht, Hando-Laur	P-1046
Habu, Junko	P-1009
Hackenberger, Dirk	O-0041
Haddoumi, Hamid	O-5025
Hadler, Hanna	<u>O-4031</u>
Haerberli, Wilfried	O-3229
Haflidason, Hafliði	O-0039, O-1011, O-1100, O-1130, O-1162, <u>O-5019</u> , P-1892, P-3615
Hagemans, Kimberley	P-1509
Hagermann, Axel	O-0045, P-1843
Haig, Jordahna	O-2112
Haile, James	O-1185, P-1204
Haileselassie, Yohannes	<u>Plen05</u>
Haines, Heather A	<u>O-2108</u> , <u>P-2509</u>
Hajdas, Irka	O-3190, <u>P-1276</u> , P-2270, P-3442
Hajima, Tomohiro	P-1430
Haliuc, Aritina	O-2203
Haliyeva, Maral	O-5058
Hall, Adrian M	O-1070
Hall, Brenda	O-1087, P-1856
Hall, Ian	O-1189, O-2113, P-1473
Hall, Julia	O-0091
Hall, Tegan	<u>O-1092</u> , <u>P-1253</u>
Halley, Robert	O-3167
Halsall, Karen	O-2207
Halsted, Christopher T.	<u>P-3823</u>
Haltia, Eeva	P-3459



INQUA 2019  
DUBLIN  
IRELAND

Hambach, Ulrich	P-1614, P-1628, P-1635, P-1636, P-2813, P-4445, P-4606
Hambleton, Ellen	P-4529
Hambrey, Michael	O-3230
Hamerlik, Ladislav	P-4238
Hamilton, Rebecca	O-1092, <u>O-3058</u> , <u>P-1284</u>
Hammarlund, Dan	O-5071, P-4438
Hammerl, Christa	O-4046
Hammond, William C.	O-4151
Han, Holly Kyeore	<u>O-1236</u>
Han, Jiangwei	O-2163
Han, Long	P-3621, P-3878
Han, Lu	P-1201
Han, Min	P-1002
Handley, Josephine	<u>O-3171</u>
Hanebuth, Till	P-3460
Haneda, Yuki	O-0118, <u>P-2479</u>
Hang, Tiit	P-1046
Hankin, Stuart	P-2507
Hann, Madeleine	<u>P-3827</u>
Hannisdal, Bjarte	O-1011, P-3615
Hannon, Gina	O-2207
Hanquiez, Vincent	P-1802
Hansen, Katrine Elnegaard	P-2490
Hansen, Louise	P-3060
Hansom, James	P-1283
Hanson, Paul	P-2902
Hansson, Sophia V	O-2131
Hansson, Sophia V.	P-2873
Hao, Qiangzhen	O-2079
Hao, Qinghe	P-4012
Hao, Qingzhen	P-1423, P-2215, P-3621, <u>P-3813</u> , P-3878
Hao, Zhixin	<u>O-0087</u>
Hao Cardinali, Sonia	O-5102



Haochen, Pan	<u>P-1023</u>
hapsari, k. anggi	<u>P-2856</u> , <u>P-4212</u>
Harada, Naomi	O-1227
Haraguchi, Tsuyoshi	O-2161
HARAGUCHI, Tuyoshi	P-4448
Harbor, Jonathan M.	P-1483, P-3485
Hardeng, Johannes	<u>P-3853</u>
Harder, Hartwig	O-3044
Hardiman, Mark	O-1123, O-3036, O-3039, <u>O-4182</u> , <u>P-1815</u> , P-1818, P-4456
Harding, Chris	O-1129
Harding, Rachel	O-5058
Hardt, Ben	O-2117
Hardt, Jacob	O-5038
Hardy, François	O-4005, P-2820, P-4625
Hare, Vincent	P-1878
Harewood-Malone, Shannon	P-3819
Harman, Naima	P-4456
Harmand, Sonia	O-4171
Harning, David	<u>O-2188</u> , <u>P-1622</u>
Harrault, Loïc	O-3102
Harrigan, Shaun	O-0091
Harris, Daniel	P-3044
Harris, Scott	O-5091
Harris, Timothy	O-0048
Harrison, Sandy	O-0106, O-4143, O-5009, P-4424
Harrison, Sandy P.	<u>O-3149</u> , P-1493
Harrison, Stephan	O-4192
Harrison, Terry	P-1225
Harrod, Chirs	P-1017
Hart, Isaac	P-1263
Hart, Jane	<u>O-2145</u>
Hartland, Adam	<u>P-1506</u> , P-4498
Hartley, Adrian	O-1218, P-3872



INQUA 2019  
DUBLIN  
IRELAND

Hartmann, Andreas	P-2507
Hartmann, Kai	P-3477
Hartung, Hannah	<u>P-3422</u>
Hartvich, Filip	P-3865
Harvey, Anne-Elisabeth	O-3179
Harvey, Jason	O-2180
Harvey, Jordan	P-1206
Harðardóttir, Sara	<u>O-1185</u>
Hasan, Ozren	P-3206
Hasebe, Noriko	P-1277
Hasegawa, Hitoshi	O-0051, O-0136, O-2161, <u>P-1277</u>
Haslam, Richard	O-1224
Hassall, Jon	P-4469
Hassall, Jonathan	O-5101
Hassel, Christiane	O-4041
Hatfield, Robert	P-2223
Hatta, Yoshiki	P-1009
Hatton, Jackie	P-3464
Hattori, Akihisa	P-2444
Hatté, Christine	O-1193, P-1409, P-1628, P-1869, P-3875
Haubenstock, Norma	O-0063
Haug, Gerald	O-3220
Hausmann, Niklas	P-1510
Hausner, Vera H.	P-2218
Havelock, Glenn	<u>P-1052</u>
Hawbaker, Todd	O-0020
Hawkes, Andrea	<u>O-3013</u> , P-3035
Hawkings, Jon	O-2094
Hawkins, Hayley	O-1181
Haws, Jonathan	<u>O-1016</u> , P-2807, P-3410
Hay, Carling	O-3213
Hayakawa, Yuichi	O-1199
Hayashi, Hiroki	O-0118



INQUA 2019  
DUBLIN  
IRELAND

Hayashida, Akira	O-2161
Hayes, Katherine	P-1819
Haynes, Deborah	O-1005
Hayward, Bruce	O-4020, P-4499
Haywood, Alan	O-2197
Hazell, Zoe	<u>P-1285</u>
Hazell, Zoë	O-1123
Hazell, Zoë J.	P-4604
He, Chengfei	O-0010
He, Feng	O-2152
He, Keyang	<u>O-3103</u>
Head, Katie	O-1104, O-3100, O-3101
Head, Martin	<u>O-0117</u> , <u>P-4514</u>
Heathon, Timothy J.	O-3196
Heaton, Tim	O-1008, O-3193
Heaton, Timothy	O-3190, <u>O-3191</u> , O-3192
Hebbeln, Dierk	P-1439
Hebenstreit, Robert	P-2886
Hechenblaickner, Brigitte	P-2270, P-2272
Heckmann, Tobias	P-2847
Hegarty, Susan	<u>O-5001</u>
Heijnis, Hendrik	O-4097, P-4252
heijnis, henk	<u>O-1030</u>
Heijnis, Henk	O-1031, O-3064, P-1469, P-4494
heikki.seppa@helsinki.fi, heikki	<u>P-1447</u>
Heikkilä, Maija	P-1440, <u>P-3437</u>
Hein, Andrew	<u>P-1477</u>
Hein, Andrew S	P-4479
Hein, Andrew S.	P-4624
Hein, Andrew S.,	P-4470
Hein, Andy	O-0113, O-4168, P-4471
Hein, Christopher	<u>O-1007</u> , <u>P-3011</u>
Hein, Michael	P-3873, <u>P-3874</u>



INQUA 2019  
DUBLIN  
IRELAND

Heinrich, Hartmut	<u>O-3218</u>
Heintzman, Peter	Plen02
Heintzman, Peter D	O-1105
Heintzman, Peter D.	<u>O-1027</u> , O-3025, <u>P-1202</u> , P-1209, P-1210
Heinzel, Chad	<u>O-0159</u> , <u>P-2225</u>
Heiri, Oliver	O-0125, O-4089, O-5004, P-1203, P-4420
Heiss, Andreas	P-4009
Hellstrom, John	O-2076, O-3098, O-4009, <u>O-4039</u> , O-4211, P-1506, P-2480, P-4450, P-4486, P-4488, P-4491
Hellstrom, John C.	O-3075, P-3488
Helm, Aveliina	O-2029
Helmens, Karin	<u>O-0034</u>
Helmer, Desiree	<u>P-4262</u>
Helmer, E.	P-3203
Hemp, Andreas	P-1232
Henderson, Andrew	O-1111, O-3100, O-3101, O-5101
Henderson, Andrew C.G.	O-5029
Henderson, Andy	O-1104, O-3099, P-3204
Henderson, Gideon	O-4037
Hendy, Ingrid	<u>O-3111</u>
Henley, Benjamin	O-4095
Henne, Paul	<u>O-0020</u>
Henne, Paul D.	O-0017
Hennebelle, Andy	<u>O-1044</u>
Henneberger, Kirstin	O-1026
Hennessy, Ronan	O-1057
Henriksen, Mona	O-1130
Henriquez, Carla	<u>P-4483</u>
Henry, Donald	O-0051
Henry, Pierre	O-3208
Henry, Sandra	O-0150
Henríquez, Carla	O-4165
Hense, Andreas	O-4149, O-4197



Hensel, Elena A.	<u>O-3020</u>
Henselowsky, Felix	<u>O-3019</u>
Henshilwood, Christopher Stuart	O-3017
Herbert, Annika	P-3501, <u>P-3504</u>
Hercman, Helena	<u>O-1204</u> , <u>P-2805</u> , P-2806, P-4501, P-4523
Herget, Juergen	<u>O-3003</u> , <u>P-3826</u>
Herman, Frédéric	O-4036
Hermanowski, Piotr	O-1201
Hernandez, Armand	O-0026
Hernandez-Almedia, Ivan	O-3183
Hernandez-Molina, Francisco J.	O-3071
HERNANDEZ-MOLINA, FRANCISCO J.	O-2118
Hernández, Armand	O-3174, O-4106, <u>P-1495</u> , P-4024, <u>P-4410</u>
Hernández, Marjorie	P-4481
Hernández, Walter	O-1042
Hernández-Almeida, Iván	P-4256
Herrault, Pierre-Alexis	O-4056
Herremans, Marc	P-1242
Herrera, Gaston	O-2095
Herrera, Gastón	P-4478
Herrera, Gerardo	P-4830
Herrero-Simón, Ramón	P-2851
Herridge, Victoria	P-2810
Herries, Andy	O-4097, P-4494
Hertler, Christine	<u>O-4134</u> , O-4135, O-4136, <u>P-1246</u> , P-4202, P-4203, P-4208
Hervé, Francisco	P-3048
Herzschuh, Ulrike	O-1022, O-1028, O-1045, O-1102, O-5008, O-5012, P-1215, P-1441, P-2218, P-3458, P-4296
Hesp, Patrick	P-2601
Hesse, Paul	P-2832, <u>P-4485</u>
Heurich, Marco	P-3627
Heusser, Linda	P-4499
Heyman, Jakob	<u>O-1070</u> , P-1890



INQUA 2019  
DUBLIN  
IRELAND

Heyvaert, Vanessa	P-3045
Hibert, Brynn	O-1046
Hickler, Thomas	O-0105
Hidy, Alan	P-3466
Hidy, Alan J.	P-1859
Higuera, Philip	<u>O-0021</u>
Hijma, Marc	P-1064
Hijma, Marc P.	O-0001
Hildebrandt, Kyndall	P-1210
Hiles, William	<u>P-4233</u>
Hill, Christopher	<u>O-5090</u>
Hill, Evan	<u>O-2044, P-3230</u>
Hill, James	<u>O-3135</u>
Hill, Ross A.	P-4529
Hill, Thomas	O-4030
Hillaire-Marcel, Claude	O-1187, P-4531
Hillenbrand, Claus-Dieter	O-4127
Hilpert, Johanna	O-5009
Hinck, Sebastian	O-1235, P-3482
Hindmarsh, Richard	O-2222, O-3230, O-3231
Hindmarsh, Richard C.A.	P-1059
Hines, Ben	P-4465
Hinnov, Linda	O-3111
Hinrichs, Kai-Uwe	P-1511
Hinthorne, James	P-2226
Hinz, Martin	P-1249
Hipkiss, Charlotte	<u>P-4467</u>
Hipondoka, Martin	O-4145
Hippe, Kristina	O-1070, O-2018, P-1860
Hirata, Takafumi	P-3457
Hirose, Kotaro	<u>P-1004</u> , P-1045, P-3457
Hirose, Masato	O-0051
Hirsch, Florian	<u>P-4824</u> , P-4826



INQUA 2019  
DUBLIN  
IRELAND

Hjelstuen, Berit Oline	O-0004
Hladik, Christine	P-1251
Hladyniuk, Ryan	O-5006
Hlaing, Kay Thwe	O-3166
Ho, Lih-Der	<u>P-1905</u> , P-2882
Ho, Sze-Ling	O-2181
Hobbs, James A.	O-0147
Hocking, Emma	<u>P-3034</u>
Hodder, Tyler	O-2142, O-4131
Hodell, David	<u>O-1090</u> , O-2041, O-2148, O-4211, <u>P-3412</u> , P-4498
Hodell, David A.	O-3071, P-1802
HODELL, DAVID A.	O-2118
Hodgson, David	O-0003, O-3231, P-1072, P-1403, P-1903
Hodgson, Dom	O-0113
Hodgson, Dominic	O-4097, P-4494
Hodgson, Dominic A	O-3183, P-4249
Hoefler, Dana	P-2212
Hoek, Wim	O-1098, O-4087, P-2417, <u>P-3446</u> , P-3852, P-3858, P-4227, <u>P-4458</u>
Hoek, Wim Z.	O-0001
Hoelzchen, Ericson	<u>P-4206</u>
Hoelzmann, Philipp	O-1228, O-3016, O-3106, O-3221
Hoevers, Renske	<u>P-1242</u> , <u>P-2862</u> , P-2868
Hof, Florian	O-4216
Hoffmann, Dirk	O-4010, P-4462, P-4516
Hoffmann, Dirk L.	O-4146
Hoffmann, Gösta	<u>O-4184</u> , P-1879, P-3010, P-3022
Hoffmeister, Dirk	O-2153
Hofmann, Felix Martin	P-2457
Hofreiter, Michael	O-1026, P-1231, P-1238
Hogan, Kelly	<u>O-4127</u>
Hogg, Alan	O-3190, O-3194, O-4204, P-3464
Hoggarth, Julie	O-3173, P-4219



INQUA 2019  
DUBLIN  
IRELAND

Holbourn, Ann	O-2115
Holcová, Katarína	P-1237
Holder, Kristy	<u>P-2870</u>
Holeksa, Jan	O-4062
Hollins, Suzanne	O-4092
Holloway, Max	O-3185
Holmes, Aline	P-4465
Holmes, Jonathan	O-2107, O-3089, P-2416
Holmes, Naomi	P-3819
Holmes, Peter	O-3034
Holmström, Lasse	O-2187
Holt, Katharine	P-4492
Holt, Katherine	<u>O-3145</u> , <u>P-2259</u>
Holuša, Jakub	P-3829
Homami Totmaj, Leila	<u>P-4289</u>
Hong, Isabel	O-3013
Hong, Seok Hwi	P-1606, <u>P-2003</u>
Hong, Seok-Hwi	P-2829
Hong, WeiLi	O-5131
Hong, Yan	O-1034
Hongwei, Kwang	P-2911
Honiat, Charlotte	<u>P-4473</u> , P-4507
Hooghiemstra, Henry	P-3235
Hooke, Janet	P-2835
Hopcroft, Peter	O-1089, <u>O-3029</u> , P-4516
Hopewell, David	O-1160
Hopf, Feli	<u>O-4096</u> , <u>P-1463</u>
Hopf, Felicitas	O-3065
Hopkins, Jenni	O-4012
Hopkins, Jenni L	<u>P-3624</u>
Hopkins, Jenni L.	O-4116
Hopla, Emma	O-5008
Hopley, Philip	<u>O-4170</u> , P-4529, <u>P-4539</u>



INQUA 2019  
DUBLIN  
IRELAND

Hopmans, Ellen C.	O-1045
Horicka, Zuzana	P-3627
Hornsey, Josephine	<u>O-1143</u> , O-3201
Horowitz, Tali	O-1206
Horton, Benjamin	P-1057
Horton, Benjamin	O-0081, O-3008, O-3013, <u>O-3213</u> , O-4152, P-1061, P-1062, P-1065, P-3019, P-4406
Horvatić, Davor	O-0084
Horváth, Erzsébet	O-1194, P-1629, <u>P-1870</u> , P-2614, P-3625
Horáček, Ivan	P-4523
Hoshino, Yasuharu	O-2161
Hostetler, Addison	P-1619
Hostetler, Savannah	P-1619
Hostetler, Steve	O-0019
Hotchkiss, Alastair	P-1221
Hotchkiss, Sara	O-0096
Hou, Juzhi	<u>O-2160</u>
Hou, Yamei	O-2163
Hovakimyan, Hayk	P-1602
Howarth, C.	P-3203
Howe, Tim	O-0063
Howell, John	O-2143, O-5058, P-1846
Hoyle, Thomas M.	O-0061
Hrachanik, Mikalai	P-4641
Hradunova, Aksana	P-4641
Hrubá, Jolana	P-3627
Hrynowiecka, Anna	O-1165, O-1166, P-1855, P-2205, P-2422, P-2427, P-4640
Hsu, Chia-Hao	O-0027
Hsu, Jin-Ping	O-0027
Hu, Chunsheng	<u>P-2894</u>
Hu, Daogong	P-3828
Hu, Fangen	P-3478
Hu, Feng Sheng	O-2138



Hu, Jianfang	<u>P-3427</u>
Hu, Ke	P-4605
Hu, Kui	P-2269
Hu, Shouyun	P-3434
Hu, Zhenbo	P-2878
Hua, Quan	O-2108, O-3069, O-3195, P-3024, P-4489
Huan, Xiujia	O-3103, <u>O-3104</u>
Huang, Doreen	O-3102
Huang, Feipeng	P-2821
Huang, Juh-Jaan Steven	P-2272
Huang, Jyh-Jaan Steven	O-1074, O-2093, P-1462, <u>P-1464</u> , P-2273
Huang, Kangyou	P-2852
Huang, Lei	O-2001, <u>P-1494</u> , P-2402
Huang, Linpei	O-1033, P-1222, P-2215, P-2269, P-4248
Huang, Min	P-1801
Huang, Wei	P-3479
Huang, Weiwen	O-2163
Huang, Xiaofang	O-4064
Huang, Xiaozhong	<u>O-2157</u> , <u>P-1248</u> , P-4419
Huang, Yongsong	O-1043, O-2001, P-3223
huang, yongsong	P-1494
Huang, Yun	P-2403
Huang, Yunming	P-4613
Huang, Zhi	O-2008
Hubbard, Alun	O-5129, P-3484
Hubbard, Bryn	O-3201
Hubble, Tom	O-0157
Hublin, Jean-Jacques	O-0052, O-0073, P-1452, P-3214
Huck, Jonny	P-2434
Huddart, David	P-2429
Hudiburg, Tara	O-0021
Hughen, Konrad	O-3190
Hughes, Anna	O-1235, P-1884, P-3822



INQUA 2019  
DUBLIN  
IRELAND

Hughes, Anna L.C.	O-1050, <u>P-3481</u>
Hughes, Leanne	O-3202, <u>P-1829</u> , <u>P-2241</u> , P-3821
Hughes, Malcolm	P-4440
Hughes, Paul	O-0039
Hughes, Phil	P-4864
Hughes, Philip	<u>O-1238</u> , O-2096, P-1485, P-1486, P-2268, P-2434, <u>P-2517</u> , P-3827
HUGHES, Philip	P-2626
Hui, Jocelyn	O-1029
Huining, Wu	P-2410
Humane, Sumedh K.	P-3447
Huminyik, Oana	O-3119, P-4425
Humphreys, Madeleine	P-3629
Hunt, Christopher	O-2044, P-2234, P-2840
Hunt, Daniel	O-0150, P-1033
Hunt, Laura	<u>P-2504</u>
Huntley, Brian	P-2257
Huot, Sebastien	P-1851, P-3857
Huseynov, Dadash	O-3050, <u>P-3402</u>
Husum, Katrine	O-3189
Hutely, Lindsay	P-1811
Huuse, Jane	O-5058
Huuse, Mads	O-5058
Huybers, Peter	P-1066
Hyden, Drake	O-5075
Hyodo, Masayuki	P-3457
Hyttinen, Outi	O-5127
Hättestrand, Clas	O-1070
Hättestrand, Martina	O-1052
Håkansson, Lena	O-5016, P-1894
Hély, Christelle	O-0016, O-5083
Hölzchen, Ericson	O-4134, <u>O-4135</u> , O-4136, P-1246, P-4207, P-4208
Hölzschen, Ericson	P-4203



INQUA 2019  
DUBLIN  
IRELAND

Höpfer, Benjamin	P-4228
Høeg, Helge	P-4433
Hüneke, Heiko	O-1129, P-1879
Hürtgen, Jochen	O-4122
Iacobucci, Giulia	<u>P-3836</u>
Iancu, Liviu	P-2230
Ibacache, Sebastian	O-3172
Ibañez, Carles	P-4024
Ibbotson, Samuel	O-3039
Ibrahim, Anan	<u>P-4245</u>
Ichinnorov, Niiden	P-1277
Idris, Mushrifah	P-2221, P-4246
Igel, Jan	O-4189, P-3863, P-4851
Iglesias, Virginia	O-0019, P-4218
Ignéczi, Ádam	P-1849
Iirgeher, Johanna	O-0063
Iizuka, Fumie	<u>O-4102</u> , P-4263
Ijaz, Umer	P-1442
Ikehara, Ken	O-3010
Ikehara, Minoru	O-3189
Ikeya, Kazunobu	<u>O-5093</u>
Ikävalko, Ossi	P-4831
Ilie, Maria Valentina	O-2011
Ilijanic, Nikolina	P-3206
Ilyashuk, Boris P.	O-2093
Ilyashuk, Elena A.	O-2093
Im, Chang-Bock	P-4801
Imhof, Michael	O-3229
Imhof, Michael A.	<u>P-1482</u>
Imhof, Walter	P-2270
Inglis, Robyn	P-4274
Ingólfsson, Ólafur	O-3203, <u>O-4128</u> , P-1894
Inkpen, Rob	O-4182



INQUA 2019  
DUBLIN  
IRELAND

Inomata, Takeshi	O-2161
Inácio, Miguel	P-4024
Ion, Elena	O-2011
Ion, Gabriel	<u>O-2011</u> , O-3127
Iorio, Marina	P-3040
Iqbal, Mohammad	O-0159
Iriarte, Eneko	P-4451
Iriarte, Jose	O-1049, O-3140, <u>O-4001</u> , O-5097
Iriarte-Chiapusso, María José	P-1255
Irino, Tomohisa	P-1024
Iriondo, Martin	O-3005
Irka, Haidas	P-4029
Iruzuki, Toshiaki	O-0118
Isaia, Roberto	P-3629
Isaksson, Elisabeth	O-3189
Ishii, Yuji	P-1022
Ishimura, Daisuke	O-3163, P-3058, P-3457
Ishiwa, Takeshige	<u>O-1232</u> , P-1001
Isola, Ilaria	P-2480, P-3488
Isola, Iaria	O-2124
Israde-Alcantara, Isabel	<u>P-2429</u>
Israde-Alcántara, Isabel	<u>P-3063</u>
Issa, Maman-Sani	P-4257
Itaki, Takuya	O-0118, O-1111
Ito, Yuka	<u>P-1827</u>
Iturrizaga, Lasafam	<u>P-2846</u> , <u>P-3505</u>
Ivanov, Maxim	O-4191
Ivanov, Mikhail	P-2460
Ivanovic, Ruza	O-2180, O-2197, <u>O-4072</u> , <u>P-1402</u> , P-1403, <u>P-1412</u> , P-1415
Ivask, Jüri	P-2469
Iversen, Frode	P-4433
Iverson, Nels	O-3113
Ivins, Erik	O-4151



INQUA 2019  
DUBLIN  
IRELAND

Ivory, Sarah	O-3058
Ivy-Ochs, Susan	O-4190, P-2430, P-2448, P-2844, P-2905, <u>P-2908</u>
Iwabuchi, Takamasa	P-2001
Iwahana, Go	P-2855
Iwai, Masao	P-1277
Iwano, Hideki	P-3457
Izagirre, Eñaut	<u>P-4474</u>
Izdebski, Adam	O-1137
Izquierdo, Tatiana	<u>O-3156</u> , <u>P-3056</u>
Izuho, Masami	<u>O-0136</u> , O-4102, P-1277, <u>P-4263</u>
Izumi, Kenji	<u>P-2222</u>
Izumi, Kentaro	O-0118
İlkmen, Erhan	P-4818
İşiler, Mehmet	P-4818
Jaagus, Jaak	P-1007
Jaccard, Samuel	P-3618
Jackson, Derek	O-2088, P-2007
Jackson, Margaret	O-2098, <u>O-4141</u>
Jackson, Rebecca	O-1185
Jackson, Stephen	O-2184, P-1819
Jackson, Stephen T.	O-5081
Jacob, Jeremy	O-4006, P-4288
JACOB-ROUSSEAU, Nicolas	O-3094
Jacobs, Liesbet	P-3236
Jacobs, Zenobia	O-0103
jacobs, zenobia	O-3065
Jacobsen, Geraldine	O-1047, O-3067, P-3024
Jacobsen, Signe Hygom	P-2493
Jaeger, Jean-Jacques	O-0123
Jaeschke, Andrea	O-0028
Jahn, Alexandra	O-0115
Jaillet, Stéphane	P-4473
Jain, Mayank	O-2223, <u>O-4040</u> , P-2452



INQUA 2019  
DUBLIN  
IRELAND

Jaishwal, Manok K.	P-4008
Jaiswal, Manoj	P-2512, P-3832
Jaiswal, Manoj Kumar	O-4179, P-1213, P-1904, P-2900, P-3834
Jakab, Gusztáv	P-2213
Jakobsen, Frank W.	P-4006
Jakobsson, Martin	O-1071, O-4127
James, Ben	O-1058
James, Leo	P-1069, P-1070
Jamieson, Stewart	O-4133
Jamšek Rupnik, Petra	O-4048, O-4188
Jancewicz, Elżbieta	P-1240
Janczak-Kostecka, Beata	O-1020
Janick, Joe	O-3110
Jankaew, Kruawun	O-3087
Jankowski, Michal	<u>O-4083</u>
Jankowski, Michał	P-4213
Jankowski, Nathan	O-3065
Jansen, Eystein	P-1417, P-4459
Jansen, John	O-3035
Jansma, Esther	P-3852
Janssen, Stephanie	O-4018
Jansson, Peter	P-2438
Janz, Lisa	<u>O-4025</u>
Jaouadi, Sahbi	<u>O-3077</u> , <u>P-2840</u>
Jara, Ignacio A.	<u>O-0026</u>
Jara-Muñoz, Julius	<u>P-1034</u> , P-3020
Jarpa, Leonora	P-1821
Jary, Zdzislaw	P-1625, <u>P-1634</u>
Jary, Zdzisław	<u>O-1190</u> , O-1191, O-1196, P-1631, P-1632, P-1633, P-1636, P-3873
Jasiewicz, Jarosław	P-4411, P-4412
Jassey, Vincent E.J.	O-2140, P-1806
Jean-Claude, Dutay	P-2481



Jeandel, Catherine	O-0094
Jenkins, Geraint	O-1127, O-5128
Jenkins, Geraint T.H.	P-4611
jennerjahn, tim	P-2856, P-4212
Jennings, Richard	P-2234
Jensen, Allison	P-1819
Jensen, Anne	<u>O-0149</u>
Jensen, Britta	O-1115, O-2212, O-2213, O-3042, O-3118, P-1206, P-1609, <u>P-1610</u> , P-1617, P-3224, P-3616, P-3619
Jensen, Camilla Marie	P-4455
Jensen, Christin	<u>O-3024</u>
Jensen, Jørn Bo	P-1071
Jensen, Mathias Skov	P-4455
Jeong, Su-Ho	<u>P-4815</u>
Jerbic, Katarina	<u>P-3206</u> , <u>P-4533</u>
Jessen, Catherine	<u>O-1159</u>
Ješkins, Jurijs	P-2906
Jha, Deepak	<u>P-2512</u> , <u>P-4235</u>
Jhangra, Bharti	P-1288
Ji, Shunchuan	<u>P-1873</u>
Jia, Jia	O-0022, <u>P-3411</u>
Jia, Xin	<u>O-2125</u>
Jiang, Dabang	O-2079, O-2084, O-4064
JIANG, Feng	P-4613
Jiang, Gaolei	P-3416
JIANG, Le-Ping	P-1020
Jiang, Leping	P-4225
Jiang, Qida	P-3478
Jiang, Wei	O-3168
Jiang, Wenqi	P-1497, <u>P-4504</u>
Jiang, Wenying	<u>O-2005</u> , O-2079
Jie, Dongmei	P-3416
Jilbert, Tom	P-3459



INQUA 2019  
DUBLIN  
IRELAND

Jimenez, Elodie-Laure	P-3214
JIMENEZ-ESPEJO, FRANCISCO	O-2118
Jimenez-Espejo, Francisco J.	O-3071
Jiménez Arenas, Juan Manuel	O-2166, P-2204
Jiménez-Espejo, Francisco	O-3151
Jiménez-Espejo, Francisco J.	P-3493
Jiménez-Moreno, Gonzalo	O-3151, P-2840, P-3493
Jiménez-Sánchez, Montserrat	O-1151, O-2072, P-1488
Jin, Changzhu	P-1225
Jin, Chunhan	O-5070
JIN, Jianhui	<u>P-4613</u>
Jin, Kwangmin	<u>P-4812</u>
Jing, Xia	P-3406
Jing, Zhichun	P-4292
Jo, Kyoung-nam	P-1228
Joannes-Boyau, Renaud	<u>O-0121</u> , P-1218
Joannin, Sebastian	P-1601
Joannin, Sebastien	O-2100
Joannin, Sébastien	P-2477
Jochum, Klaus P	P-2482
Jochum, Klaus P.	O-3074
Jochum, Klaus Peter	P-1519
Jochum, Markus	O-4098
Joerg, Schaefer	O-4019
Johansson Ström, Olof	P-2904
Johansson, Hans	O-3038
Johansson, Maria U.	P-2253
Johns, Charles	O-1161
Johnson, Chris	P-1823, <u>P-3216</u>
Johnson, Geoffrey	<u>O-2169</u>
Johnson, Kirstin	<u>P-1025</u> , P-1069, <u>P-1070</u>
Johnson, Mark	O-0044, <u>P-2904</u> , P-2910
Johnson, William	P-2602



INQUA 2019  
DUBLIN  
IRELAND

Johnston, Bob	P-1014
Jokinen, Simo	P-3437
Jomelli, Vincent	O-2020, P-2458
jomelli, vincent	<u>O-1142</u>
JOMELLI, Vincent	O-2016
Jompa, Jamaludding	P-3014
Jones, Andrew	P-3819
Jones, Ben	P-2876
Jones, Brian	O-3035
Jones, Brian G.	P-1060
Jones, Cerys	O-0150
Jones, Claire	<u>P-1289</u> , P-1465, <u>P-1813</u> , P-3046
Jones, Julie	<u>O-0090</u> , P-4403
Jones, Lee	O-3202, P-3821
Jones, Matthew	O-2107, P-2504
Jones, Miriam	<u>O-2201</u> , P-2876
Jones, Philip	O-0091, P-3464
Jones, Richard	O-3228, O-4020, O-4050, P-3464
Jones, Richard Selwyn	<u>O-3187</u> , <u>P-2435</u>
Jones, Samantha	<u>O-2159</u> , <u>P-1252</u> , <u>P-2861</u>
Jones, Tyler R.	<u>O-0076</u>
Jones, Vivienne	<u>O-5072</u>
Jonuks, Tönno	P-1046
Joos, Fortunat	O-0017, O-2053
Joosten, Hans	O-2132
Jordan, Jason	P-1052
Jorge, Strelin	O-4019
Jose, Jithin	P-4025
Joshi, Priyanka	O-2156, <u>P-2432</u>
Joshi, Rajesh	P-4534
Jouffroy-Bapicot, Isabelle	<u>P-1258</u>
Jouvet, Guillaume	O-3229, P-1482
Jovane, Luigi	P-3234



Ju, Jianting	P-2402, P-2510
Judy, R.M., Allen	P-4442
Juggins, Steve	P-4441
Juliusson, Arni Daniel	<u>O-5068</u>
Jull, A. J. Timothy	P-1276
Jum, Chang-Pyo	P-3013
Jun, Chang-Pyo	<u>P-2474</u>
Jungclaus, Johann	O-1035, P-1432, <u>P-4434</u>
Junge, Andrea	<u>O-2122</u> , <u>P-1254</u>
Junginger, Annett	O-3031, O-4174, P-1208, P-3805, P-4273
Junno, Aripekka	P-4214
Juračić, Mladen	P-3017
Just, Janna	P-4272
Juutinen, Sari	P-3437
Jóźwik, Katarzyna	P-2627
Jõeleht, Argo	P-1046
Jõris, Olaf	P-1628, P-3876
Jørgensen, Tina	O-1105
K, Anupama	P-2219
Kaakinen, Anu	O-2166, O-3125
Kaboth-Bahr, Stefanie	O-0028, <u>O-1071</u> , O-1074
Kaczka, Ryszard J.	O-4208
Kadereit, Annette	P-3448, P-3885
Kadlec, Jaroslav	P-1630
Kadowaki, Seiji	<u>O-0051</u> , O-5093
Kageyama, Masa	O-0008, P-2222
KAGEYAMA, Masa	<u>P-4424</u>
Kahsay, Tsegay	P-4288
Kai, Jinlei	P-2415, P-2423
Kai, Ning	<u>O-2082</u>
Kaislo, Linnea	O-2144
Kaistrenko, Victor M.	P-1058
Kajanto, Karita	<u>P-4837</u>



INQUA 2019  
DUBLIN  
IRELAND

Kajita, Hiroto	P-1009
Kajukała, Katarzyna	P-2266, P-2866
Kakuhikire, Charles	<u>P-2242</u>
Kalaidjian, Ellis	O-3013
Kalanke, Julia	<u>P-3417</u>
Kale, Vishwas. S	P-3834
Kaliar, Anuska	O-2193
Kalicki, Tomasz	P-3873
Kallio, Hilikka	P-4831
Kalliokoski, Maarit	<u>O-3040</u> , <u>P-3623</u>
Kaltenrieder, Petra	P-1226
Kalteyer, Donna	P-1619
Kamenos, Nicholas	O-4033
Kameo, Koji	O-0118
Kaminski, Michael A.	P-4484
Kamleitner, Sarah	<u>P-2844</u>
Kanamatsu, Toshiya	O-3010
Kandeler, Ellen	P-4228
Kaneda, Heitaro	<u>P-4808</u>
Kanehara, Masaaki	P-4226
Kang, Ji-Hoon	<u>P-4813</u>
Kang, Shugang	P-2836
Kang, Sujin	O-4073
Kang, Wengang	P-2415, <u>P-2423</u>
Kangarli, Talat	P-3612
Kanik, Nadine	P-2224
Kano, Akihiro	O-0027
Kanzow, Torsten	P-4838
Kapffer, Jutta	P-1209
Kaplab, Jed O.	P-4298
Kaplan, Jed	O-0016, O-5008
Kaplan, Jed O.	O-1125
Kaplan, Michael	O-3046, <u>O-4019</u> , O-4164, P-2516, P-2518, P-4477



INQUA 2019  
DUBLIN  
IRELAND

Kaplan, Samantha	O-3048
Kappenberg, Arne	P-1814
Kapustina, Maria	O-5127
Karabanov, Alexandr	P-4641
Karampaglidis, Theodoros	P-1885
Karasiewicz, Tomasz	O-2211
Karbouch, Mostapha	O-3077
Karevskaya, Inessa	O-5020, P-1909
Karger, Cornelia	O-1045
Karhu, Juha A.	P-1229
Karius, Volker	P-3887
Karkani, Anna	P-3064
Karls, Jens	O-3016
Karmaza, Bronislavas	P-2912
Karmazienė, Danguolė	P-2912
Karpinski, Emil	<u>O-0041</u> , O-1025
Karpińska-Kończak, Monika	P-1256, P-2265, P-2266, P-2865, <u>P-2866</u> , <u>P-2867</u>
Karpukhina, Natalia	<u>O-5020</u> , <u>P-4845</u> , P-4852, P-4855, P-4860, P-4865
Karrow, Paul	P-2503
Karstens, Jens	P-1073
Karušs, Jānis	P-2906
Karvar, Gamze	O-1210
Karátson, Dávid	P-1614
Kase, Yoshihiro	P-3041
Kashima, Kaoru	P-1002
Kasper, Thomas	O-3061, P-4530
Kasprzak, Marek	P-3873
Kasvi, Elina	P-3825
Kataoka S., Kyoko	P-3041
Kataoka, Kyoko	<u>O-1116</u> , <u>P-3617</u>
Kataoka, Kyoko S.	P-4500
Katoh, Shigehiro	<u>P-3457</u>
Katsuki, Kota	<u>P-1018</u> , P-3008



INQUA 2019  
DUBLIN  
IRELAND

KATSUKI, Kota	P-1019
Katsuta, Nagayoshi	P-1277
kattel, Giri	P-2249
Katy, Flowers	P-4456
Katz, Oded	O-4035
Kaufman, Darrell	<u>P-1499</u> , P-3619, P-4619
Kaufman, Darrell S.	O-3131, O-5029, P-3625
Kaverin, Dmitry	P-2857
Kavkova, Radana	O-5109, P-3627
Kawahata, Hodaka	<u>O-1021</u> , <u>P-1009</u>
Kawajiri, Kiyokazu	P-3868
Kawakami, Gentaro	P-3041
Kawamata, Moto	<u>P-2444</u>
Kawamura, Kenji	O-1085, O-1088
Kazancı, Nizamettin	O-3129
Kazbaris, Mindaugas	P-1852
Kašpárek, Ladislav	O-3155
Kearney, Kevin	O-4030, O-5001
Kearney, Rebecca	<u>O-4091</u> , P-3433, <u>P-3620</u>
Kearsey, Tim	O-1224, <u>O-5049</u>
Keaveney, Evelyn M	P-4237
Keddadouche, Karim	O-1053, O-1151, P-2457, P-3409, P-4617
Keely, Brendan	O-0078
Keen-Zebert, Amanda	P-2838
Keenan-Jones, Duncan	<u>O-0075</u>
Kehew, Alan	P-1851
Kehl, Martin	O-3020, O-5024, P-2229, <u>P-3611</u>
Kellam, Cade	O-0062
Keller, Bill	O-5074
Keller, Elizabeth	P-2872
Keller, Jason	O-2055
Keller, Jörg	O-3036
Keller, Katherine	O-2201



Keller, Liz	P-4492
Kellerer-Pirklbauer, Andreas	P-2451
Kelley, Alice	<u>O-0068</u>
Kelley, Joseph	<u>O-2086</u> , O-2088, P-2004, P-2007
Kelley, Samuel	<u>O-2142</u>
Kelly, Josh	P-3413
Kelly, Joshua	<u>O-1158</u>
Kelly, Meredith	O-2098, O-4141
Kelly, Richard	O-4131
Kelsey, Alison	P-1421, <u>P-3471</u> , <u>P-4464</u>
Kelso, Clare	O-0088
Kelterbaum, Daniel	P-1006
Kemp, Andrew	P-4406
Kemp, Justine	O-2108, <u>O-3064</u> , P-3501
Kempf, Philipp	O-3087, O-3162, O-4121, P-3028, P-3045
Kende, julia	O-3208
Kender, Sev	O-1189
Kenis, Piotr	P-1631
Kennedy, Kirsten	O-1202
Kennet, Derek	O-3108
Kenny, Philip	P-2234
Kenzler, Michael	P-1879
Kerr, Phillip	<u>O-0033</u>
Kershaw, A. Peter	O-3067
Kershaw, Peter	<u>O-2110</u> , O-3059, <u>P-1421</u>
Kessedjian, Surin	P-1601
Kessler, Augustin	<u>O-2042</u>
Khan, Abul Amir	P-2893
Khan, Imran	<u>P-3859</u>
Khan, Nicole	O-0081, O-3213, O-4152, <u>P-1061</u> , P-1062, P-1065, <u>P-3019</u>
Khan, Nicole S.	O-1161
Kharchenko, Sergey	P-1911
Kharevich, Vladimir	O-0135



INQUA 2019  
DUBLIN  
IRELAND

Kharlamov, Andrey A.	P-1058
Khashevskaya, Daria	<u>P-2460</u>
Khashevskaya, Darisa	P-2456
Khatsenovich, Arina	O-0055, <u>O-0056</u> , O-5094
Khazaradze, Giorgi	O-4187
Khohlova, Olga	P-3882
Kholkina, Margarita	P-1032
Khormali, Farhad	P-3611
Khoshnavan, Homayoun	P-3608
Khristoforov, Ivan	P-3006
Kiahtipes, Christopher	<u>O-3097</u>
Kibii, Job	O-2099
Kida, Risako	O-0051
Kienast, Stephanie	P-2603
Kienel, Ulrike	O-5034
Kihno, Kersti	P-1838
Kijm, Niels	O-3159
Kilgore, Susan	O-0033
Kim, Chang-Hwan	P-2474
Kim, Dong-Eun	P-3026
Kim, Gil Young	<u>P-3830</u>
Kim, Gil-Young	P-2829, P-4525
Kim, Jangsuk	<u>O-4103</u>
Kim, Ji-Eun	<u>O-0024</u>
Kim, Jin Cheol	P-1002
Kim, Jin Cheul	<u>P-1606</u> , P-2003, P-2826, P-4016
Kim, Jung-Hyun	O-4073
Kim, KyeongJa	P-4810
Kim, Min-Cheol	P-4805
Kim, Soo Hyun	<u>O-0096</u>
Kim, Yongmi	P-1228, <u>P-4525</u>
Kim, Young-Seog	P-4815, P-4816
Kinder, Małgorzata	<u>O-3116</u> , <u>P-3421</u>



INQUA 2019  
DUBLIN  
IRELAND

Kindermann, Karin	O-3019
Kindler, Lutz	O-2100, P-1601
King, Amy	P-3469
King, Edward	O-1081
King, Georgina	<u>O-4036</u> , O-4118, P-4610
King, Georgina E.	O-4114
King, James	P-1435
Kingsbury, Melanie	O-2078
Kinnaird, Tim	O-4030
Kinnaird, Timothy	P-3038
Kino, Kanon	<u>P-2489</u>
Kinyanjui, Rahab	<u>O-4159</u>
Kioka, Arata	P-1464
Kipfstuhl, Sepp	O-4014
Kirby, Eric	<u>O-1066</u> , O-1067
Kirby, Matthew	O-3112
Kirillova, Valeriia	P-2246
Kirkbride, Martin	O-1143, <u>O-1145</u> , O-3201, <u>P-4827</u>
Kirkeng Jørgensen, Erlend	P-1621
Kirkitadze, Giorgi	P-1006
Kirkpatrick, Lynette	O-2089
Kirleis, Wiebke	<u>O-1095</u> , <u>P-2233</u>
Kirsimäe, Kalle	P-2469
Kisielinski, Caroline	<u>P-1211</u>
Kiss, Balázs	P-3625
Kissel, Catherine	P-4515
Kitaba, Ikuko	<u>O-2161</u> , P-2428, P-3457
Kitagawa, Hiroyuki	O-0051, P-1022, P-4268
Kitagawa, Junko	<u>P-2261</u>
Kittel, Piotr	P-2266
Kiura, Purity	O-4159
Kjaer, Kurt	O-0130
Kjeldsen, Kristian	O-0116



INQUA 2019  
DUBLIN  
IRELAND

Kjellman, Sofia Elisabeth	O-5016
Kjellström, Erik	O-5010
Kjær, Helle	<u>O-2015</u>
Kjær, Kurt	O-3197
Klaminder, Jonatan	O-1101, O-3102
Klamt, Anna-Marie	O-2210, <u>P-2269</u>
Klasen, Nicole	O-3019, O-3106, O-4177, P-1614, <u>P-1635</u> , P-2813
Klein, François	O-3185, P-4409, P-4441
Klein, Vincent	O-3109
Kleiner, Thomas	P-3482
Kleinhans, Maarten	O-1078, O-3159, P-3858
Klekovkina, Daria	O-4056, O-4119
Klemann, Volker	<u>P-3018</u>
Kletetschka, Gunther	<u>O-5109</u> , P-3627
Klinger, Yann	P-4821
Klockmann, Marlene	P-4416
Klokočník, Jaroslav	O-5109
Klooss, Stefanie	P-2233
Klooß, Stefanie	O-1095
Kluczynska, Grażyna	P-1035, P-2487
Kluge, Tobias	O-3067, P-2498
Kluzek, Eric	O-3227
Knauff, Jarrod	O-3048, P-1836
Kneer, Dominik	P-3014
Kneisel, Jutta	P-1249
Knies, Jochen	O-5131
Knight, Jasper	O-4032, <u>O-4192</u> , P-3501, <u>P-3502</u> , P-3503
Knight, Lauren	<u>O-3198</u> , <u>P-2436</u>
Knipping, Maria	P-4009
Knopf, Thomas	P-4228
Knorr, Gregor	P-1408, P-1419, P-1478
Knox, Kyle	O-0067, O-0152
Knudsen, Karen Luise	P-2490



INQUA 2019  
DUBLIN  
IRELAND

Knudsen, Karen-Luise	O-2185
Knudsen, Mads Faurshou	O-1054
Knul, Monika	O-2100, P-1287
Ko, Kyoungtae	<u>P-2826</u> , P-3027
Ko, kyoungtae	P-2830
Kobayashi, Takao	<u>P-4817</u>
Koc Tasgin, Calibe	O-1210
Kocsis, László	O-4070
Koerner, Kelsey	O-1184
Koester, Alexandria	P-1483, P-3485
Koester, Alexandria J.	P-3823
Koffman, Bess	<u>O-3046</u>
Koffman, Toby	O-3046
Kofler, Werner	P-2272, P-2273
Koinig, Karin	<u>O-2093</u>
Koinig, Karin A.	P-1464
Kojima, Hideaki	P-2261
Kolar, Jan	O-5009
Kolařík, Petr	P-1630
Kolb, Thomas	O-3032, O-3223, <u>P-2887</u> , <u>P-4612</u>
Koll, Rebecca	O-3214
Kolobova, Ksenia	P-2239
Kolobova, Kseniya	P-2231
Kolska Horwitz, Liora	O-0050
Koltai, Gabriella	<u>P-4457</u>
Komar, Maryna	P-2885
Komatsu, Goro	P-2419
Komoo, Ibrahim	P-1057
Kondo, Hisao	O-4045
Kondo, Reisuke	P-4629
Kondo, Yasuhisa	P-4268
Kong, Gee Soo	P-3830
Kong, Lingyang	<u>P-4221</u>



INQUA 2019  
DUBLIN  
IRELAND

Kong, Ting	<u>O-3209</u>
Konstantinov, Evgeny	O-5020, P-3814, P-4845, <u>P-4852</u> , <u>P-4860</u>
Konstantinov, Mikhail V.	P-4263
Kont, Are	O-1080, P-1007
Kopf, Achim	O-3085
Kopp, Robert	O-3213, O-4152, P-1061
Koprowski, Marcin	P-4537
Korhola, Atte	<u>O-2187</u> , P-3437
Koriche, Sifan	O-3033
Koriche, Sifan A.	<u>O-3206</u>
Korkala, Heta-Maria	O-2144
Korkin, Sergey	O-5110, P-4850
Korkina, Elena	<u>P-4850</u>
Korpanty, Chelsea	P-2246
Korpela, Mikko	P-3440
Korponai, János	O-0122
Korsakova, Olga	<u>P-4635</u>
Korte, David	O-0048
Korte, Laura	O-0092
Kosonen, Emilia	<u>P-4831</u>
Kostecki, Robert	O-1020
Kostelecký, Jan	O-5109
Koster, Benjamin	P-3039
Koster, Willem	O-1213, <u>O-4060</u>
Koster, Wilmer	P-4287
Kostopoulos, Dimitris S.	O-2164
Kothieringer, Katja	P-1908
Kotilainen, Aarno	O-5127
Kotlia, B.S.	P-1459
Kotowski, Adam	<u>P-2205</u> , <u>P-2422</u> , P-4640
Kotyza, Oldřich	O-0085
Kouli, Katerina	O-3150, P-2477
Kousis, Ilias	P-2477



INQUA 2019  
DUBLIN  
IRELAND

Koutsodendris, Andreas	P-2477
Kovaleva, Galina	O-3055
Kovaleva, Olga	P-2009
Kovarik, Johanna	O-2074
Kovačević, Nikola	O-3022
Kovács, János	<u>O-4070</u> , P-2609
Kovács, József	P-1870, P-2614
Kowarik, Kerstin	P-2272, P-2273
Kozhurin, Andrey	P-3037
Kozłowski, Janusz Krzysztof	P-3873
Kołaczek, Piotr	O-2140, P-1256, P-1806, <u>P-2265</u> , <u>P-2266</u> , P-2865, P-2866, P-2867
Kończak, Magdalena	P-2407
Kraas, Frauke	O-3166
Krabbendam, Maarten	O-4130
Krahn, Kim	O-1228, O-3106
Krahn, Kim J.	P-3443
Krahn, Kim Jasmin	<u>P-4639</u>
Krakovsky, Masha	O-2100
Kraml, Michael	O-3036
Krapp, Mario	O-1237
Krause, David	O-5114
Krause, Samantha	<u>P-3237</u>
Krause, Teresa	O-2184
Krawczyk, Marcin	O-1190, O-1196, P-1625, <u>P-1632</u> , <u>P-1633</u> , P-1634, P-1636
Krawiec, Arkadiusz	O-0049
Krebs-Kanzow, Uta	P-3482
Kreemer, Corné	O-4151
Krejčí, Jakub	O-3155
Krek, Alexander	O-5127
Kremer, Katrina	O-3085, O-5073, P-3042
Krentscher, Christiane	O-5099, P-3209
Kreutzer, Sebastian	P-3885



INQUA 2019  
DUBLIN  
IRELAND

Kriiska, Aivar	P-1046
Krishnan, K	O-2068
Krishnan, Sivakumar	P-1213, P-1904
Krivosnogov, Sergey	O-2003
Krklec, Kristina	O-2075, <u>P-2818</u> , <u>P-2819</u>
Kromer, Bernd	O-3190, O-3194, P-3613
Krueger, Johanna	P-1208
Krumov, Ivaylo	O-0052
Krus, Jonas	P-2815
Kruse, Stefan	O-1028
Krzywińska, Jarmilla	P-3829
Krzyszowski, Dariusz	O-1152
Krzywicki, Tomasz	P-4641
Krämer, Alexander	O-4048
Kröhling, Daniela	O-3005
Kröhling, Daniela M.	<u>O-3126</u> , <u>P-4232</u>
Kröpelin, Stefan	O-3016
Krüger, Kirstin	P-4433, P-4437
Krüger, Susanne	P-1246
Kubiak-Martens, Lucy	O-1020
Kublitsky, Iurii	<u>P-4028</u>
Kubota, Yoshimi	O-0118, O-2115, P-2479
Kuch, Melanie	O-1025
Kuehn, Stephen	P-1612, <u>P-1619</u>
Kuhn, Steven	O-0138
Kuhnert, Henning	O-4069, O-4071, P-4508
Kuhry, Peter	P-2854
Kuijpers, Antoon	O-1233, P-2490, P-4441
Kukowski, Nina	P-3624
Kulikova, Tatiana	<u>P-3888</u>
Kulkarni, Charuta	<u>O-1121</u>
Kumar, Naveen	P-4025
Kumar, Anil	O-4053



INQUA 2019  
DUBLIN  
IRELAND

Kumar, Pankaj	P-4290
kumar, Parvendra	<u>P-1896</u>
Kumar, Parvendra	O-1013
Kumar, Raj	<u>O-3123</u>
Kumaresan, Anbarasu	O-4179, P-1213
Kumerasan, Anbarasu	P-1904
Kummer, Sabine	O-4184
Kunes, Petr	O-4062
Kuneš, Petr	O-2206, O-2207, P-3451, P-4299, P-4420
Kunikita, Dai	O-4026
Kuosmanen, Niina	<u>O-2207</u> , O-4062
Kupriaynov, Dmitry	<u>P-1825</u>
Kupriyanov, Dmitry	P-1803, <u>P-1812</u> , P-2850
Kupryjanowicz, Mirosława	O-2211, P-2401, P-2848, <u>P-3405</u>
Kurbanov, Redzhep	O-0098, O-1191, <u>O-3051</u> , O-3053, O-3054, O-3056, P-1638, P-1639, P-2231, <u>P-2239</u> , P-2460, P-2620, P-3608, P- 3609, P-3610, P-4234, P-4865
Kurbanov, Roger	P-2456
Kurbanova, Fatima	<u>P-3882</u>
Kurbatov, Andrei	P-1612
Kurina, Irina	P-1257
Kurjanski, Bartosz	<u>O-2143</u> , <u>P-1846</u>
Kurozumi, Taiji	O-0051
Kurths, Juergen	P-2473, P-2475
Kusilman, Maria	P-2850
Kust, Pavel	<u>P-1865</u>
Kutterolf, Steffen	O-3221, P-3624
Kutty, Sujatha	O-1023
Kuznetsov, Eduard	<u>P-4417</u>
Kuzucuoglu, Catherine	<u>O-1039</u>
Kuzucuoğlu, Catherine	<u>P-3835</u>
Kvavadze, Eliso	<u>O-1094</u> , O-2162
Kvisvik, Bjørn	P-3484



INQUA 2019  
DUBLIN  
IRELAND

Kwiecien, Ola	<u>O-4078</u>
Kyalo-Omamo, Margaret	P-1208
Kyaw, Kyaw	O-3166
Kyazike, Elizabeth	<u>O-2172</u> , <u>P-4265</u>
Kylander, M.E.	O-2128
Kylander, Malin	O-2094, O-2198, O-4055, P-2217, P-2873
Kylander, Malin E	O-2131
Kylander, Malin E.	<u>O-1084</u> , <u>O-2127</u>
Kyrikou, Styliani	O-3150
Kázmér, Miklos	P-3010
Kähkölä, Noora	P-4831
Köhler, Anne	<u>O-2024</u> , O-3073
Köhler, Peter	O-3192, <u>P-1478</u>
Költringer, Chiara	<u>O-0098</u> , O-1191, P-1425, P-1639
Köse, Oğuzhan	P-1889, <u>P-2447</u>
Kühn, Peter	<u>P-3884</u> , P-4228
Küppers, Ulrich	P-3628
Küssner, Kevin	P-2521
Kłapyta, Piotr	P-2448
Křížek, Marek	O-5114
L. Filipsson, Helena	P-1045
La Selle, Seanpaul	O-3088
Laabs, Benjamin	O-2021
Laag, Christian	<u>P-1636</u>
Laaps, Julian	O-5009
Labaj, Andrew	O-5074
Lacey, Jack	O-2109, <u>P-2221</u> , <u>P-4246</u>
Lacey, Jack H.	O-3150, O-5030
Lacourse, T.	P-3203
Lacquement, Frédéric	P-1833
Ladd, Nemiah	O-5103, P-1475, P-3209
Ladd, Nemiah S.	O-5099
Ladstätter, Sabine	P-4009



Laepple, Thomas	O-2181, P-2470
Laermanns, Hannes	<u>P-1006</u> , P-3053, <u>P-4009</u>
Laeuchli, Benjamin	<u>O-1072</u> , <u>P-3414</u>
Lagroix, France	P-1409
Lahaye, Christelle	O-1018
Lahijani, Hamid A.K.	<u>P-3403</u>
Lahuerta Pineiro, Nuria	<u>O-4110</u>
Lai, Hai-Cheng	P-4608
Laird, Kathleen	O-2111
Lajeunesse, Patrick	O-5132
Lakeman, Thomas	O-1081, P-3824
Lal, Ravish	O-2070, <u>P-1288</u> , <u>P-2893</u>
Lam, Nina S.N.	O-1083
Lamb, Angela	O-0037
LAMB, Henry	P-4448
Lamb, Henry	O-1036, O-1140, O-1160, O-2161, O-3021, O-3193, <u>O-4174</u> , P-2421, P-4272, P-4505
Lamb, Henry E.	O-3031
Lamb, Henry F.	O-0150, O-1022, O-3096, O-4173, P-2253, P-3805, P-4273
Lamb, Rachel	O-5058
Lambert, Fabrice	O-0012, P-1433, P-3473
Lambiel, Christophe	P-4829
Lamentowicz, Mariusz	O-2140, O-2202, P-1256, P-1806, P-1816, P-2265, P-2266, P-2865, P-2866, P-2867
Lammers, Youri	O-1027, <u>O-1100</u> , O-1105, O-3025, P-1201, P-1209
Lamothe, Michel	<u>O-0031</u> , O-4005, P-2820, <u>P-4602</u> , <u>P-4625</u> , P-4844
Lamoureux, Scott F.	P-3432
Lamsters, Kristaps	P-2827, <u>P-2906</u>
Lamy, Frank	O-4163, P-2521
Lancaster, Nicholas	<u>O-2000</u> , <u>P-2838</u>
Lancelotti, Carla	O-5009
Land, Alexander	P-3613
Landais, Amaelle	<u>O-1000</u> , O-2039, O-4014, P-3468, P-4515



Landais, Amaëlle	O-1193
Landaverry, Brandon	<u>P-1436</u>
Landgraf, Jessica	P-3022
Landvik, Jon	O-0115
Lane, Chad	P-3035
Lane, Christine	<u>O-1036</u> , O-1037, O-1234, O-2109, O-3037, O-4087, O-4174, P-2252, <u>P-3433</u> , P-4272, P-4273, P-4458
Lane, Christine S.	O-3114, O-4173, P-3805, P-4444
Lane, Tim	O-4133
Lane, Timothy	O-5085, <u>P-2458</u> , <u>P-3484</u>
Lang, Andreas	O-3003
Lang, Frabziska	P-3039
Lang, Jörg	O-4189, P-3825, P-4851
Langan, Carolin	P-3448
Langdon, Catherine	O-3063
Langdon, Pete	O-3100, O-5101, P-4466
Langdon, Peter	O-1075, O-1104, O-2057, <u>O-3063</u> , O-3099, O-3101, O-3117, P-2256, P-4467, P-4468, <u>P-4469</u>
Lange, Carina B.	P-3838
Langford, Cat	<u>P-4275</u>
Langford, Harold	P-4601, <u>P-4616</u> , <u>P-4861</u>
Langohr, Roger	P-4227
Lankarani, Mohammad	O-3209, P-3404
Lantzsch, Hendrik	P-1454
Lapazaran, Javier	P-2841
Lappe, Ronja	O-4109
Larcombe, Piers	O-2087, P-3043
Larick, Roy	P-1610
Larin, Sergei	P-2426, P-2874
LARIN, SERGEI	<u>P-1413</u> , <u>P-1414</u>
Larina, Natalia	<u>P-2426</u> , <u>P-2874</u>
LARINA, NATALIA	P-1413, P-1414
Lario, Javier	P-3497, P-4531



INQUA 2019  
DUBLIN  
IRELAND

Larkin, Zacchary	P-4485
Larrasoña Gorosquieta, Juan	O-4199
Larsen, Aud	P-1442
Larsen, Darren	O-0115, O-1064, O-4047
Larsen, Eiliv	P-3824
Larsen, Nicolaj Krog	O-3197
Larson, Phil	O-3048
Larson, Rebekka	O-1002
Larsson, Simon	<u>P-4446</u>
Larter, Robert	O-4127
Lasserre, Marina	O-4056
Last, Jonathan	P-1285, P-1287
Latinovic, Milena	P-3018
Latorre, Claudio	O-4003, <u>O-4004</u> , O-4155, O-4157, O-4158
Lau, A Y Annie	<u>O-4111</u>
Lau, A.Y.Annie	<u>P-3044</u>
Lauer, Daniel	O-2135
Lauer, Tobias	O-2100, P-1630, P-2615, P-3873, P-3874, P-4602
lauer, Tobias	P-1601
Laug, Andreas	<u>O-2155</u> , O-4074, <u>P-2510</u>
LAUKHIN, STANISLAV	P-1413, P-1414
Laurie, Nina	P-1265
Lauriol, Bernard	O-2117
Lauterbach, Stefan	O-2155, P-1457, P-1458, P-3417
Lavery, Paul S	P-2010
Lavrushin, Vasiliy	O-3205
Lavrushin, Yuri A.	O-3204
Lavrushin, Yuriy	<u>O-3205</u>
Law, Antonia	<u>P-2258</u> , <u>P-4866</u>
Lawson, Ian	O-3037, P-1265, P-2252, P-4233
Layzell, Anthony	<u>O-3217</u> , <u>P-2901</u>
Lazar, Jean	O-2158
Lazauskienė, Jurga	P-2825



Lazăr, Cătălin	O-4108, P-4260
Le Corre, Mael	<u>O-0142</u> , P-3214
Le Duc, Cynthia	O-1187
Le Gall, Bernard	P-4011
Le Heron, Daniel	O-0129, <u>O-2146</u> , P-2909, <u>P-2911</u>
Le Roux, Gaël	O-0094, P-1433
le Roux, Petrus	O-0143
Le Roy, Melaine	P-2451, P-2453, <u>P-2455</u> , <u>P-4482</u>
Lea, James	O-4033
LEANNI, Laetitia	O-2016
Lear, Caroline	O-1189
Leavitt, Peter	<u>O-0104</u> , P-2010
Lebamba, Judicaël	O-5083
Lebedeva, Marina	P-1639, P-1865
Lebreiro, Susana M.	O-2118, O-3071
Lebreton, Vincent	O-3077, P-2840
Lecavalier, Benoit	O-3227
Lecavalier, Benoit S.	P-1059
Ledger, Paul M	O-3027
Ledru, Marie-Pierre	O-3060, P-2425, P-3225, P-3462
Lee, Craig	<u>O-0065</u> , P-2238
Lee, Ethan	<u>O-1144</u>
Lee, Eunmi	<u>P-1228</u> , P-4525
Lee, Gwang Soo	P-3830
Lee, Gwang-Ryul	P-3013
Lee, Gwang-Soo	P-2003, P-2829
Lee, Hoil	<u>P-1223</u> , P-2826, P-3008, P-3013
Lee, Hong-Jin	P-4812
Lee, James	O-0109
Lee, Jin-Young	P-1223, <u>P-3008</u>
Lee, Jon	P-4833
Lee, Jonathan	<u>O-1224</u> , O-5049
Lee, Kyung Eun	<u>O-2115</u>



INQUA 2019  
DUBLIN  
IRELAND

Lee, Lindsay	O-4072
Lee, Min Kyung	P-1446
Lee, Sang Deuk	P-1223, P-3008
Lee, Seong-Joo	P-2474
Lee, Seung Ryeol	P-3027
Lee, Seung Ryol	P-4817
Lee, Sun-Seon	O-0024
Lee, Tae-Ho	P-4816
Lee, Victoria	P-1403
Lee, Yong Il	P-1446
Lees, Brian	P-1012
Leet, Kennie	<u>P-4278</u>
Lefebvre-Fortier, Claudie	<u>P-1832</u>
Lefort, Jean-pierre	<u>P-4632</u>
Lege, Thomas	P-3863
Leger, Tancrede	<u>P-4470</u>
LeGrande, Allegra	<u>O-5067</u>
Lehman, Scott	O-0115
Lehmann, Jonas	O-4078
Lehmann, Sophie	P-2223
Lehmkuhl, Frank	<u>O-1192</u> , O-4114, P-1614, P-1627, P-1628, P-1635, P-2813, P-4445
Lehndorff, Eva	O-2153, P-1814, P-4228
Lehsten, Veiko	O-1125
Lehtosalo, Tuuli	P-3437
Lei, Guoliang	<u>P-2502</u>
Lei, Shao	O-3103
Leicher, Niklas	O-1163, O-3150
Leira, Manel	O-4107, P-1495, <u>P-4024</u> , P-4256
Leiva-Dueñas, Carmen	<u>P-2010</u> , P-2012
Lejju, Julius	O-2172
Lelandais, Thomas	P-4839
Lemanik, Anna	P-3873



Lemke-Jene, Lester	P-1408
Lemma, Bruk	O-3021, <u>P-3207</u> , P-4505
LEMONNIER, Eva	P-4229
Lemonnier, Kévin	P-2267
Lempe, Bernhard	O-1154
Lenaerts, Jan	O-3185
Leng, Melanie	O-1189, O-1205, O-2109, O-3098, O-3184, O-4094, O-4174, O-5032, O-5101, P-1407, P-1513, P-2221, P-2416, P- 4246, P-4251, <u>P-4272</u>
Leng, Melanie J.	O-3150, O-5029, O-5030
Lennox, Sandra	<u>O-4016</u>
Lenton, Timothy M.	O-2058
Leonard, Eric	<u>O-2021</u>
Leoni, Gabriele	P-4820
leprieur, fabien	<u>P-3229</u>
Leroy, Suzanne	O-2005, <u>O-3208</u> , <u>P-3401</u>
Leroy, Suzanne A.G.	O-3204
Leshtakov, Krassimir	P-1261
Leskovar, Jutta	P-2273
Lespez, Laurent	O-4056, P-1261
Lesur, Joséphine	O-2102
Leth, Jørgen	P-1071
Lethbridge, Emily	P-3861
Leunda, Maria	O-1139, <u>P-1226</u> , <u>P-1810</u> , P-1872, P-4284
Leunda, María	P-1266, P-2841
Leuzinger, Urs	P-2270, P-2273
Levasseur, Guillaume	P-4421
Levchenko, Vlad	P-1811
Levesque, Marc Antoine	P-1882
Levin, Naomi	P-1878
Levy, Yuval	P-4821
Lewin, Shaun	O-5009
Lewington, Emma L.M.	<u>O-0043</u>



Lewis, Jason. L.	O-4171
Lewis, Levi S.	O-0147
Lewis, Richard	O-5032
Lewis, Stephen R.	O-0045, O-5000, P-1843
Lewis, Tara	O-5032
Leydet, Michelle	P-4420
Lezzerini, Marco	P-3810
Li, Baosheng	P-1498, P-2836
Li, Beibei	O-4080
Li, Chang'an	P-3416
Li, Chunhai	O-1033, P-2206
Li, Chuxian	<u>O-0094</u>
Li, Chuxian	P-1431
Li, Dewen	O-4049
Li, Dong	O-4011, P-1503
Li, Feng	<u>O-0138</u> , P-3205
Li, Fengjiang	P-1222, <u>P-2215</u> , P-2409, P-2611, P-3878
Li, Furong	O-5008, <u>O-5012</u> , O-5013, P-4296
Li, Gaojun	P-1515
Li, Hong-Chun	O-1074, <u>O-3219</u>
Li, Hongwei	P-2834, <u>P-3478</u>
Li, Jianyong	O-1034
Li, Jiazhu	<u>P-4502</u>
Li, Jiazhu	O-5050
Li, Jie	<u>P-2405</u> , P-2408
Li, Jingjing	P-2405, <u>P-2408</u>
Li, Kang	P-4811
Li, Kangkang	<u>P-2228</u>
Li, Laurent	P-2481
Li, Melody	P-2221, P-4246
Li, Ming	O-4049
Li, Mingkun	P-1005
Li, Mingqi	P-1422, <u>P-4538</u>



Li, Nan	P-3813
Li, Pei	P-4526
Li, Qi	<u>P-1445</u>
Li, Qin	P-1497, <u>P-4422</u> , P-4504
Li, Quan	P-1801
Li, Rui	P-2464
Li, Shaoheng	<u>P-2464</u>
Li, Shihu	P-4522, P-4526
Li, Shun	P-3406
Li, Tao	O-4037
Li, Wen-jia	O-3158
Li, Xianglei	P-1418, P-2480
Li, Xiangzhong	P-2500
LI, XIAOJUN	<u>P-3811</u>
Li, Xiaoqiang	<u>O-1167</u> , P-1808, P-3205, P-4223
Li, Xun	P-4499
Li, Yameng	P-2402
Li, Yan	P-2886, <u>P-4605</u>
Li, Yi-Yuan	P-4608
Li, Yiyin	<u>P-1805</u>
Li, Yue	O-3044, <u>P-2508</u> , P-4443
Li, Yuecong	<u>O-4065</u> , <u>P-4279</u> , P-4292
Li, Yuetian	O-0119
LI, Zhizhong	P-4613
Lian, Olav	P-2617
Liang, Lianji	P-1424
Liang, Mao-Chang	P-1514
Liang, Peng	P-2834, P-3478
Liang, Zuobing	P-2464
Liao, Alice Chien-Yi	P-1462
Liao, Chien Yi	<u>P-1466</u>
Licciardi, Joseph	<u>O-1064</u> , O-4047
Lidong, ZHU	<u>P-4021</u> , <u>P-4230</u>



Liedtke, Mercedes	<u>P-1044</u> , <u>P-2506</u>
Lienert, Sebastian	O-0017
Lifton, Nathaniel A.	P-1483, P-3485
Lightowler, Amy	O-0132
Liiva, Arvi	P-1838
Lim, Aaron	O-0133
Lim, Enyu Joeline	O-5076
Lim, Jaesoo	P-1223, P-1228, P-3008
Lim, Joeline	O-1023
Lima, Mauricio	<u>O-4003</u> , O-4004, O-4157
Limoges, Audrey	<u>O-1184</u> , O-1185
LIMONDIN LOZOUET, Nicole	P-1874
Limondin-Lozouet, Nicole	<u>O-1208</u> , P-1868
LIMONDIN-LOZOUET, Nicole	P-4229
Limondon-Lozouet, Nicole	O-5040
Limonta, Mara	P-2429
Lin, Di-Yi	P-1834
Lin, Qi	P-2249
Lin, Sam	O-0103, O-0139
Lin, Tsai-Wen	P-1462
Lin, Tsai-wen	<u>O-1074</u>
Lin, Weiwei	P-3881
Lin, Wuhui	O-3168, <u>O-4180</u> , <u>P-4603</u>
Lin, Xiao	P-2402
Lin, Yating	P-4504
Linch, Lorna	O-1056, P-1883
Linch, Lorna D.	<u>O-5116</u> , <u>P-1864</u>
Lincoln, Paul	O-1123, <u>O-4195</u> , <u>P-2424</u> , P-4456
Linda, Nothdurft	O-4093
Lindauer, Susanne	P-1628, P-3022, P-3613
Lindblom, Sofia	O-1233
Lindemann, Christin	<u>P-4449</u>
Linderholm, Hans	P-4423



Lindhorst, Sebastian	P-3011
Lindqvist, Mimmi A.	O-1052
Lindqvist, Teemu	P-4831
Lindsey, Emily	P-1227, P-3218
Lindström, Johan	O-5010
Ling, Yating	P-1497
LING, Zhiyong	P-4613
Linge, Henriette	<u>O-1054</u>
Lingner, Débora	P-3226
Linzen, Sven	P-1835, P-3208
Lipar, Matej	<u>P-3487</u>
Lipenkov, Volodya	O-5064
Lipka, Ewelina	<u>P-1867</u>
Lipscomb, William	O-3227
Lira, Maria-Paz	P-4479
Lirer, Fabrizio	<u>O-3153</u> , O-3154, P-1013, P-3494, P-3495
Lis, Allaart	<u>O-5016</u>
Lisco, Stefania	P-3023
Lisiecki, Lorraine	O-0132
Lisova, Alexandra	P-1911
Lister, Adrian	<u>O-0036</u> , O-4115, P-2810
Lister, David	P-3464
Lisztes-Szabó, Zsuzsa	<u>P-3451</u>
Lisá, Lenke	O-2218
Lisé-Pronovost, Agathe	O-4097, P-4494
Litt, Thomas	O-4197, O-4200, P-1814, P-3422, P-4621
Littell, Virginia	P-2876
Little, Amanda	O-5075
Liu, Bin	<u>P-4430</u>
Liu, Dawei	<u>O-1077</u> , P-3838, <u>P-3847</u>
Liu, Fenghao	P-3427
Liu, Guohui	O-3168
Liu, Haijiao	<u>P-1424</u>



Liu, Jian	O-5051, O-5070, P-4431
Liu, Jianbao	P-3479
Liu, Jiaqi	P-1611, P-2411, P-3408, P-3828
Liu, Jinrui	P-2821
Liu, Kam-biu	<u>O-1083</u> , P-4026
liu, lian	<u>P-1801</u>
Liu, Linjing	<u>P-3416</u>
Liu, Minxuan	P-3201
Liu, Ping	<u>P-4522</u>
Liu, Qiang	P-2245, P-2411, P-3408
Liu, Shih-Hung	<u>P-2886</u>
Liu, Sisi	<u>O-1028</u>
Liu, Weiguo	O-2160, P-1498, P-2500
Liu, Xiaohong	P-1422
Liu, Xiaokang	<u>O-2047</u>
Liu, Xingming	O-4180
Liu, Xingxing	P-1424, <u>P-1444</u> , P-3482
LIU, Xiuming	P-4613
Liu, Yanguang	O-1188
Liu, Yeyi	O-2079
Liu, Yongqing	P-2911
Liu, Zhengyu	O-0010, O-5070
Liu, Zijun	O-5006
Livingstone, Stephen	O-0046, O-0047, O-0131, O-1055, O-1143, O-3230, O-5118, O-5128, <u>P-1849</u> , P-1884
Livingstone, Stephen J.	O-0043, O-5063, O-5131, P-1900
Livio, Franz	O-4044, P-4806
Ljung, Karl	O-5071
Ljung, Karl	P-1026, P-1030, P-4438
Llamas, Bastien	O-0103
Llana-Fúnez, Sergio	O-1151
Llanes, Francesca	P-3049
Llano, Carina	O-0143



Lloren, Ronald	<u>O-5103</u> , <u>P-1475</u>
Lloyd, Jeremy	O-0132
Lloyd, Jerry	O-5061
Lloyd, Jerry M.	P-4838
Lo, Li	O-0027, P-3215
Loader, N.J.	<u>O-4042</u>
Loader, Neil	O-4205, O-4210
Loader, Neil.J	P-1505
Lobacheva, Daria	<u>P-3603</u>
LOCHT, Jean-Luc	P-1874
Lockhart, Edward	<u>O-5060</u> , O-5128
Loewer, Markus	O-4189, P-4851
Loftus, Emma	P-2235
Lofverstrom, Marcus	O-3227
Logvina, Elizaveta	O-5019
Lohila, Annalea	P-2857
Lohmann, Gerrit	O-1235, O-3192, P-1408, P-1419, P-1449, P-3482
Lohne, Øystein Strand	O-1130
Loisel, Julie	<u>O-2050</u>
Lojen, Sonja	P-2818
Lomax, Johanna	P-1409
Lombao, Diego	O-5025
Lombardo, Umberto	P-3462
Lomoschitz, Alejandro	P-2605
Long, Antony	O-2088, P-1056, P-2004, P-2007, P-2257
Long, Hao	P-3205, P-4605
Long, Kelsie	O-3137
Long, Mike	O-2013
Long, Tengwen	<u>O-1175</u>
Longman, Jack	O-2203
Longmore, Maureen	O-3064
Longstaffe, Fred	O-5006, P-2503
Lončar, Nina	O-3075



Lončarić, Robert	O-3075, <u>P-2803</u>
Loo, Amelia	P-1615
Looby, Elizabeth	P-4288
Loope, Henry	<u>P-2454</u>
Lopes, Ana Isabel	O-4069
Lopes, Cristina	<u>P-1416</u>
Lopes, Fernando C.	P-2883
Lopes, Vera	P-4022, P-4024
Lorberau, Kelsey	O-1027, O-1105, <u>O-2033</u>
Lorberau, Kelsey E.	P-1209
Lorenz, Stephan	P-4434
Lorenzen, Eline D.	O-1185
Lorenzini, Luca	P-4013
Lorenzo, Florencia	P-2832
Lorig, Fabian	O-4135
Lorrey, Andrew	O-0090, O-3145, O-4020, <u>O-4204</u> , P-3466, <u>P-4492</u> , P-4493
Lorscheid, Thomas	P-1053
Loskutov, Evgeny	P-2473, P-2475
Lougheed, Bryan	<u>O-4013</u> , P-2519, P-4413, <u>P-4630</u>
Loughlin, Nicholas	<u>O-3134</u> , O-3173, <u>P-4209</u>
Loutre, Marie-France	P-2470
Lovell, Harold	O-0047, O-3198, P-2436, P-4471
Lowe, David	O-3145, P-4492
Lowe, David J.	<u>O-1117</u> , <u>P-4604</u>
Lowe, John	O-2092, O-3041, P-3626, P-4453
Lowell, Thomas	O-3199, P-2454, P-4853
Lowenstein, Tim	O-3110, P-4278
Lozano-Fernández, Iván	P-2204
LOZANO-LUZ, ROCIO	O-2118
Lozano-Luz, Rocío	O-3071
Lozhkin, Anatoly	P-1273
Lozić, Sanja	P-2818
Lu, Cheng-Hao	<u>P-1834</u>



INQUA 2019  
DUBLIN  
IRELAND

Lu, Hao	<u>O-0022</u>
Lu, Houyuan	O-2079, O-3103, O-3104, P-2215, P-2409, P-3201, <u>P-3202</u> , P-4225
Lu, Huayu	<u>O-1229</u> , O-2149, O-4176, P-2206, P-3808, P-3812
Lu, Ruijie	O-2047, <u>P-3474</u>
Lu, Shawn	<u>O-0107</u>
Lu, Shenggao	<u>P-3877</u>
Lu, Zhengyao	O-5010
Lubritto, Carmine	O-3153
Luca, Bellucci	P-2208
Lucero, Gustavo	O-0143
Luciane, Fontana	P-2414
Ludikova, Anna	P-4028
Ludlow, Francis	O-5066, <u>P-4429</u>
Ludlow, Francis M.	P-2505
Ludwig, Patrick	<u>O-0009</u> , <u>P-2229</u> , P-4298, P-4415
Ludwikowska-Kędzia, Małgorzata	O-1152
Luelmo-Lautenschlaeger, Reyes	<u>P-1817</u> , P-4019
Luengo, Mariel Samanta	<u>P-2211</u> , <u>P-4023</u>
Luetscher, Marc	O-4146, <u>O-4216</u> , P-2905, P-2908
Lugli, Federico	O-3224
Lugovoy, Nikolay	P-1911, <u>P-3007</u>
Luis M., García Montes	P-3063
Lukas, Sven	<u>O-1132</u> , O-3200, P-3820, P-4857
Lulewicz, Isabelle	P-1251
Lund, Steve	O-3110
Lundeen, Zachary	O-3214
Lunina, Oksana	<u>P-2823</u>
LUNINA, OKSANA	<u>O-4049</u>
Luo, Yan	P-1610
Luo, Yunli	P-1497, P-4422
Luostarinen, Tiia	<u>P-1440</u>
Luoto, Miska	P-3440



Luoto, Tomi	O-0034, O-0125
Luoto, Tomi P.	O-4074
Lupascu, Naliana	O-3127
Lupien, Rachel	O-4169, O-4174
Luzuriaga, Carmen X.	O-3139
Luzzadder-Beach, Sheryl	O-3138, <u>O-3215</u> , O-4052, P-3237
Luzón, Carmen	O-2166
Lv, Xinmiao	O-2001
Lyon, Becky	P-1210
Lyons, Kieran	P-2497
Lyons, S. Kathleen	O-3176
Lyons, Susan	O-2025
Lyu, Anqi	<u>P-2478</u> , P-2485
Lyv, Yanwu	O-4049
Lähteenoja, Outi	O-2055
Léanni, Laetitia	P-2443
Léanni, Laëtitia	O-1151, P-2457
Lécuyer, Christophe	P-1869
Lévesque, Marc-Antoine	O-5087
Lézine, Anne-Marie	O-5083, P-2222, <u>P-2267</u>
Lóki, József	P-2616
López Correa, Matthias	O-1154
López Costas, Olalla	O-2198
López Recio, Mario	P-2889
López, Gloria I.	<u>O-3014</u> , <u>P-3062</u>
López, J. Andrés	P-1210
López, José Manuel	P-1259
López, Raquel	P-1266
López, Robert	O-4187
López-Costas, Olalla	<u>P-2873</u>
López-Martínez, Jerónimo	P-2841
López-Moreno, Juan Ignacio	P-2841
López-Romero, Elías	P-1016



López-Sáez, José Antonio	P-1817, <u>P-4019</u>
López, José Manuel	O-3175
Löhr, Stefan	O-3067
Löwemark, Ludvig	O-0025, O-0107, O-1071, O-1074, O-4013, <u>P-1462</u> , P-1466, <u>P-1514</u>
Løseth, Helge	O-0007
Løvschal, Mette	O-1173
Lücke, Andreas	O-4018
Lückge, Andreas	P-1511
Lüthgens, Christopher	O-5038, O-5112, P-1905, <u>P-2450</u> , P-2452, P-2882, P-4479
M 152 cruise team, RV Meteor	P-3047
M. Dokken, Trond	P-4459
M.A. Heyvaert, Vanessa	O-3087, O-3162
M.P. Berben, Sarah	<u>P-4459</u>
Ma, Chunmei	O-5082
Ma, Hao	P-4603
MA, JIAXIN	P-3811
Ma, Le	O-4011, P-1418
Ma, Qingfeng	O-2001, P-2402
Ma, Ting	<u>O-1124</u> , <u>O-1171</u> , P-2852
Ma, Zhibang	<u>O-2178</u> , P-2499
Ma, Zhikun	O-4027
Maas, David	<u>O-1226</u> , O-4074, O-4087
Maas, David J.	P-2271
Maas, Gilbert	P-1828
Macario-González, Laura	O-3221
MacDonald, Alan	O-3202
MacDonald, Dana	P-1037
MacDonald, Glen	P-1227, P-4010
Macdonald, Neil	O-0091, P-3429
MacGregor, Claire	<u>P-4486</u>
Machado, M. José	P-3497
Machado, Maria	O-3079



INQUA 2019  
DUBLIN  
IRELAND

Machiya, Hirokazu	P-2855
Macho, Isabel	P-2870
Macias Fauria, Marc	O-0038
Macias-Fauria, Marc	P-2251
Mackay, Anson	<u>O-2204</u> , O-4142
Mackay, Helen	O-1104, O-3099, <u>O-3100</u> , P-1273, P-3204
MacKay, Helen	O-3101, O-5101
Mackay, Jon	O-3202
Mackensen, Andreas	O-2183, O-2185
Mackenzie, Lydia	<u>O-2210</u> , <u>P-1021</u> , P-3024
Mackiewicz, Maksym	P-4224
Mackintosh, Andrew	O-3187, O-4020, P-3466
Macklin, Mark	O-1220
MacLachlan, Suzanne	P-1473
MacLeod, Alison	O-2092, <u>O-3039</u> , O-3041, O-5015, P-1468, P-3626, P-4447, <u>P-4867</u>
MacPhee, Ross	O-0041
MacPhie, Anna	P-1265
Macumber, Andrew	P-1233
Macumber, Andrew L.	O-0077
Maddison, Eleanor	P-2257
Maddy, Darrel	<u>O-1219</u> , P-1279, <u>P-1907</u>
Madelaine, Stéphane	O-0073
Madella, Marco	O-5009
Mader, Sarah	O-4122
Madhavan, Midhun	P-1514
Madhusoodhan, Satish Kumar	<u>P-4500</u>
Madoc-Jones, James	O-4032
Madritsch, Herfried	P-1897
Madsen, David B.	P-1003
Maduna, Nombuso	O-2089
Maeno, Fukashi	O-3090
Maezumi, S. Yoshi	<u>O-3140</u> , P-1037, P-1467



Maezumi, Shira	O-4001
Maezumi, Yoshi	O-1049
Maffezoli, Niccolo	O-2015
Maggi, Valter	O-0008, O-0013, <u>O-0095</u> , P-2603, P-3430
Magi, Brian	P-1824
Magniez, Pierre	P-3491
Magori, Brigitte	P-2845
Magri, Donatella	P-1039, <u>P-1234</u> , P-1255, P-3498
Maguire, Kaitlin	O-0101
Magyari, Enikő	O-4091, P-3620
Magyari, Enikő	<u>O-0122</u> , <u>P-4299</u>
Magyari, Enikő Katalin	P-2213
Mahowald, Natalie	O-0008, O-0010, O-0092, P-2603
Maidana, Nora	O-0026, P-4496
Maidana, Nora I.	O-4018
Mair, Andrew	<u>O-2180</u>
Mair, Douglas	O-4033
Maire, Richard	P-4473
Majecka, Aleksandra	P-3486, P-4641
MAJEWSKI, Jędrzej	P-1062
Majewski, Jędrzej	P-1057
Majewski, Jędrzej	P-3019
Majewski, Wojciech	O-5057
Majo, Chris	O-1046
Major, István	O-0122
Makarewicz, Cheryl	O-4025
Makaske, Bart	O-3159, P-3858
Makeev, Alexander	P-1639, P-1865, P-3610, P-3882
Makhubela, Tebogo	O-3034
Makri, Stamatina	<u>O-4084</u> , <u>P-3450</u> , P-4250
Makshaev, Radik	<u>O-3052</u> , P-3603, P-3607
MAKSIMOV, FEDOR	P-1413, P-1414
Maksimov, Georgii	P-4636



INQUA 2019  
DUBLIN  
IRELAND

Malaizé, Bruno	<u>O-5102</u> , P-1449
Maldonado Castro, Antonio	O-4017, <u>P-4496</u>
Maldonado, Antonio	O-0026, O-3169, O-4156, O-4157, O-4161
Malet, Emmanuel	P-1214
Malinsky-Buller, Ariel	<u>O-2100</u> , <u>P-1601</u>
Mall, Neeraj	P-4239
Mallett, Tom	O-4097, P-4494
Malmierca-Vallet, Irene	<u>P-4506</u>
Maloney, Ashley	P-4469
Mancini, M. Virginia	O-4059, P-2254
Mandal, Shailendra K.	<u>O-0151</u> , <u>P-1015</u>
Mandel, Rolfe	O-3217, P-1211, P-2901, <u>P-2902</u>
Mangano, Gabriella	P-2810
Mangelsdorf, Kai	O-1045
Mangerud, Jan	O-0039, <u>O-1050</u> , O-1100, O-1130, O-1162, P-1892, P-3481
Mangini, Augusto	P-2482
Mangold, Alexander	O-0093
Manica, Andrea	O-1026, O-1237
Manjunatha, Busnur	<u>P-4025</u>
Mann, Daniel	O-0063
Mann, Thomas	P-3014
Mannella, Giorgio	<u>O-1163</u> , P-2472
Mannermaa, Kristiina	O-0146, P-4214
Manning, Christina	O-1180, O-1181
Manning, Joe	<u>O-5066</u>
Manning, Joseph	P-2505
Manning, Katie	O-4022, O-5028
Manning, Sturt	O-3190
Mannino, Marcello	O-0074
Manrique, Nelida	P-3224
Mansell, Lauren	P-4287
Mansilla, Claudia	O-1157, O-3028, P-4264
Mansilla, Claudia A.	<u>P-4475</u>



INQUA 2019  
DUBLIN  
IRELAND

Mao, Limi	O-2210, <u>P-1008</u> , P-1022, <u>P-1268</u> , P-4012
Mao, Xin	P-3416
Marandi, Andres	P-2469
Marcelli, Augusto	O-0095
Marcelli, Marina	P-4820
Marchant, Ross	O-2174, P-3219
Marchese, Fabio	P-4029
Marchese, Silvia	O-5036
Marchetti, David	O-5091
Marciani, Giulia	O-3224
Marcisz, Katarzyna	<u>O-2140</u> , <u>P-1806</u> , P-2265, P-2266
Marco, Taviani	P-4029
Marcolla, Arianna	<u>O-5041</u>
Marcos, M. Alejandra	O-4059
Margalef, Olga	<u>O-2132</u>
Margari, Vasiliki	<u>O-4211</u>
Margaritelli, Giulia	O-3153, P-3494
Margaritora, Davide	O-3224
Margaryan, Liana	P-3606
Margielewski, Włodzimierz	P-2265
Markgold, Martin	O-1237, O-2097, <u>O-4132</u> , O-5048, P-1845, P-1884, P-1890, P-1891, P-4623
Mariani, Guido S.	O-2124
Mariani, Guido Stefano	<u>O-3121</u> , <u>P-1887</u>
Mariani, Michela	O-2062, O-4097, P-4252, <u>P-4282</u> , P-4494
Mariethoz, Gregoire	O-3098
Marine Geoscience, BGS	O-1198
Marini, Mattia	P-1887
Marinova, Elena	O-5009
Mark, Darren	O-1180, O-1181, P-1610, P-4270
Markkula, Inkeri	<u>P-2854</u>
Markle, Bradley R.	O-0076
Markova, Evgenia	O-5110, <u>P-1224</u>



INQUA 2019  
DUBLIN  
IRELAND

Markova, Evgenia Markova	P-2811
Markovaara-Koivisto, Mira	O-4126
Marković, Slobodan	P-3621
Marković, Slobodan	<u>P-1423</u>
Marković, Slobodan B.	P-1614
Markowska, Monika	<u>O-3031</u>
Marks, Leszek	O-2211, P-1862, P-2627, <u>P-3486</u> , <u>P-3829</u> , P-4641
Marlon, Jennifer	<u>P-1824</u>
Marquer, Laurent	O-5083, P-1428, <u>P-4281</u> , <u>P-4294</u> , P-4443
Marques, Helena	O-3174
Marquet, Pablo	O-0102
Marquez, Rudi	O-4007
Marra, Fabrizio	O-1138
Marreiros, Joao	O-2100, P-1601
Marreiros, João	O-0052
Marrero, Shasta	O-1067
Marret, Fabienne	O-3208
Marsh, Erik	O-0143
Marshall, Jim	P-1407
Marshall, Jon	P-4489
Marshall, Jonathan	O-3184, O-4094, O-5032, P-1513, P-3413
Marshall, Katie	O-1148
MARSHALL, Michael	P-4448
Marshall, Michael	O-3193
Marshall, Peter	O-1161, O-1213
Marta, Perez	P-4442
Martel, Stephen	O-1070
Martel-Cea, Alejandra	P-1821, <u>P-4481</u>
Martens, Vibeke Vandrup	<u>O-0064</u>
Marti, Etienne	P-4803
Martikainen, Pertti	P-2857
Martillo, Carlos	O-3014
Martin, Fabiana	O-3028, P-4476



INQUA 2019  
DUBLIN  
IRELAND

Martin, Fabiana M.	<u>P-4264</u>
Martin, Julian	P-4471
Martin, Julian R. V.	<u>O-4166</u>
Martin, Louise	P-4215
Martin-Garcia, Gloria	O-1090
Martin-Puertas, Celia	P-3449
Martinelli, Nicoletta	O-1097
Martinez Cortizas, Antonio	O-5005
Martinez Izquierdo, Haydar	O-2107
Martinez Lamas, Ruth	<u>P-4402</u>
Martinez Lopez, Joao Gabriel	P-2812
Martinez, Kirk	O-2145
Martinez, Philippe	O-3188, P-1449, P-1457, P-1458
Martinez-Abarca, L.Rodrigo	P-1266
Martinez-Murillo, Juan F.	<u>P-3860</u>
Martini, Fabio	P-1607
Martini, Mateo	O-4019, <u>O-4193</u>
Martini, Mateo A.	P-3442
Martinod, Joseph	O-4186
Martins, Antonio	O-1059
Martins, António	P-2896
Martins, António A.	P-2883
Martkoplshvili, Inga	<u>P-1244</u>
Martos, Yasmina M.	P-1454
Martrat, Belen	<u>O-3152</u> , O-3154, O-4211, P-3499, P-4423
Martín-García, Rebeca	O-3222
Martín-González, Jesús A.	O-3182, P-1216
Martínez Cortizas, Antonio	O-2127, <u>O-2198</u> , P-2010, P-2873
Martínez Méndez, Gema	<u>P-2246</u> , <u>P-4519</u>
Martínez, Pablo	O-1093
Martínez-Carreño, Natalia	P-2491
Martínez-Cortizas, Antonio	O-2083, P-2012
Martínez-García, Alfredo	P-1428



INQUA 2019  
DUBLIN  
IRELAND

Martínez-Grau, Héctor	O-1093
Martínez-Graña, Antonio	P-3497
Martínez-Polanco, María Fernanda	<u>P-3227</u>
Marushchak, Maija	P-2857
Marx, Sam	O-3035
Marx, Samuel	O-3066
Marzeion, Ben	O-0006
Marzocchi, Warner	O-4124
Marín, Liliana	P-2610
Mas e Braga, Martim	P-1420, P-1483, P-3485
Masana, Eulalia	<u>O-4187</u>
Masana, Eulàlia	P-2243
Masci, Lucrezia	O-1137
Masi, Alessia	<u>O-1137</u> , P-2477
Maslin, Mark	P-4454
Mason, Andrew	O-4037
Mason, Joseph	O-0096
Mason, Joseph A.	O-2149, P-3808
Massa, Charly	P-2864
Massaferro, Julieta	O-0026, P-4481, P-4496
Massault, Marc	O-3209
Masson, Zachary	P-2812
Massé, Guillaume	O-1184, O-1185, P-2495, P-4441
Mastronuzzi, Giuseppe	P-3023
Masuda, Harue	O-1006
Mata, María del Pilar	P-4254
Mata-Campo, Maria Pilar	O-1139, P-4241
Mateawo, Jacob	O-5140
Mateo, Miguel Ángel	P-2010, P-2012
Mateos, Ana	O-4134, O-4135, O-4137, <u>O-4138</u> , <u>P-4201</u> , P-4202
Mateos, Rosa M.	P-4830
Matero, Ilkka	P-1415
Mather, Anne	<u>O-1218</u> , O-1220, P-1831, P-2898, <u>P-3872</u>



Mathes-Schmidt, Magret	P-3053
Mathewes, R.W.	<u>P-3203</u>
Mathewes, Rolf	<u>P-2203</u>
Mathieu,	O-1193
Mathieu, Jérôme	O-1193
Matishov, Gennady	<u>O-3055</u>
Matlakhova, Ekaterina	<u>O-3001</u>
Matley, Kia	<u>O-3069</u>
Matmon, Ari	O-2219, P-1859
Matoušková, Šarka	O-1204
Matoušková, Šárka	P-2806
Matsumoto, Dan	O-3008, P-3025, P-3029
MATSUSHI, Yuki	P-3871
MATSUZAKI, Hiroyuki	P-3871
Mattey, David	O-4010, P-4462
Matthews, Ian	O-2092, O-3039, O-3041, O-3144, O-4195, O-5015, P-1468, P-2416, P-2424, <u>P-3622</u> , P-3626, <u>P-4463</u>
Matthews, Ian P	O-4085
Matthews, Ian P.	O-4088, P-1472, P-2271, P-3441, P-3445, P-4862
Matthews, Tom	O-0091
Matthias, Isabelle	O-2029
Matthies, Tim	<u>P-3876</u>
Matthiessen, Jens	O-1187, O-4073
Mattielli, Nadine	O-0093, O-0094, P-1435, P-3847
Mattila, Jussi	O-4126
Maughan, Gideon	O-3170
Maul, Lutz Christian	P-4206
Mauquoy, Dmitri	P-2266, P-3840
Maurer, Eline	P-2868
Maurer, Jakob	P-2273
Maurice, Louise	O-3202
Maxson, Charles	<u>O-4094</u>
Maxwell, Kathrine	O-3163, <u>P-3033</u> , P-3058



INQUA 2019  
DUBLIN  
IRELAND

Maxwell, Simon	O-4170
May, Jan-Hendrik	O-3035, O-3066, P-4494
May, Simon Matthias	<u>O-2153</u> , P-1006, P-4610
Mayewski, Paul	P-3464
Mayfield, Roseanna	<u>O-2057</u>
Mayle, Francis	O-2171, P-3226
Mayle, Francis E.	O-3140
Mayle, Frank	O-3135
Mayr, Christoph	O-1114, <u>O-1154</u> , O-4018, P-4473
Mazei, Natalia	P-2850
Mazier, Florence	O-5008, O-5010, O-5013, O-5014, O-5083, P-4281, P-4294
Mazzanti, Paolo	P-3836
Mazzini, Ilaria	<u>O-5108</u>
Mazzone, Sarina	P-3413
Mažeika, Jonas	P-1035
Mc Keown, Lauren	O-5000
McBeath, Anna	O-1046
McCallum, Adrian	P-2607
McCalpin, James	<u>O-0155</u> , <u>P-3866</u> , P-4803
McCarroll, D.	O-4042
McCarroll, Danny	O-3230, O-4210
McCarron, Ambrose	<u>P-1407</u>
McCarron, Stephen	<u>O-0133</u> , O-1056, <u>P-4001</u> , P-4004
McCarron, Steven	O-5128
McCarthy, Gerard	O-0091
McClatchie, Meriel	<u>O-2026</u> , O-5009, P-4220
McClellan, Noah	O-4037
McClenaghan, Beth	P-4840
McClure, Malcolm	<u>P-2240</u>
McClymont, Erin	<u>O-2113</u>
McConnell, Joe	P-4439
McConnell, Joseph	P-2238
McConnell, Joseph R.	O-3113



INQUA 2019  
DUBLIN  
IRELAND

McCormack, Finbar	O-1104
McCormick, Finbar	O-3099
McCoy, Floyd	O-5065
McCoy, William D.	P-3625
McCullagh, Denise	<u>P-2497</u>
McCulloch, Robert	O-1157, O-2078, <u>O-3028</u> , O-4156
McCulloch, Robert D.	P-4264, P-4475
McDermott, Frank	<u>O-2073</u> , <u>P-2234</u>
McDonald, Eric	O-1066, <u>O-1067</u> , O-3049
McGee, David	O-1108, O-2117, O-3110, P-2223
McGeever, Alwynne	P-1230
McGinley, Seamus	O-4160
McGlone, Matt	O-3145, P-4492
McGough, Stephen	O-1219
McGovern, Thomas	<u>O-0148</u>
McGowan, Suzanne	O-5076, P-2221, P-2258, P-4237, P-4246, P-4251, P-4259
McGregor, Glenn	O-3184, O-4094, P-1513, P-4489
Mcgregor, Glenn	O-5032
McGregor, Helen	P-4423
McGuire, Amy	<u>O-3037</u> , <u>P-2252</u> , P-3433
McGuire, Jenny	O-2135
McHugh, Cecilia	<u>O-3010</u>
McInerney, Francesca	O-3184, P-4489
McIntosh, Peter	P-1895, P-2613, P-3500
McKay, Mark	<u>P-2511</u>
McKay, Nicholas	O-0011
McKay, Nicholas P.	O-5029
McKay, Nick	P-1499
McKeehan, Kevin	P-1836
McKeown, Michelle M	<u>O-2054</u>
McLachlan, Jason S.	O-5081
McLauchlan, Kendra	O-0021
McLaughlin, Jim	O-2129, O-2199



INQUA 2019  
DUBLIN  
IRELAND

McLean, Danielle	P-3629
McMahon, Harry	O-1132
McManus, Jerry	O-4072, O-4211
McMartin, Isabelle	<u>O-0030</u> , <u>P-1881</u>
McMichael, Crystal	<u>O-0100</u> , O-1048, O-3140
McNeely, Cameron	P-1619
McNulty, Emma	P-4278
McPherron, Shannon	O-0052, O-0073
McRostie, Virginia	O-4155, O-4157
McSweeney, Sarah	O-1158
McWethy, Dave	P-3840
McWethy, David	<u>P-2238</u>
Mdludlu, Ayanda	P-2235
Meadows, Michael	O-4015
Meadows, Michael E.	O-2152, P-4530
Meco, Joaquín	P-2605
Mecozzi, Beniamino	O-5108
Medeiros, Andrew	O-0125
Medialdea Utande, Alicia	O-1055, O-2153
Medialdea, Alcia	O-3230
Medialdea, Alicia	O-1127, O-3079, <u>O-4118</u> , O-5128, O-5130
Medina Gonzalez, Roger	O-2107
Meehan, Robert	O-1057
Mehl, Adriana	P-2832
Mehra, Shashi	<u>O-2067</u>
Mehta, Bulbul	P-3454
Mehterian, Sevag	P-1502
Meier, Rudolf	O-1023
Meijer, Tom	O-5040
Meiling Man, Meiling Man	P-2852
Meine, Lennart	O-2153
Meinhold, Guido	P-4833
Meire, Lorenz	P-1440



INQUA 2019  
DUBLIN  
IRELAND

Meireles, José	P-2899
Mejía, Catalina	P-3063
Mekhaldi, Florian	P-4617
Mekki, Helael	O-5023
Mekonnen, Betelhem	P-3207, <u>P-3210</u>
Mele, Daniela	P-3023
Meleg, Ioana N.	P-1231
Meletti, Carlo	O-4124
Melinte, Mihaela	O-2011
Melinte-Dobrinescu, Mihaela	O-3127
Melles, Martin	O-3016, O-3057, P-1471, P-1635
Mellet, Claire	O-5060
Melnick, Daniel	P-1034, P-3020, P-3032, P-3034
Melnikov, Vladimir	P-4846
Meltzner, Aron	P-3019
members, SISAL Working Group	O-5124
Memiş, Ümit	O-3210
Mencaroni, Marco	P-1013
Mendelova, Monika	<u>O-4168</u>
Mendez, Williams	O-3014
Mendonça Filho, João Graciano	P-2011
Mendonça, Joalice de Oliveira	P-2011
Mendoza, Milette	O-5076
Meng, Hongwei	O-1033
Meng, Qingquan	P-3425
Menounos, Brian	O-0114, P-2814
Mensing, Scott	P-3431
Menviel, Laurie	O-4211
Menzies, John	O-0127, <u>O-0128</u> , P-1863, P-1900
Mercatante, Giuseppe	P-3804
Merceron, Gildas	O-2164, P-2207, P-4529
Merchel, Silke	P-2446
Mercier, Herlé	P-1405



INQUA 2019  
DUBLIN  
IRELAND

Mercuri, Anna Maria	O-2124, P-2477
Meredith, Karina	O-3183, O-4092, P-4488
Merer, Solène	O-2174
Meretta, Pablo E.	P-2254
Merkel, Ute	O-0092
Mertes, Jordan R.	P-2457
Meschede, Martin	O-1129
Messenger, Erwan	O-1024, O-4006, <u>P-1212</u> , <u>P-1214</u> , P-4281
Messmer, Martina	P-4298, P-4414
Meszner, Sascha	O-3124
Metcalfe, Brett	O-4013, <u>P-4413</u> , P-4630
Metcalfe, Sarah	<u>O-2107</u> , O-3173, P-4251
Mettig, Georg	O-3124
Meunier, Guillaume	P-1258
Meyer, Axel	P-4245
Meyer, Hanno	O-5035
Meyer, Michael	O-3035, P-1235
Meyer-Heintze, Simon	P-1627
Meyer-Jacob, Carsten	O-2083, <u>O-5074</u> , P-3432, P-3437, P-4248
Meyers, Stephen	O-0096
Mezzini, Stefano	O-2061
Mhammdi, Nadia	P-4610
Miao, Yunfa	<u>P-1804</u> , P-3425
Michaelis, Dierk	<u>P-2216</u>
Michaelis, Rune	P-3006
Michczyńska, Danuta J.	O-1152
Michczyński, Adam	O-1152
Michel, Elisabeth	P-2521, P-4515
Michel, Simon	P-1802
Michelangeli, Fabrizio	<u>P-3498</u>
Michelutti, Neal	O-5074
Michetti, Alessandro Maria	<u>O-4044</u> , P-4806, P-4809
Middelkoop, Hans	O-0001, O-3082



INQUA 2019  
DUBLIN  
IRELAND

Middleton, Maarit	O-4126
Miebach, Andrea	<u>O-4197</u>
Miehe, Georg	O-1149, O-3021
Miettinen, Arto	O-1184, O-3189, P-2493
Mifsud, Charles	O-4116
Mighall, Tim	O-2198, <u>O-5005</u>
Mihevc, Andrej	O-1204, O-2071
Mii, Horng-Sheng	O-0027, O-3219
Mikdad, Abdeslam	O-3073, P-3803
Mikko, Henrik	P-4842
Miko, Slobodan	P-3206
Mikolajak, Teresa	O-3108
Mikšovský, Jiří	O-0085
Milano, Stefania	<u>P-1452</u>
Milecka, Krystyna	O-1020, P-3486
Miles, D.	O-4042
Miles, Dan	O-1042, O-4210
Miles, Evan	O-1145, O-3201
Miles, Katie	O-3201
Millar, Chris	<u>P-2431</u>
Millar, Ian	O-3122
Miller, Angus	P-1281
Miller, Brendan	<u>O-5088</u>
Miller, Gifford	<u>O-0115</u> , O-1099, O-2188, P-1622
Miller, Joshua H.	<u>O-0060</u>
Milli, Salvatore	P-3836
Mills, Keely	P-2221, P-2504, P-4246, P-4255
Mills, Stephanie	O-3068, <u>O-3142</u> , <u>P-1831</u>
Mills, Steve	O-1161
Millán, Rocío	P-4254
Milner, Alice	P-2863
Milner, Alice M.	P-2271, P-3441, P-3449
Minami, Masayo	P-4226



INQUA 2019  
DUBLIN  
IRELAND

Mineli, Thays Desiree	P-3225
Mingjie, Sun	<u>P-2414</u>
Mingram, Jens	P-3408, P-3417, P-3839
Minina, Yevgenia	P-2622
Miola, Antonella	O-5041
Miot da Silva, Graziela	P-2601
Miotk-Szpiganowicz, Grażyna	P-2866
Mirea, Ionuț	O-1207
Mischke, Steffen	O-1028, O-2155, O-3073, O-4199, O-4202, <u>P-1446</u> , <u>P-3489</u> , P-3803, P-4275
Misrocchi, Stefano	<u>P-1476</u>
Mishra, Praveen K	P-3454
Miska, Serge	O-3204, O-3209
Misra, Krishna G.	<u>P-4535</u>
Misra, Pavani	<u>P-3419</u>
Misra, Sandhya	P-4535
Mitchard, Edward	P-1265
Mitchell, Edward A D	O-2054
Mitchell, Fraser	<u>P-1230</u>
Mitchell, Peter	O-5027
Mitchell, Stephen	O-3167
Mitrovica, Jerry	O-4072, P-1066
Mitrovica, Jerry X.	O-0029, O-0032
Mitsui, Takahito	O-1085
Miura, Hideki	O-1232, P-1001
Mix, Alan	P-1416
Miyairi, Yosuke	<u>P-4629</u>
Mleczak, Mateusz	O-1128
Mlencek-Vautravers, Maryline	O-1090
Mode, William	P-1853
Modin, Igor	P-4865
Moernaut, Jasper	O-2093, O-3011, O-3087, O-4046, <u>O-4121</u> , P-1464, P-2828, <u>P-3028</u> , P-3862



INQUA 2019  
DUBLIN  
IRELAND

Moffat, Ian	O-0121
MOHAMMADKHANI, Kourosh	P-3855
Mohan, Rahul	O-3189
Mohapatra, P.P.	O-5014
Mohtadi, Mahyar	P-1250
MOINE, Olivier	O-5115
Moine, Olivier	<u>O-1193</u> , P-1409, P-1869, <u>P-3875</u>
Moise, Aurel	O-1035
Moiseenko, Tatyana	O-5072
Mojtabavi, Seyedhamidreza	P-4455
Mojtahid, Meryem	P-1405
Mokadem, Fatima	P-2458
Mokeddem, Zohra	O-4211
Moldovan, Oana	P-1502
Molenaar, Ariana	<u>O-3011</u> , <u>P-2828</u> , P-3862
Molin, Paola	P-2891, <u>P-2892</u>
Molinari, Chiara	<u>O-1125</u>
Molisso, Flavia	P-3040
Mollenhauer, Gesine	P-2521
Molloy, Karen	O-2022
Molnár, Mihály	P-2213, P-2616, P-3451
Molodkov, Anatoly	P-1838, P-1855
Momohara, Arata	P-3025
Moncel, Marie-Hélène	O-4135
Monecke, Thomas	O-0124
Monegato, Giovanni	O-1153, O-1168, O-5041, <u>P-2624</u> , <u>P-2842</u> , P-2844
Moneno, Patricio	P-4480
Monique, TOSSOU	<u>O-5137</u>
Monnier, Jean-Laurent	P-4632
Montade, Vincent	<u>O-3061</u>
Montalti, Mélanie	O-3077
Montana, Giuseppe	P-2225
Monteath, Alistair	O-3130



Monteiro da Fonseca, Estefan	P-1042
Monteiro Rodrigues, Sérgio	P-2899
Monteys, Xavier	P-1404, P-4001, P-4004
Montgomery, Janet	P-2232
MONTORO GIRONA, Miguel	<u>O-3179</u>
Montoya, Encarni	O-3134, <u>O-3139</u>
Montoya, Marisa	O-2040
Montávez, Juan Pedro	<u>O-5054</u>
Montúfar, Rommel	O-3139
Moon, Seulgi	O-1070
Mooney, Scott	<u>O-1046</u> , O-5076, <u>P-3464</u>
Moore, Kathryn	P-4439
Moorhouse, Heather	O-2109
Morales Molino, Cesar	O-2041
Morales, Carla	P-4017
Morales, Cesar	P-2212
Morales, Juan Ignacio	O-5025
Morales, Mariano	O-3172
Morales-Molino, Cesar	<u>O-2032</u> , P-4420
Morales-Molino, César	P-1226, P-1817, P-4256, P-4291
Morata, Natalia	P-4473
Moravcová, Alice	<u>O-2206</u>
Morcote Rios, Gaspar	O-5097
Moree, Jelle	O-1078
Moreias, Stella Maris	<u>O-1068</u>
Moreiras, Stella	<u>O-3143</u>
Morel, Charlène	O-4056
Morello, Flavia	O-1157, P-1017, P-1262, P-4264, P-4475
Morellón, Mario	P-4254, <u>P-4256</u>
Moreno, Ana	O-1139, <u>O-3222</u> , P-1266, P-2507, <u>P-2841</u> , P-3048, P-4254, P-4451
Moreno, Davinia	<u>P-2880</u>
Moreno, Patricio	O-4019, <u>O-4165</u> , P-1433, P-2274, P-4483, P-4497



INQUA 2019  
DUBLIN  
IRELAND

Moreton, Steve	O-3230, O-5128
Moreton, Steven	O-5130
Moreton, Steven G.	O-1055, O-5063
Moretti, Massimo	P-3023
Moretto, Michael	O-3199, P-4853
Morey, Ann	<u>O-3012</u>
Morigi, Caterina	P-4013
Morin, Efrat	O-1206, O-3030
Morin, Hubert	O-3179
Morin, Jorge	P-2889
Morisaki, Kazuki	<u>O-4099</u>
Morley, David	O-2204
Morley, Mike	O-3142
Morlock, Marina A.	<u>O-3057</u> , <u>P-1471</u>
Morozova, Liudmila M.	O-0039
Morris, Jesse	O-3214
Morris, Paul	O-2130, <u>O-2197</u> , O-2202, P-2849, P-2858, <u>P-2860</u>
Morrison, Alex	O-5101
Morrison, Kathleen	O-5009
Mortimer, Estelle	P-1072
Moscariello, Andrea	P-3442
Moscatelli, Lorenzo	P-2472
Moseley, Gina	P-4473
Moseley, Gina E.	O-4216
Moser, Katrina	O-5006
Moses, Cherith	P-1465, P-3046
Moska, Piotr	O-1190, O-1191, O-5114, P-1634, P-3856, P-3873
Moskal-Del Hoyo, Magdalena	P-2205
Moskal-del Hoyo, Magdalena	O-5009, P-2427
Moskalewicz, Damian	<u>P-3061</u>
Moskovtsev, Alexander	P-3005
Mosley, Luke	O-1005
Mosley-Thompson, Ellen	O-1088



INQUA 2019  
DUBLIN  
IRELAND

Moss, Patrick	<u>O-1029</u> , O-2110, P-1049, P-2601, P-3024, P-3413, <u>P-3500</u>
Motavalli-Anbaran, Seyed-Hani	O-3209, P-3404
Motavalli-Anbaran, Seyed-Jasser	P-3404
Mothulatshipi, Sarah	O-5026, P-3801
Motta, Laura	O-1138
Mouillot, David	P-3229
Mouillot, Florence	P-1824
Mouillot, Florent	P-1802
Mouralis, Damase	O-1039, P-3833
Mourgues, Régis	P-4839
Mousaeva, Lyudmila	P-3870
Moy, Andrew	P-3468
Moy, Chris	P-4492
Moyle, Madeleine	<u>O-5003</u>
Mozzi, Paolo	<u>O-1153</u> , O-1168, O-3078, O-5041, <u>P-3844</u>
MR, Resmi	P-1453
Mroczek, Przemyslaw	<u>P-1243</u> , <u>P-4224</u>
Mroczek, Przemysław	O-1190, P-2885, P-3061, P-4638
Mroczkowska, Agnieszka	P-1816
Mrotzek, Almut	P-2216
Mudelsee, Manfred	O-3220
Mueller, Daniela	O-3065, O-4119, P-1897, P-3476, <u>P-4614</u>
Mueller, Wolfgang	P-4462
Muhs, Daniel	<u>O-4215</u>
Muhs, Daniel R.	<u>P-2605</u>
Muiruri, Veronica	O-4169
Mukaiyama, Kenjiro	O-2090
Mukherjee, Udit	O-0079
Mukhin, Dmitry	P-2473, <u>P-2475</u>
MUKHOPADHYAY, SOURAV	<u>P-3832</u>
Mullan, Donal	O-2130, O-2202
Muller, Wolfgang	O-4010
Mulligan, Riley	O-1202



INQUA 2019  
DUBLIN  
IRELAND

Mulvaney, Robert	O-1088
Mulville, Jacqui	O-1161
Munar, Jeffrey	<u>O-2010</u>
Munch Kristiansen, Søren	P-3628
Munoz, Samuel	<u>O-3216</u>
Munro-Stasiuk, Mandy	<u>O-0048</u> , P-1844
Munroe, Jeffrey	<u>O-0097</u>
Munuera, Manuel	P-2202
Mur-Cacucho, Elena	P-2851
Murakami, Alejandro	O-3135
Murayama, Masafumi	P-1277, P-4490
Murchie, Tyler	<u>O-1025</u> , P-1206
Murguzur, Francisco J.A.	O-3025
Murphy, Claire	O-3184
Murphy, Conor	<u>O-0091</u>
Murphy, Michael	<u>P-4247</u>
Murphy, William	P-2438
Murray, Andrew	P-3610
Murray, Andrew	O-2223, O-3051, O-3054, O-4040, O-4176, P-1639, P-2440, P-2456, P-2460, P-3609, P-4626, P-4865
Murray, Andrew S.	O-3161, P-2452, P-2883, P-2889
Murray, Andrew Sean	P-2620
Murray, Emily	O-1104, O-3099
Murray-Wallace, Colin	O-4110
Murray-Wallace, Colin V.	P-1060
Murton, Della	<u>O-1073</u> , O-1237, <u>P-2433</u>
Murton, Julian	O-1237, <u>O-5044</u> , O-5045, P-1204, <u>P-2608</u>
Murton, Julian B.	O-5042, P-2625
Muscheler, Raimund	O-3190, O-3194, <u>O-3196</u> , O-4014, O-4116, <u>P-4617</u>
Mushkin, Amit	<u>O-4035</u> , <u>P-2821</u>
Muthreich, Florian	<u>O-2034</u>
Muto, Atsuhiko	P-1853
Muñoz Sobrino, Castor	<u>P-2491</u>



Muñoz sobrino, Castor	<u>P-1220</u>
Muñoz-Martín, Alfonso	P-2851
Myklebust, Reidun	O-4129
Mäusbacher, Roland	P-4530
Méndez, César	O-0143, <u>O-3169</u> , O-4156
Méndez-Quintas, Eduardo	P-2899
Möhrchen, Ramona	O-2153
Mörth, Carl-Magnus	O-2127, O-2131
Müller, Daniela	<u>O-4086</u> , <u>P-3436</u>
Müller, Johannes	P-1249
Müller, Juliane	O-5016, P-4519
Müller, Jurek	O-0017, <u>O-2053</u>
Müller, Katharina	O-4189, P-3863
Müter, Dirk	P-1030
Nadachowski, Adam	P-3873, P-4206
Nadal-Romero, Estela	P-3860
Nadali, Davide	P-3836
Nadimikeri, Jayaraju	<u>O-1004</u>
Nag, Debarati	O-2156
Nagahashi, Yoshitaka	O-1116, P-3617, P-4500
Nagashima, Kana	<u>O-1227</u> , P-4490
Nagel Støren, Eivind Wilhelm	O-4051
Nagle, Caitlin	<u>P-1014</u>
Nahapetyan, Samvel	P-4270
NAHM, Wook-Hyun	<u>P-3013</u>
Naik, Sambit Prasanajit	P-4815
Naito, Yuichi I.	<u>O-0123</u> , <u>P-1231</u>
Nakagawa, Takeshi	O-2161, O-3193, P-2428, P-3457
NAKAGAWA, Takeshi	<u>P-4448</u>
Nakamura, Toshio	<u>P-4226</u>
Nakashima, Douglas	P-2218
Nakashima, Rei	P-1022
Nakatsuka, Takeshi	P-1422



INQUA 2019  
DUBLIN  
IRELAND

Nakazato, Hiroomi	O-0118
Nakazawa, Yuichi	<u>O-4100</u>
Nakileza, Robert	O-2098, O-4141
Nakov, Daniil	P-2426
Namegaya, Yuichi	O-3008, P-3029
Nanavati, William	<u>P-4218</u>
Nanson, Gerald	O-3035
Nanson, Rachel	P-3024
Nantke, Carla	<u>O-1003</u>
Napier, Tiffany J.	<u>P-1511</u>
Narancic, Biljana	<u>O-5035</u>
Narcisi, Biancamaria	O-0013
Naregundi, Karunakara	P-4025
Nartišs, Māris	P-2827
Nash, David	<u>O-0088</u> , P-3801
Nash, David J.	O-5026, O-5116
Nassour, Yacoub Abdallah	P-3806
Nasu, Hiroo	O-2161
Natawidjaja, Danny	P-3019
Natsuki, Daigo	O-4026
Naudts, Evi	P-3806
Naughton, Filipa	<u>O-2041</u> , P-1802, P-2484, P-2488
Naumenko, Mikhail	P-3606
Nava Fernandez, Cinthya	P-1506
Navarrete, Vanessa	O-5009
Navarro, Francisco	P-2841
Navarro, Lionel	O-3179
Navya, Reghu	<u>O-5013</u> , O-5014
Nazarov, Dmitry	O-1130
Nazarova, Larisa	O-4074, O-5021, <u>P-1058</u> , P-3458
Nazarova, Larissa	O-0125
Ndiema, Emmanuel	O-4159
Neall, Vincent	<u>O-1038</u>



INQUA 2019  
DUBLIN  
IRELAND

Neef, Reinder	O-3016
Neevin, Igor	P-1032, P-2009, P-3005
Negi, P.S.	P-1459
Negrini, Robert	P-4496
Nehme, Carole	P-3807, P-4264
Neil, Helen	P-4499
Nel, Turid Hillestad	<u>O-3017</u>
Nelson, Michelle	P-1438
Neme, Gustavo	O-3175, P-1259
Nemomissa, Sileshi	P-3207, P-3210
Nepop, Roman	O-3003
Nerea, Piñeiro-Juncal	P-2010
Nesje, Atle	P-3060, P-3822
Neudorf, Christina	P-2617
Neugebauer, Ina	<u>O-1228</u> , O-3106, O-4087, P-3436, <u>P-4444</u>
Neuhuber, Stephanie	O-5112
Neukom, Raphael	O-3183, P-4423
Neville, Lisa A.	O-0077
Newall, Jennifer	<u>P-3485</u>
Newall, Jennifer C.	<u>P-1483</u>
Newmann, Frank H.	O-0050
Newnham, Rewi	O-2133, O-3145, O-4012, O-4020, P-2872, P-3470, P-4492, P-4499
Newnham, Rewi M.	P-4604
Newsome, Seth D.	O-3176
Newton, Andrew	O-5058
Newton, Anthony	O-1040, O-1119, <u>O-3119</u> , P-1621, P-2869, P-3861, <u>P-4425</u>
Newton, Mihaela	<u>P-4843</u>
Newton, Robert	O-2180
Ng, Felix	P-1849
Ng, Felix S.L.	O-0043
Ng, Hong Chin	O-4072
Ngonadi, Chioma	<u>O-5138</u>



INQUA 2019  
DUBLIN  
IRELAND

Ngonadi, John Uche	O-5138
Nguyen, Hanh	P-1432
Nguyen, Van Lap	O-1079, P-1022
Ni, Jian	O-5012, O-5121
Ni, Sha	P-1030
Nian, Xiaomei	<u>P-1031</u>
Nichol, Scott	O-2008
Nichols, Jonathan	P-2864
Nicoll, Kathleen	<u>O-3018</u> , <u>O-3120</u> , P-3802
Nicolussi, Kurt	O-2093, <u>P-2451</u>
Nicosia, Cristiano	O-1097, P-1267
Niedermeyer, Eva M.	O-2152
Nield, Grace	P-4005
Nielsen, Anne	O-5010
Nielsen, Anne Birgitte	<u>O-4057</u> , O-5071
Nielsen, Søren Borg	O-4098
Niemeier, Ulrike	P-1432
Nieto Lugilde, Diego	O-0101
Nieuwenhove, Nicolas Van	O-1185
Nigg, Valentin	O-3085, <u>P-3042</u>
Nigmatova, Saida	O-3044, O-4066, P-4281, P-4294, P-4443
Nikitina, Daria	<u>O-0067</u> , O-0152
Nilsson, Andreas	O-4116
Nilsson, Hanna	P-1004, <u>P-1045</u>
Ning, Liang	<u>O-5070</u> , P-4431
Ninnemann, Ulysses	P-4630
Ninnes, Sofia	<u>O-2083</u> , O-3102
Nir, Nadav	O-2100
Nirgi, Triine	P-1046
Nisancioglu, Kerim	P-4837
Nishida, Naohisa	O-0118
Nishimura, Yuichi	<u>O-4183</u> , <u>P-3031</u> , P-3036, P-3054
Nishina, Kenji	P-3041



INQUA 2019  
DUBLIN  
IRELAND

Niska, Monika	<u>O-1166</u> , <u>P-2427</u>
Nita, Dan	P-2810
Nitychoruk, Jerzy	P-3486, P-3829, P-4641
Niu, Lu	P-3482
Nixon, Francis Chantel	<u>O-1081</u>
Nobayashi, Atsushi	<u>P-4269</u>
Noble, Paula	P-3431
Noble, Stephen	O-4037
Noguchi, Atsushi	<u>P-4271</u>
Noguchi, Takuroh	P-1018
Nogue, Sandra	O-1121
Nogue-Bosch, Sandra	O-3063
Nogu�-Bosch, Sandra	P-4466
Nokandeh, Jebrael	P-3401
Noma, Nanase	P-1277
Nomade, Sebastien	O-1163, P-2472
Nomade, S�bastien	P-4515
Nomura, Ritsuo	P-1028
NOND�D�O, Philippe	P-4229
Noone, Simon	O-0091
Nooren, Kees	O-2107
Noormets, Riko	P-1894
Nora, David	O-2100
Nordt, Lee	O-1216
Nordvik Hovland, Morten	O-1130
Noret, Aur�lie	O-3209
Norman, Kasih	O-0103
Norris, Nathaniel	O-3199, P-4853
Norris, Sophie	<u>O-2097</u> , <u>P-1845</u>
Norton, Kevin	O-3187, O-4020, P-3466
Nory�kiewicz, Agnieszka	O-4083
Nory�kiewicz, Agnieszka M.	O-4086, P-4213, P-4449
Nor�dahl, Hreggvi�ur	O-3040, O-4128



INQUA 2019  
DUBLIN  
IRELAND

Nota, Kevin	<u>O-1101</u>
Nothdurft, Luke	P-3024
Novac, Marec	O-5009
Novak, Andrej	<u>O-4208</u>
Novellino, Paula	O-0143
Novello, Valdir F.	O-3109
Novenko, Elena	<u>P-1803</u> , P-1812, <u>P-2850</u> , P-2871
Novi, Lyuba	P-1013
Novothny, Ágnes	<u>O-1194</u> , O-1195, P-1629, P-2614, <u>P-3625</u>
Nováková, Lucie	P-3865
Nowacki, Dirk	<u>O-4109</u> , <u>P-3448</u>
Nowacki, Łukasz	P-4641
Nowaczyk, Norbert	O-1045, P-1519
Nowatzki, Maike	O-3044, P-4281, P-4294
Nowell, April	<u>O-1017</u> , O-2043, O-4201
Nuevo Delaunay, Amalia	O-0143, O-3169, <u>O-4156</u>
Nunez, Cecelia	P-1265
Nurminen, Fiia	P-4803
Nuñez, Lautaro	O-4161
Nyguyen, Trinh	O-1029
Nystuen, Johan Petter	O-0004
Näslund, Jens-Ove	O-1070
Négyesi, Gábor	P-2616
Nørgaard-Pedersen, Niels	O-2183, P-1071
Nürnberg, Dirk	P-1441
Ó Cofaigh, Colm	O-0131, <u>O-5063</u> , O-5130
O'Boyle, Louise	O-3164
O'Brien, Haley D.	O-4175
O'Carroll, Ellen	<u>O-2025</u>
Ó Cofaigh, Colm	O-3230
O'Connell, Michael	<u>O-2022</u>
O'Connor, Jim E	P-1617
O'Connor, Susan	O-5095



INQUA 2019  
DUBLIN  
IRELAND

O'Donnell, Robbie	P-3035
O'Donnell, Rory	P-1404
O'Donnell, Shawn	P-3230
O'ishi, Ryouta	P-2489
O'Keefee, Eimear	P-2497
O'Leary, Michael	<u>O-2085</u>
O'Rourke, Dennis	P-1211
O'Toole, Ronan	O-4034
O. Grimalt, Joan	P-2486
Obase, Takashi	O-1085, <u>P-4512</u>
Oboh-Ikuenobe, Francisca E.	P-2002
Obreht, Igor	P-1614, P-2813
Obremaska, Milena	P-1816, P-2866, P-4449
Obrochta, Stephen	O-1085, <u>P-2519</u>
Obrocki, Lea	O-4029, <u>P-3039</u>
Obst, Karsten	O-1129, P-1879
Ochando, Juan	<u>P-2202</u>
Oches, Erick A.	P-3625
Oconnor, Shoshannah	P-3024
Odgaard, Bent	O-1173
Odé, Astrid	P-2263
Oeggl, Klaus	<u>O-1096</u>
Oeggl-Wahlmüller, Notburga	P-2270
Oelkers, Rose	O-3195
Oetjen, Jan	P-3059
Ogami, Takashi	<u>O-2090</u>
Ogilvie, Astrid	O-5068
Ogle, Neil	O-2152
Ogola, Christine	<u>O-2099</u>
Ogrinc, Nives	P-4240
Oguchi, Takashi	<u>O-1199</u>
Ohgaito, Rumi	O-1085, <u>P-1430</u>
Ohlendorf, Christian	O-1114, O-1154, O-4018



INQUA 2019  
DUBLIN  
IRELAND

Ohlwein, Christian	O-4149
Ohno, Hiroshi	P-2855
Ohyama, Motonari	O-2161
Oien, Rachel	<u>P-2439</u>
Oinonen, Markku	P-4214
Ojala, Antti	O-4126, P-4438, P-4831
Oka, Akira	O-1085
Okada, Makoto	O-0118, P-2479
Oksanen, Otto	<u>O-2166</u>
Oksanen, Pirita	P-2854
Oksman, Mimmi	<u>P-2493</u>
Okuda, Masaaki	O-0118
Okumura, Koji	<u>O-4045</u> , P-4803, P-4821
Okuno, Jun'ichi	O-1232, <u>P-1001</u>
Okur, Hilal	<u>P-3833</u> , P-3842, <u>P-4205</u>
Okx, Joop	P-1828
Olafsdottir, Sædis	O-5019
Oldfield, Frank	P-3878
Oldknow, Christopher	P-2835
Olgun, Nazlı	P-3605
Oliva, Belen	O-1139
Oliva, Belén	P-2841
Oliva, Marc	<u>O-3147</u> , <u>P-1486</u> , <u>P-3886</u>
Oliveira, Dulce	O-2041, P-1457, P-2484, P-2486, <u>P-2488</u>
Olley, Jon M	O-2108, P-2509
Ollivier, Vincent	O-2100
Ollé, Andreu	O-4135
Olofson, Johan	P-2218
Olofsson, Johan	O-3102
Olsen, Jesper	O-1054, O-1173, O-1233, O-3197, P-3613, P-4441
Olsen, John W.	O-0056
Olson, Kristian	<u>O-3110</u>
Olson, Link	P-1210



INQUA 2019  
DUBLIN  
IRELAND

Ombashi, Havananda	O-3039
OMORI, Takayuki	P-4448
Omori, Takayuki	O-2161, P-2428
Omrani Rekavandi, Hamid	P-3401
Oms, Oriol	O-2166, P-2204, P-3804
Onaca, Alexandru	<u>P-2845</u>
Onuki, Shizuo	O-4026
Oohashi, Kiyokazu	O-4117
Opazo, Natalia	<u>O-0012</u>
Opdyke, Bradley	P-1823
Opgenoorth, Lars	O-1022
Opitz, Rachel	P-4425
Opp, Christian	<u>P-3809</u> , <u>P-4828</u>
Ordonez, Alejandro	<u>O-0126</u> , O-2007, <u>P-4426</u>
Orengo, Hector	O-2151
Orfanos Cheuqelaf, Andrea	P-2246
Organ, Jennifer	O-5062, <u>O-5089</u>
Orijemie, Emuobosa	<u>O-5134</u>
Orkhonselenge, Alexander	<u>P-2419</u>
Orliac, Catherine	O-5102
Orliac, Michel	O-5102
Orme, Lisa	O-2198, <u>O-3189</u>
Orsi, Anais	P-3468
Orsi, Anaïs	O-1088
Országh, Tamás	O-1194
Ortega, Cristina	P-4017
Ortega-Becerril, José A.	P-1427
Ortuño, Maria	O-4187
Ortuño, María	<u>P-2243</u>
Ortuño, Teresa	P-3462
Orłowska, Anna	<u>P-1899</u> , <u>P-1901</u>
Osborne, Anne	O-3093
Osburn, Magdalena R.	O-5100



INQUA 2019  
DUBLIN  
IRELAND

Osipova, Eugenija	O-5039
Osipova, Evgenia	P-4632
Osipowicz, Grzegorz	O-4083, P-4213
Osleger, Dillon	O-0132
Osmont, Dimitri	P-2264
Ossendorf, Götz	<u>O-2102</u>
Ostermann, Marc	O-4190, <u>P-1871</u>
Ostrooumov, Mikhail	P-3063
Oswald, W. Wyatt	O-5081
Ota, Yuki	P-1009
Otaola, Clara	P-1259
Otcherednoy, Alexander	P-3874
Otero, Jaime	P-2841
Otsubo, Makoto	O-4117
Ott, Florian	O-2080, O-4087, P-4449
Otterå, Odd Helge	P-4495
Ottesen, Dag	<u>O-0007</u> , <u>P-1068</u>
Otto, Taylor	<u>O-5024</u>
Otto-Bliesner, Bette L	<u>O-0010</u>
Otto-Bliesner, Bette L.	<u>P-4509</u>
Ou, XianJiao	<u>P-2445</u>
Ou, Xianjiao	P-4611
Ouellet-Bernier, Marie-Michèle	<u>O-0086</u> , O-2186
Out, Welmoed	O-5009
Outes, Valeria	P-4218
Ouyang, Tingping	O-2163, <u>P-1005</u>
Over, Jin-Si R.	O-4217
Ovsepyan, Yaroslav	P-3004
Ovsepyan, Yaroslav	O-4214
Owen, Lewis A.	<u>O-1141</u>
Owen, Olwyn	O-5005
Owen, R. Bernhart	O-4169
Owen, Richard	P-4278



INQUA 2019  
DUBLIN  
IRELAND

Owens, Rebecca	<u>P-1241</u>
Oxilia, Gregorio	O-3224
OXLAJ, Enecon	P-4229
Oyelami, Ayobami	<u>O-5140</u>
O'Hare, Paschal	P-4617
O'Regan, Matt	O-1071
P, Morthekai	O-2068
P. Harrison, Sandy	O-5124
Paasche, Oyvind	O-3186
Paasche, Øyvind	P-3484
Pace, Bruno	O-4124
Pachtmann, Maximilian	O-3124
Paciorek, Christopher J.	O-5081
Packalen, Maara	O-2199
Packalen, Maara S.	O-2129
Padgett, Jason	O-3013
Padhan, Tosabanta	P-1288
Padilha, Mária	O-4069, P-2486
Pados, Teodora	<u>O-2189</u>
Paijmans, Johanna LA	O-1026
Pailler, Yvan	P-1029, P-4011
Pailles, Christine	O-3208
Paillés, Christine	O-3221
Paine, Clea	<u>O-5094</u>
Paixao, Eduardo	O-2100
Pajon, Jesus	P-2506
Pajón, Jesús M.	P-2482
Pak, Dorothy	O-3111
Pal, Ilona	P-3620
Palacios, David	P-1486, P-2443
Palacios, Davuid	O-3147
Palacios, Patricia I.	O-4059
Palagushkina, Olga	P-1058



INQUA 2019  
DUBLIN  
IRELAND

Pallàs, Raimon	O-4187, P-2243, P-2434
Palmer, Adrian	<u>O-2092</u> , O-3041, O-3144, O-4195, O-5015, P-1468, P-2416, P-2424, P-3626, P-4447, P-4472, P-4867
Palmer, Adrian P	O-4085
Palmer, Adrian P.	O-4088, P-1472, P-2271, P-3441, P-3445, P-4862
Palmer, Alan	<u>P-1624</u>
Palmer, Jonathan	O-3190, O-4204, P-4492
Palmer, Jonathan G	O-2108
Palmer, Jonthan	O-3194
Palmer, Julie	P-1624
Palmer, Suzanne	O-1156, <u>O-3089</u> , P-1037, P-1467
Palmisano, Alessio	O-5078
Palmqvist, Paul	O-3182, P-1216
Palmu, Jukka-Pekka	O-4126, P-1846, P-4831
Palombo, Maria Rita	O-4135, P-1234, P-4202
Palstra, Sanne	P-4835
Panagiotakopulu, Eva	P-3221
PANAGIOTAKOPULU, EVA	<u>O-3026</u> , <u>P-4297</u>
Panagiotopoulos, Konstantinos	O-3150, P-2477
Panaiotu, Cristian	P-4260
Pandey, Shilpa	<u>P-2008</u>
Pangui, Edouard	P-1435
Panin, Andrei	<u>P-3856</u> , P-4855, <u>P-4865</u>
Panin, Andrey	P-4845, P-4852
Panizzo, Virginia	P-2221, P-4246
Pannes, André	P-2510
Pant, Naresh Chandra	P-2893
Pant, Naresh. C.	O-2070
Pantoja, Silvio	O-4055
Pantosti, Daniela	P-3040
Papa, Rey Donne	O-5076
Papanikolaou, Ioannis	O-4029, P-3039
Papenmeier, Svenja	P-3006



INQUA 2019  
DUBLIN  
IRELAND

Papikyan, Astghik	O-2162
Papina, Tatjana	P-2264
Papini, Mauro	P-3804
Papkina, Alena	P-3882
Papp, Eva	P-1823
Pardi, Melissa	<u>O-3180</u>
Pardiwalla, Yezad	<u>O-2066</u>
Pardoe, Heather	<u>P-1275</u> , <u>P-4283</u>
Parducci, Laura	O-1101, <u>P-1201</u>
Parfitt, Simon	O-5040
Parham, Peter	P-1057
Paris, Clément	P-3875
Parish, Meredith	O-0021
Park, Junghun	P-4617
Park, Ki Ju	P-3830
Park, Sujeong	P-1223, P-3008
Parker, Adrian	<u>O-3108</u> , P-3476
Parkes, Matthew	<u>O-1057</u>
Parnachov, Sergey	P-3826
Parnell, Andrew	O-3008, <u>O-4148</u> , P-4406
Parow-Souchon, Hannah	<u>O-2045</u>
Parrenin, Frederic	O-4211
Parrenin, Frédéric	O-4014
participants, Expedition 374	P-4519
Parton, Ash	P-3476
Parés, Josep M.	P-4276
Pascucci, Vincenzo	O-1153
Pashley, Vanessa	O-5031
Pastre, Jean-François	O-1039
Patel, Narendra K.	<u>P-2888</u>
Patel, Raman	O-2069
Patel, Tasnim	<u>O-3162</u> , P-3045
Paterson, Andrew	O-5074



INQUA 2019  
DUBLIN  
IRELAND

Pati, Pitambar	P-2888, <u>P-4008</u>
Patil, S.K.	P-4290
Patiño-Rosario, Silvana	O-3195
Patole-Edoumba, Elise	P-1452
Patricia, Cabello	O-4106
Patten, Danika	O-0159
Patterson, R. Timothy	<u>O-0077</u>
Patterson, Rachel	O-2035
Patterson, Tim	O-2035
Patton, Henry	O-5118, <u>O-5129</u> , P-3484
Patton, Nicholas	P-1484, P-2601, P-2607
Pató, Zsuzsanna Anna	<u>P-2213</u>
Paul Töchterle, Paul	O-4146
Paulen, Roger	<u>O-0127</u> , P-1863, <u>P-4840</u> , P-4841
Paulet, Yves-Marie	P-1029
Paumard, Victorien	O-2085
Paus, Aage	O-1162
Pavez, Jennifer	P-4017
Pavlenok, Galina	<u>O-0135</u>
Pavlova, Irina	O-2020
Pawar, Vikas	O-2151
Pawlak, Jacek	O-1204, <u>P-4501</u>
Pawley, Steven	O-5042
Pawłowska, Kamilla	<u>O-2168</u>
Pawłowski, Dominik	O-1020
Payne, Richard	O-2202, P-2209
Payo Garcia, Andres	P-1025
Pazonyi, Piroska	O-0122
Peaple, Mark	O-3110
Pearce, Christof	O-1189, O-1233, O-2189, P-2490, P-2493, P-2495
Pearce, Danni	<u>O-4033</u> , P-1883, P-3822
Pearce, Nicholas J G	P-1617
Pearce, Nick	P-4460



INQUA 2019  
DUBLIN  
IRELAND

Pearce, Petra	O-0090
Pearce, Richard	O-1075
Pears, Ben	<u>O-4050</u> , P-3204
Pearson, Charlotte	O-3190, P-3613, <u>P-3614</u> , <u>P-4440</u>
Pearson, D. Graham	P-1610
Pearson, Emma	O-4174, P-3805
Peat, David	O-5023
Pedersen, Ben	P-2259
Pedersen, Mikkel	O-1100, P-1201
Pedersen, Stig A. Schack	O-1129
Pederson, Gregory	P-2238
Pederzani, Sarah	<u>O-0073</u>
Pedraza, Javier	P-1486, <u>P-1885</u> , P-2851
Pedrazzi, Dario	O-1042
Pedros, Pablo	O-3188
Pedro, Joel	O-4020, O-4097, P-4494
Pedro, Joel Benjamin	O-4098
Pedrotta, Tiziana	O-0099, P-1258
Peeters, Frank	P-1406
Peeters, Jan	O-0001, O-4212
Peglar, Sylvia M.	O-2029
Pelleter, Ewan	P-4402
Pelletier, Jon	O-1206
Pelletier, Nicolas	<u>P-1809</u>
Pellicer, Xavier	<u>O-1197</u> , <u>O-2192</u>
Pelling, Ruth	O-5079
Pellissier, Loic	P-3229
Pellitero, Ramón	P-3231
Pellitero-Ondicol, Ramon	P-4827
Peltier, Carly	O-4019, <u>O-4164</u> , <u>P-2518</u>
Peltier, Richard	O-0081, P-3407
Peltier, W. Richard	O-1009
Pena, Leopoldo D.	P-3494, P-3495



INQUA 2019  
DUBLIN  
IRELAND

Penaud, Aurelie	P-3490
Pendea, Florin	P-4260
Pendleton, Simon	O-0115
Peng, Fei	O-0139, P-4267
Peng, Shasha	P-1005
Peng, Zhiyuan	O-2079
Penkman, Kirsty	O-0078, O-4115, <u>O-5040</u> , P-4236, P-4601, <u>P-4618</u> , P-4631
Penny, Dan	O-0157, O-1092, P-1253, P-1284
Pepe, Caterina	O-1138
Pepin, Nicholas	P-2436
Peralta, Eva	O-3175, P-1259
Perchiazzi, Natale	P-2472
Perea, Ramon	O-2032
Perego, Renata	O-1097
Pereira, Alison	O-1163, P-2472
Pereira, Diamantino	P-2883
Perez Filho, Archimedes	P-2879, P-2881
Perez, Laura	<u>P-3460</u>
Perez, Marta	O-1126, O-1161
Perez-Lopez, Raúl	<u>P-1427</u> , <u>P-4830</u>
Perez-Mejias, Carlos	P-2507
Peric, Zoran	P-1628, P-4443
Perica, Dražen	P-2818
Perkins, Andrew	O-1131
Perkins, James	<u>P-4220</u>
Perner, Kerstin	P-2490
Peros, Matthew	P-1044, <u>P-2224</u> , P-2506, <u>P-2812</u>
Perotti, Luigi	P-4832
Perron, J Taylor	O-1070
Perry, George	O-2136
Perry, Linda	O-4027
Persson, Per	P-4438
Perucha, M. Ángeles	P-4804



INQUA 2019  
DUBLIN  
IRELAND

Perucha, María A.	P-4802
Peruzza, Laura	O-4120
Pessenda, Luiz	O-2004, P-4007, P-4026
Pestova, Ludmila	P-2622
Pestryakova, Luidmilla	O-5021
Pestryakova, Lyudmila	P-3458
Petchey, Fiona	<u>O-5104</u>
Peteet, Dorothy	O-3199, P-4853
Peterschmitt, Jean-Yves	<u>P-4421</u>
Petersen, Kenneth	O-3214
Peterson, Gustaf	<u>O-0044</u> , <u>P-2910</u> , <u>P-4842</u>
Petherick, Lynda	<u>O-4007</u> , P-3024, P-3501, <u>P-3503</u>
Peti, Leonie	O-4012, <u>O-4116</u> , P-1469, <u>P-1470</u>
Petit, Jean-Robert	O-5064
Petre, Alexandru	P-2459
Petrie, Cameron	O-2148, O-2151
Petrini, Michele	O-3227
Petrosyan, Artur	P-1601
Petrov, Oleg	<u>O-2196</u>
Petrova, Vanya	P-1261
Petrova, Vera	O-3205
Pey, Jorge	P-2841
Peyron, Odile	P-2477, P-3490
Peña, Juan Carlos	O-3080, P-3851
Peña-Monne, Jose-Luis	P-2440
Peñuelas, Josep	O-2132
Pfaffner, Nora	<u>P-3885</u>
Phadtare, N.R.	P-1460
Phartiyal, Binita	O-2002, <u>O-2156</u> , P-2432
Phase 2, GPWG	P-1820
Philcox, Michael	<u>O-5017</u>
Phillips, Emrys	O-0127, O-3202, <u>O-5119</u> , <u>P-1069</u> , P-1070, P-1074, <u>P-1866</u> , P-1867, P-1903, P-3818, <u>P-4823</u> , P-4833



Phillips, Fred	O-1067
Phillips, Hazel	<u>P-3429</u>
Phillips, Marcia	P-1860
Phipps, Steve	P-3473
Phipps, Steven	<u>P-1480</u> , <u>P-4423</u>
Phua, Marcus	<u>O-1118</u> , P-1615
Phulara, Mohit	P-4534
Pickarski, Nadine	<u>P-1814</u> , P-4621
Pickering, Robyn	<u>O-4172</u> , <u>P-1878</u> , P-2235, P-3807
Pickles, Brian John	<u>O-3177</u>
Pico, Tamara	O-0029, <u>O-0032</u> , P-1066
Pidek, Irena	<u>O-1165</u> , <u>P-4638</u>
Pidek, Irena A.	P-1243, P-4224
Pienitz, Reinhard	O-5035
Pierce, Kenneth	O-1064
Pierik, Harm Jan	<u>O-1078</u> , O-1098, O-3082, <u>P-3852</u>
Pieruccini, Pierluigi	<u>O-5036</u> , O-5108
Pigois, Jon-Philippe	O-4092
Piilo, Sanna	O-2051, <u>P-2853</u> , P-2857
Pike, Joshua H.	<u>P-4862</u>
Pilaar Birch, Suzanne	<u>O-5123</u>
Pilaar Birch, Suzanne E.	O-5122
Pilar, Jeanneret	<u>O-4194</u>
Pilarczyk, Jessica	<u>O-3008</u> , O-3167
Pilgrim, Julien	P-4639
Pillans, Brad	P-1823
Pilloix, Malo	P-2865
Pilotto, Francesca	O-5120, <u>P-4418</u>
Piloyan, Artak	P-3606
Pimentel, Christopher	O-3174
Pinder, Robyn C.	<u>P-4277</u>
Pineau, Rozenn	O-2135
Pinheiro, Vanessa	P-4007



INQUA 2019  
DUBLIN  
IRELAND

Pini, Roberta	<u>O-1168</u> , O-3224, <u>P-1235</u> , P-3430, P-3498
Pinkerneil, Sylvia	O-5034, P-3439
Pino, David	O-3004, P-3846
Pint, Anna	O-0002, O-1228, <u>O-3106</u> , O-3162, O-3166, P-3045, P-3448, P-4009, <u>P-4014</u>
Pinto Llona, Ana Cristina	P-1236
Pinto, Joaquim G.	O-0009
Pinzi, Stefania	P-3040
Pinzón, Flory	O-2161
Piotrowska, Natalia	O-0094, O-2204, <u>O-4181</u>
Piotrowski, Jan A.	O-0049, <u>O-1201</u> , O-2141, P-2816
Piovan, Silvia	P-3844
Piovesan, Gianluca	P-3431
Piraquive Bermudez, Daniela	<u>O-2205</u> , <u>P-4295</u>
Piret, Loic	<u>O-2094</u> , <u>P-4856</u>
Pirson, Felix	P-4014
Pisano, Maria	P-2211
Pisareva, Valentina	P-4845
Pisaric, Michael	<u>O-4209</u> , P-1206, P-2218
Pisarska-Jamrozy, Małgorzata	<u>O-1128</u>
Pisarska-Jamroży, Malgorzata	P-3864
Pisarska-Jamroży, Małgorzata	P-2824, P-2825, P-2827
Pisarska-Jamroży, Małgorzata (Gosia)	P-1879, P-2822
Pitelkova, Iva	O-3025, P-1202
Pither, Jason	O-3177
Pittard, Mark	O-3228
Pitura, Mateusz	<u>P-1902</u>
Pizzimenti, Luca	P-3021
Piñeiro-Juncal, Nerea	<u>P-2012</u>
Piñero, Pedro	P-2204
Pla-Rabes, Sergi	<u>O-2030</u> , O-3174, P-1495
Placencia, Juan A.	P-3838
Plak, Andrzej	P-1243, P-4224



INQUA 2019  
DUBLIN  
IRELAND

Planke, Sverre	O-4129
Plessen, Birgit	O-1228, O-2155, O-2161, O-3106, O-4086, O-4202, <u>O-5034</u> , P-3417, P-3439, P-3489, P-4444, P-4449
Plets, Ruth	<u>O-2088</u> , O-5062, <u>P-2004</u> , P-2007, P-2497
Ploom, Kuldev	<u>P-1838</u>
Ploug, Johan	O-1233
Plummer, Christopher	P-3468
Plummer, Mitchell	O-2021
Plunkett, Gill	O-1172, <u>O-2027</u> , O-3113, P-3204, P-4220, P-4438
Poblete, Fernando	P-3048
Poblome, Jeroen	O-2049
Poch, Rosa María	O-2048
Pochat, Stéphane	P-4839
Pochocka-Szwarc, Katarzyna	P-4641
Poetter, Stephan	P-1635
Poglajen, Sašo	P-1041
Pohl, Henrik	P-2273
Poinar, Hendrik	O-0041, O-1025, P-1206, P-2218, Plen02
Pokhrel, Prakash	O-4045
Pokines, James	O-4201
Pokines, James T.	O-2043
Polanco-Martínez, Josué M.	P-2471
Polkinghorne, Martin	P-1253
Poll, Christian	P-4228
Pollard, David	O-1236, O-3226, O-3230, P-1401
Pollard, Edward	O-0150
Pollard, Timothy	<u>P-2480</u>
Pollock, Lukas	P-4851
Polo-Díaz, Ana	<u>O-2048</u> , P-4231
Polom, Ulrich	P-3863, P-4851
Polshin, Vladimir	O-3055
Polydorou, Miltiadis	P-3064
Pompeani, David	O-0021



INQUA 2019  
DUBLIN  
IRELAND

Pompei, María de la Paz	P-1259
Ponce, Juan Federico	P-4482
Ponche, Jean Luc	P-1452
Ponomarenko, Elena	P-3884, P-4300
Ponomarev, Alexander Andreevich	P-3869
Ponomarev, Andrey Alexandrovich	P-3869
Ponomareva, Vera	O-3042
Popescu, Răzvan	P-2459
Popit, Tomislav	O-4208
Popov, Alexei	O-0056
Popova, Lilia	P-4206
Popp, Trevor	O-2015
Poraj-Górska, Anna	<u>P-4244</u> , P-4619
Porat, Naomi	O-0050, P-3850
Porcayo, Antonio	P-1003
Porch, Nicholas	O-3069
Porfido, Sabina	O-4044, P-4806
Porinchu, Dave	O-0125
Porinchu, David	<u>P-2220</u>
Porter, Trevor	O-2213, Plen02
Portillo Sotelo, Jose Luis	P-4819
Poska, Anneli	O-5010
Posnansky, Merrick	O-3095
Pospelova, Vera	<u>O-4217</u>
Possnert, Göran	P-4617
Potito, Aaron	<u>O-4160</u>
Potter, Ben A.	P-1210
Potts, Alastair	O-4015
Potì, Alessandro	O-5024
Poulenard, Jérôme	O-1024, O-4006, P-1214
Pourmand, Ali	P-1502
Power, Matthew	O-1099
Power, Mitchell	O-3214, P-1263, <u>P-4288</u>



INQUA 2019  
DUBLIN  
IRELAND

Power, Mitchell J.	O-3140
Powers, Michael	O-0152
Połtowicz-Bobak, Marta	P-3873
Prado, Luciana	P-2425, <u>P-3465</u>
Prado, Patricia	P-4024
Praeg, Daniel	O-5060, O-5128, P-4001, <u>P-4004</u>
Praet, Nore	P-3619
Prampolini, Mariacristina	P-4029
Prange, Matthias	P-1406, P-1420, P-1483, P-3485
Prasad, S.	O-5013, O-5014
Prasad, Srinivasan	O-2158, P-1457, P-1458
Pratap, Arti	P-3044
Pratiwi, Adnya	P-3219
Pratte, Steve	O-2210, <u>P-1431</u>
Prebble, Joe	P-4492
Prebble, Joseph	P-4499
Prebble, Matthew	O-5099, P-3209
Preece, Katie	<u>O-1180</u> , O-1181, P-4270
Preece, Richard	O-5040
Prendergast, Amy	<u>O-0074</u> , O-2044, <u>P-1504</u> , <u>P-1510</u>
Prendergast, Amy L.	O-4175
Prentice, I. Colin	O-3149, <u>P-1493</u>
Prentice, Stephen	P-1233
Preoteasa, Luminita	<u>P-2230</u>
Preoteasa, Luminița	P-4260
Preoteasa, Luminița	O-4108
Preston, Gareth	O-3108, P-3476
Preusser, Frank	O-3108, O-4056, <u>O-4119</u> , P-1897, P-3476, P-4614
Previtali, Franco	P-2429
Prevosti, Francisco	P-4264
Price, Gilbert	O-4093
Priestley, Stacey	<u>O-4092</u> , <u>P-4488</u>
Primmer, Nicholas	O-2107



INQUA 2019  
DUBLIN  
IRELAND

Prins, Lasse Tésik	<u>O-0005</u>
Prins, Maarten A.	O-3125
Priya, Priya	<u>P-2604</u>
Prochazka, Vaclav	P-3627
Proctor, Chris	P-2809
Prohaska, Thomas	O-0063
Project Members, FACSIMILE	P-1907
Prospero, Joseph	O-0092
Pross, Jörg	O-3036
Prothro, Lindsay	<u>O-5057</u>
PRUD'HOMME, Charlotte	O-5115
Prud'homme, Charlotte	O-1193, O-2218, O-3044, <u>O-4066</u> , P-1428, P-1628, <u>P-1869</u> , P-4294, P-4443
Prufer, Keith	O-4078
Pruner, Peter	P-2806
Pruner, Petr	O-1204, O-2071, P-4523
Przybylo, Piotr	O-1233
Psenner, Roland	O-2093
Pucha-Cofrep, Darwin	O-3195
Pudasaini, Shiva	P-3059
Pukelytė, Violeta	<u>P-2912</u>
Pupo, Felipe Matos	P-2224
Purcell, Catriona	O-1055
PURDUE, Louise	P-4229
Puseman, Kathryn	P-2238
Puspaningrum, Mika	<u>P-4208</u>
Pustoc'h, François	P-4632
Putici (Pascal), Maria Daniela	<u>P-2459</u>
Putkinen, Niko	P-4831
Putnam, Aaron	O-1087, O-4021, P-1856
Puzanova, Tatiana	P-3882
Puzzilli, Luca Maria	P-4820
Pyne, Rebecca	O-1088



INQUA 2019  
DUBLIN  
IRELAND

Pyne-O'Donnell, Sean	<u>P-3616</u>
Pál, Ilona	O-0122
Pálsson, Gísli	P-4425
Pärn, Joonas	P-2469
Pélachs-Mañosa, Albert	P-2851
Pérez, Carlos	P-1266, P-2841
Pérez, Liseth	O-3221
Pérez, Pablo	P-1017
Pérez-Alberti, Augusto	P-1486
Pérez-Arlucea, Marta	O-4106
Pérez-Asensio, Jose N.	P-3495
Pérez-Asensio, José N.	P-3494
Pérez-Díaz, Sebastián	P-1011, P-1817, P-4019
Pérez-López, Raúl	<u>P-4802</u> , P-4804
Pérez-Mejías, Carlos	O-3222, P-4451
Pérez-González, Alfredo	P-2899
Pötter, Stephan	<u>P-1614</u> , P-2813
Qiang, Xiaoke	P-1424
Qin, Huafeng	P-4522
Qin, Jintang	O-0119
Qin, Jungan	O-1175
Qin, Xiaoguang	<u>O-0023</u> , P-1913, P-2228, P-3828
Qiu, Fengyue	O-0119, P-1031
Qiu, Shifan	O-2163
Qu, CHEN	P-4021
Quade, Jay	O-3030
Quak, Justin	O-5076
Questiaux, Daniele	O-3064
Quick, Lynne	<u>O-4015</u>
Quick, Lynne J.	O-1214
Quik, Cindy	P-3858
Quillet, Anne	<u>O-2052</u>
Quincey, Duncan	O-1143, O-1144, O-1145, O-3201, O-5086



Quinlan, Roberto	O-0125
Quinn, Rhonda L.	O-4171
Quinn, Rory	O-2088, P-2004, P-2007
Quintana Krupinski, Nadine	<u>O-2185</u>
Quiquet, Aurélien	<u>O-1014</u>
Quiroga, Gisela	O-3175
Quittmeyer, Richard	O-4188
Quix, Eva	P-3049
R. Strecker, Manfred	P-1034
Raab, Thomas	P-4824, <u>P-4826</u>
Raatikainen, Markus	O-2144
Rabanser, Monika	O-1132
Rabbani, Maria	<u>O-4082</u>
Rabbel, Wolfgang	O-4031, P-3039
Raberg, Jonathan	O-1099
Rabett, Ryan	P-3230
Rabideaux, Nathan	P-4278
Rabot, Alexandre	O-2126
Rabumbulu, Mulalo	O-3034
Rach, Oliver	O-1045, O-1226, O-2080
Rachlewicz, Grzegorz	P-1867
Racko, Stanislav	O-3155
Raczyk, Jerzy	O-1190, O-1196, P-1634, P-1636
Radbourne, Alan D	P-4237
Rademaker, Kurt	O-1087, P-1856
Rades, Eike F.	<u>P-2452</u>
Radulov, Alexander	P-3865
Rae, James	O-1008, <u>O-1086</u>
Raffa, Francesco	P-1013
Raffaele, Sardella	<u>P-2208</u>
Rahaman, Waliur	P-4025
Rahimzadeh, Neda	<u>P-4622</u>
Rahman, Mubashshera	<u>P-4261</u>



INQUA 2019  
DUBLIN  
IRELAND

Raible, Christoph C.	P-1482, P-4298, P-4414
Raidla, Valle	P-2469
Raigemborn, María Sol	P-4524
Raingear, Anne	P-1833
Raisbeck, Grant	P-4617
Rajaguru, Sharad	P-3832
Rallings, Taran	P-3218
Ralph, Timothy	P-4485
Ramamonjisoa, Zanajaoarimanana	O-3061
Rambeau, Claire	O-4056, O-4119, P-3849
Ramil-Rego, Pablo	P-1220
Ramirez Ruiz, Veronica	O-5097
Ramirez, Alec Benjamin	O-3163, P-3058
Ramirez-Pedraza, Iván	P-2808
Ramisch, Arne	<u>O-1212</u>
Ramos, Noelyna	O-3163, P-3033, <u>P-3058</u>
Ramos- Scharrón, Carlos	O-1002
Ramos-Román, María J.	O-3151, <u>P-3493</u>
Ramsey, C	O-4042
Ramspott, Matthew	P-1826
Ramstein, Gilles	<u>O-2119</u> , <u>P-2481</u>
Ranathunga Arachchige, Keerthika Nirmani	<u>P-3880</u>
Randolph-Quinney, Patrick	P-2234
Rangel, Adriane	<u>O-2091</u>
RANHOTRA, PARMINDER SINGH	<u>P-4290</u>
Ranhotra, Parminder Singh	<u>P-4534</u>
Rani, Supriya	O-0151
Ranivoharimanana, Lovasoa	O-1108
Ranjbaran, Mohsen	P-3404
Ranner, Helen	P-2257
Rao, Zhiguo	O-2163
Raposeiro, Pedro M	O-3174



INQUA 2019  
DUBLIN  
IRELAND

Raposeiro, Pedro M.	P-1495
Rapuc, William	P-2262, P-4240
Rasbold, Giliane	P-3234
Rasbury, Troy	O-3010
Raschke, Elena	P-1215
Rasmussen, Craig	O-1206
Rasmussen, Peter	O-1173
Rasmussen, Sune O.	O-4014
Rasmussen, Sune Olander	O-4008, O-4009, <u>O-4098</u> , P-4455
Rasmussen, Tine L.	O-4075
Rast, Sebastian	P-1432
Ratajczak, Zak	O-2059
Ratajczak-Szczerba, Magdalena	O-1020
Ratcliffe, Joshua	O-2133, P-2872
Raub, Tim D.	P-3805
Rauh, Patricia	<u>P-2446</u> , P-3884
Ravalason, Holy	O-2174
Ravazzi, Cesare	O-1097, O-1168, O-3224, P-1235, P-2210, P-3430, P-3498
Raven, Mathew	O-3184
Ravier, Edouard	<u>P-4839</u>
RAVINDRA RAO, ARJUN	<u>O-1170</u> , <u>P-3228</u>
Rawat, Ashish	P-2461
Rawat, Suman Lata	P-1459, <u>P-1460</u>
Rawat, Varsha	<u>P-1459</u>
Rawling III, J Elmo	<u>P-1853</u>
Rawlinson, Aaron	<u>O-1019</u> , O-1217, <u>P-1271</u> , P-1290
Ray, Jessica	O-1185, <u>P-1442</u>
Ray, Jyotiranjana S	O-2123
Razafimbelo, Tantely	P-3236
Razali, Nur Fairuz Binte	P-1615
Razanamahandry, Vao Fenotiana	P-3236
Razjigaeva, Nadezhda	P-1058
Rea, Brice	O-2143, O-4033, O-4133, <u>O-5058</u> , P-1846, P-2439



Reade, Hazel	<u>O-3181</u> , <u>P-4427</u>
Reading, Peter	O-0158
Readitt, Emma V. A.	<u>P-1465</u> , <u>P-3046</u>
Rebotim, Andreia	P-4508
Recasens, Cristina	O-3046
Recio Espejo, Joes Manuel	O-3124
Redon, Bérangère	O-2126
Ree, Richard H.	O-1028
Reed, Jane M.	P-3422
Reed, Liz	O-2076, P-2604
Rees, Andrew	O-2133, O-3145, O-4012, <u>O-5007</u> , P-2872, P-3470, P-4492, P-4499
Rees, Andrew B.H.	P-4604
Rees, Callum	P-1624
Rees-Hughes, Luis	<u>O-1200</u> , <u>P-1047</u>
Rees-Owen, Rhian	O-1008
Reeves, Jessica	O-3066
Regard, Vincent	P-3505
Regattieri, Eleonora	O-1163, O-2124, O-4211, <u>P-2472</u> , P-2480, P-3488
Reghu, Navya	<u>P-2219</u>
Regnell, Carl	O-1130
Regnéll, Carl	O-5019, <u>P-1892</u> , <u>P-4859</u>
Rehfeld, Kira	O-5124, P-4405
Rehn, Emma	<u>O-1047</u>
Reicherter, Klaus	O-4029, O-4048, <u>O-4122</u> , P-3039, <u>P-3047</u> , P-3053, P-3054, <u>P-4819</u>
Reid, Brian	O-3157, O-4055, P-3840
Reid, Michael	P-4239
Reilly, Brendan	O-5091
Reilly, Brendan T.	P-1454
Reilly, Eileen	O-2025
Reimann, Tony	P-1839, P-3837, P-4609
Reimchen, Thomas	P-2203



INQUA 2019  
DUBLIN  
IRELAND

Reimer, Paula	O-1008, O-1154, <u>O-3190</u> , O-3191, O-4205, P-1063, P-2232
Reimer, Paula J	<u>P-4237</u>
Reimer, Paula J.	O-2152, O-3196
reimer, peter	P-2856, P-4212
Reimer, Ron	O-3190
Reimink, Jesse	P-1410
Reinardy, Benedict	O-2127, <u>P-1073</u> , P-2438, <u>P-3822</u>
Reindersma, Reinder	O-2193
Reinhardt, Eduard	P-2224
Reinhardt, Liam	<u>P-2237</u>
Reis, Luiza	<u>O-2004</u>
Reitalu, Triin	<u>O-2029</u> , P-2859
Reitner, Jürgen	O-0128, P-1871, P-2450
Reitner, Jürgen M.	<u>O-4190</u> , <u>P-2843</u>
Reize, Felix	O-3166
Rekant, Pavel	P-3005
Remmele, Sabine	P-3613
Remondo, Juan	P-4256
Ren, Xiaolin	<u>O-3105</u>
Ren, Zhikun	P-2821
Renaut, Robin	P-4278
Rendell, Andrew	O-3108
Renderu, William	P-3214
Rengefors, Karin	P-1004
Renken, Sabrina J.	<u>O-4071</u>
Renno, Jean-François	P-3462
Renou, Sylvain	P-3214
Renouf, John	P-4632
Renssen, Hans	P-1447
Repapis, Christos	P-3064
Repkina, Tatiana	P-4637
Repkina, Tatyana	P-3007
Requena-Rojas, Edilson J.	O-3195



Resk, Francis	O-4158
Retamosa Gámez, Jose Alberto	P-4819
Retelle, Michael	O-3203, O-5016
Rethemeyer, Janet	O-0028, P-1635
Rettori, Roberto	O-3153
Reuther, Joshua D.	P-1210
Revelles, Jordi	O-2120, P-2212
Rey, Fabian	O-2209, O-4084, O-4089, O-5004
Rey, Pierre-Jerome	O-4006
Rey-Iglesia, Alba	O-0040, P-1238
Reyes Macaya, Dharma	P-2246
Reyes, Alberto	<u>O-1115</u> , O-2117, O-2213, <u>P-1410</u> , P-4858
Reyes, Omar	O-4156, P-1262
Reynard, Jerome	P-2235
Reynhout, Scott	O-4164
Reynolds, Sally C	P-4529
Rezek, Zeljko	O-0052
Rezsöhazy, Jeanne	<u>O-4206</u>
Rhode, David	<u>O-2104</u> , <u>P-1003</u>
Rhodes, Rachael	O-1089, O-4211
Ribeiro, Maria Margarida	O-1101
Ribeiro, Sofia	O-1184, O-1185, P-1440
Ribolini, Adriano	O-1133, P-1013
Riboulot, Vincent	P-4402
Ricardo, Sarah	P-3233
Rice, Jessey	P-4841
Rich, Anne	O-1046
Richard, Maïlys	P-3476
Richards, David	O-3190, <u>O-4037</u> , <u>P-2810</u>
Richards, David A.	O-0061
Richards, Michael	P-2203, P-3214
Richards-Slidel, Eden	<u>P-4236</u>
Richardson, Sarah J	O-2054



Richer, Suzi	<u>O-1135</u> , O-5001
Richter, Detlev	P-4516
Richter, Marcus	<u>P-4624</u>
Richter, Nora	O-1043, O-3174
Rick, Torben	P-1251
Riddell, Scott	O-2208, <u>P-1260</u>
Ridush, Bogdan	P-4206
Riede, Felix	P-1621, P-3628
Riedesel, Svenja	<u>P-1617</u>
Rieger, Niclas	P-1449
Ries, Marie-Claire	P-2272
Rifai, Hamdi	O-1118, O-2112, P-1615
Rigot, Jean-Baptiste	<u>P-3855</u>
Rijal, Dilli P.	O-1027, <u>O-3025</u> , P-1202, <u>P-1209</u>
Rijal, Dilli Prasad	O-1105
Rilo, Ana	<u>P-1040</u>
Rimkus, Tomas	P-1035
RINTERKNECHT, Vincent	O-2016
Rinterknecht, Vincent	O-1151, P-2458, P-3409
Rinterknecht, Vincent R.	O-1053, P-2816
Rioual, Patrick	O-2005, O-2204, P-2423
Rippin, David	O-1143, O-4130
Riquelme, Rodrigo	O-4161
Riris, Philip	<u>O-4002</u>
Risberg, Jan	P-1046
Rittenour, Tammy	<u>O-1148</u> , O-3048, P-1438, P-1484, P-2601, P-2607
Ritter, Catarina	O-3174
Ritter, Joachim	O-4122
Rivals, Florent	<u>P-2808</u> , <u>P-3211</u>
Rivas, Victoria	P-4256
Rivera, Ai-ling	O-3156
Rivera-Collazo, Isabel	<u>O-0066</u> , <u>O-1155</u>
Riveron, Alain	O-1039



INQUA 2019  
DUBLIN  
IRELAND

Rixhon, Gilles	O-1220, O-4056, O-4119, P-3884, <u>P-4620</u>
Rizal, Yan	P-1610
Rižnar, Igor	O-4188
Robel, Alexander A.	O-1012
Roberge, Philippe	O-1187
Roberson, Sam	O-2192, P-1829
Robert, Xavier	O-4125
Roberti, Gioachino	P-3224, P-4832
Roberts, C Neil	<u>O-1126</u>
Roberts, Carole	O-5072
Roberts, Dave H	P-4843
Roberts, Dave H.	O-5063, P-4838
Roberts, David	O-0131, O-3230, <u>O-4133</u> , O-5061, O-5128, <u>O-5130</u> , P-1830, P-3818
Roberts, Georgia	O-4096, O-5096, P-4528
Roberts, Helen	O-1036, O-1160, O-4174, P-2445, P-4272
Roberts, Helen M	P-1617
Roberts, Helen M.	O-0150, O-1161, <u>O-4173</u> , O-4178, P-3805, P-4273, P-4277, P-4611, P-4615
Roberts, Jason	P-1480, P-3468
Roberts, Neil	O-5078
Roberts, Nicholas	O-5088, P-3224
Roberts, Patrick	O-2158, <u>O-5022</u>
Roberts, Phil	P-1823
Roberts, Richard	O-0103
Roberts, Stephen J	O-3183, P-4249
Roberts, William H. G.	O-0076
Robertson, Iain	<u>P-4537</u>
Robertson, Jenni	P-1036
Robin, Nicolas	P-3011
Robins, Lotem	P-2837
Robinson, Alexander	O-2040
Robinson, Erick	O-3170, O-3175, O-4003



INQUA 2019  
DUBLIN  
IRELAND

Robinson, Jose	<u>O-5097</u>
Robinson, Laura	O-4037, O-4072
Robinson, Mark	O-4001
Robinson, Ruth	P-3038
Robinson, Zoe	P-4866
Robson, Hannah	O-5072
Robson, Patrick	<u>O-1160</u> , P-1033
Robson, Patrick J.	O-0150, P-3805
Roche, Didier	O-2039, O-2042, P-4413, P-4458
Roche, Didier M	O-2038
Roche, Didier M.	O-1014
Roche, Helene	O-4171
Roche, Jenni	P-1230
Rockwell, Thomas	<u>O-4043</u> , O-4187, P-3865, <u>P-4821</u>
Rodbell, Donald	P-1509, P-2223
Rodehacke, Christian	P-3482
Rodes, Ángel	O-4168
Rodet, Joel	P-4264
Rodet, Joël	P-3232
Rodrigues, Suzan	P-2425, <u>P-4015</u>
Rodrigues, Teresa	O-2041, O-4069, P-2471, P-2484, <u>P-2486</u> , P-2488
Rodrigues, Érika	P-4007
Rodrigues, Érika F.	O-1083
Rodriguez, Jesús	P-4207
Rodriguez, Paulo Cesar	O-2095
Rodríguez, Jesús	O-4134, O-4135, <u>O-4137</u> , O-4138, P-4201, <u>P-4202</u>
Rodríguez, Juan Antonio	O-2195
Rodríguez, Paulo C	<u>P-4478</u>
Rodríguez-Gómez, Guillermo	<u>O-3182</u> , <u>P-1216</u>
Rodríguez-Oroz, Delia	<u>P-2442</u>
Rodríguez-Pascua, Miguel A.	P-4802, P-4804
Rodríguez-Ramírez, Antonio	P-4019
Rodríguez-Rodríguez, Laura	<u>O-1151</u> , P-1486, <u>P-3409</u>



Rodríguez-Tovar, Francisco Javier	P-2471
Rodríguez-Vidal, Joaquín	P-3056
Rodríguez-Zorro, Paula A.	<u>O-3060</u> , <u>P-3225</u>
Rodysill, Jessica	P-1499
Rodés, Angel	P-4479
Rodés, Ángel	P-1477, P-3484
Roe, Hannah	P-4866
Roe, Helen	<u>O-2035</u> , <u>P-1233</u>
Roe, Helen M.	O-0077
Roe, Kevin	O-4211
Roelofs, Lonneke	O-1078
Roettig, Christopher-B.	<u>O-3032</u>
Roettig, Christopher-Bastian	O-3047, O-3218
Rogers, Karyne	O-4007
ROGERSON, MICHAEL	O-2118
Rogerson, Mike	O-3071, <u>O-4146</u> , P-1407, P-3807
Rogov, Victor	P-1638, P-1639
Rogozhina, Irina	P-1420, P-1483, P-3485
Rohland, Stefanie	P-1208
Rohr, Christian	O-2209
Rojas, Alejandra	<u>P-4520</u>
Rojas, Maisa	O-5052, P-1433, <u>P-3473</u>
Roland, Thomas	<u>O-2133</u> , O-2202, P-2872
Roldan, Jimena	P-4232
Rolett, Barry	O-1171
Rolfe, Chris	<u>P-1485</u>
ROLFE, Christopher	P-2626
Roman, Małgorzata	<u>P-1893</u>
Romandini, Matteo	O-3224
Romanenko, Fedor	O-4191
Romanenko, Konstantin	P-1865
Romanos, Hector	<u>P-4284</u>
Romanos, Héctor	P-1266



INQUA 2019  
DUBLIN  
IRELAND

Romanowska, Iza	O-4135
Romero, María	P-2243
Romundset, Anders	P-3001
Ronchi, Livio	<u>O-2009</u> , O-3078, P-3017, <u>P-3845</u>
Ronge, Thomas	P-2521
Rook, Lorenzo	P-3804
Roquero, Elvira	<u>P-2889</u> , P-3497, P-4802, P-4804
Ros, Xavier	P-2851
Rose, James	O-1224
Rose, Jared	P-1619
Rose, Phil	O-5058
Roseby, Zoe	O-4127
Rosell, Jordi	P-2808
Rosell, Lorena	O-4125
Rosellò, Zoraida	P-2243
Rosen, Arlene M.	O-4025
Rosendahl, Daniel	P-3024
Rosentau, Alar	<u>P-1046</u> , P-4028
Rosenzweig, Ravid	O-1206
Roskin, Joel	P-2618, P-2837
Ross, Martin	O-2142, <u>O-4131</u> , <u>P-4841</u>
Ross, Peter	P-3043
Rossato, Sandro	O-1153, O-1168
Rossi, Veronica	O-2120
Rossignol, Linda	O-1018, O-2113, O-4077, <u>P-1605</u>
Rostek, Frauke	O-3060, P-3225
Rota, Emilia	O-1100
Rotaru, Sabin	O-4108, P-2230, P-4260
Rothacker, Leo	P-3879
Rother, Henrik	O-3146, P-1879, P-2427
Rothhaupt, Karl-Otto	P-4262
Roturier, Samuel	P-2218
Roucoux, Katherine	O-3037, P-2252, P-4233



Roucoux, Katherine H.	<u>P-1265</u>
Roudrigues, Erika	P-4026
Rouland, Sylvie	O-3061
Rousseau, Denis-Didier	O-1193, <u>P-1409</u> , P-1869, P-2215, P-2520
Routh, Joyanto	O-2158
Routson, Cody	P-1499
Rou�, Marie	P-2218
Rovere, Alessio	O-1235, <u>P-1053</u> , <u>P-3014</u> , P-3015
Rowan, Ann	O-1143, O-1145, <u>O-3201</u>
Rowe, Cassandra	O-1047, P-1065, P-1811
Rowson, James	P-2209
Roy, Biswajit	<u>P-3883</u>
Roy, Ipsita	P-4290
Roy, Keven	O-0081, O-3213, P-1057, P-1062
Roy, Martin	<u>O-5087</u> , P-1832, P-1882, P-2496
Roy, Sandrine	<u>O-4186</u>
Royles, Jessica	O-2133, P-2872
Royo, Elena	P-1266
Rubbelke, Claire	P-1819
Rubiales, Juan Manuel	P-1226
Rubio-Ingl�s, Ma Jes�s	O-3174
Rudaya, Natalia	<u>O-2003</u> , P-2264, P-4296
Ruddock, Julian	<u>O-1140</u>
Rudenko, Olga	O-4214, <u>P-2871</u> , <u>P-3004</u>
Rudinskaya, Anna	O-4191
Rudnickait�, Eugenija	<u>P-1875</u> , P-4848
Ruffell, Alastair	O-0046
Rugel, Georg	P-2446
Ruhi, Albert	O-2060
Ruiz Fern�ndez, Jes�s	P-3886
Ruiz, Francisco	P-3056
Ruiz, Lucas	P-4482
Ruiz, Paulina	P-4477



INQUA 2019  
DUBLIN  
IRELAND

Ruiz-Fernández, Jesús	O-3147
Ruiz-Sánchez, Francisco Javier	O-2167
Ruksys, Annabel	<u>O-2170</u>
Rule, Susan	O-2110, <u>O-3059</u> , <u>P-1823</u> , P-3216, P-4528
Rull, Valentí	O-3139, O-3174
Running, Garry	O-3048
Rusakov, Alexey	P-1639, P-1909, P-3610, P-3854, P-3888
Rush, Graham	<u>O-0080</u> , <u>P-2492</u>
Ruskeeniemi, Timo	O-4126
Russell, Andrew	O-0048, <u>P-1844</u>
Russell, James	O-1043, O-2098, O-2184, O-3058, O-4141, O-4169, O-4174, P-1819, P-3223
Russell, James M.	O-3057, P-1471
Russo Ermolli, Elda	P-1267
Russo, Emmanuele	<u>O-5055</u>
Rust, Alison	O-1113, P-1620
Rutherford, Ian	O-0157
Rutledal, Sunniva	O-3114, P-4459
Ryabchuk, Daria	<u>O-5127</u> , <u>P-2009</u> , P-3005
Ryabchuk, Darya	P-1032
Ryan, Ciara	O-0091
Ryan, Deirdre	P-1053
Ryan, Deirdre D.	O-1235, <u>P-1060</u>
Ryan, Matthew	O-2220, O-3145, O-4020, P-3466, <u>P-4465</u> , P-4492, <u>P-4499</u>
Ryan, Peter	O-3148
Ryberg, Eleonor	<u>P-2217</u>
Rybin, Eugeny P.	P-1278
Rybin, Evgeny	<u>O-0055</u> , O-0056, O-5094
Rychel, Joanna	O-2211, <u>P-2627</u> , <u>P-4641</u>
Rydberg, Johan	O-1084, O-3102
Rydningen, Tom Arne	O-5016
Rylova, Tatyana	P-4641
Ryoo, Chung-Ryul	<u>P-4807</u> , P-4813



INQUA 2019  
DUBLIN  
IRELAND

Ryu, Junghyung	O-1083, P-4026
Ryu, Uemura	O-0027
Ryves, Dave	P-4255
Ryves, David	P-2221, P-2504, P-4246
Ryves, David B	P-4237
Ryzner, Kamila	O-1190, O-1196, P-1633
Rzeszewski, Michał	P-3421
Rzodkiewicz, Monika	P-4411, <u>P-4412</u>
Räsänen, Aleksi	P-3437
Röhl, Ursula	O-4069
Rüpke, Lars	P-1478
Rüther, Denise C.	O-5131
S, Prasad	P-2219
S., Rostamabadi	P-3403
saad, asmadi	P-2856, P-4212
Saad, Asmadi	O-3136, P-1623
Saarinen, Juha	O-2166
Saarni, Saija	P-2260, P-3459
Saavedra-Pellitero, Mariem	O-1111, P-4490
Sabaa, Ashwaq	P-4499
Sabale, Pandurang	P-3832
Sabatier, Pierre	O-1024, O-4006, P-1214, P-1258, P-2262, P-4240
SABI OROU BOGO, Abib Guimmongui	O-0161
Sabiham, Supiandi	O-3136, P-1623
sabiham, supiandi	P-2856, P-4212
Sabine, Marjolaine	P-1405
Sabine, Wulf	P-4442
Sacchetti, Fabio	O-5062, P-2497
Sachs, Julian	P-4469
Sachse, Dirk	O-1045, O-1226, O-2080, O-4074, <u>O-4087</u> , P-2271, P-3493
Sacks, Bill	O-3227
Sadasivam, Senthil Kumar	O-4179, <u>P-1207</u> , <u>P-1213</u> , P-1904
Sadatzki, Henrik	P-1417, P-1442



INQUA 2019  
DUBLIN  
IRELAND

Sadchikova, Tamara	O-3205
Sadori, Laura	O-1137, <u>O-1138</u> , <u>P-1267</u> , P-2477
Sadoway, Tara	O-1025, Plen02
Sae-Lim, Jarunetr	O-1043
Saenger, Casey	P-4409
Safaraliev, Nosir	P-1428
Sagar, Stephen	P-3043
Sagawa, Takuya	O-1111
Sagnotti, Leonardo	P-3040, P-3431
Sagredo, Esteban	O-4164, P-2518
Sagy, Amir	P-2821
Sah, Ritu	O-4119
Saha, Koushik	P-2512
Saha, Sourav	O-1141
Sahakyan, Kristina	P-1602
Sahakyan, Lilit	P-1602, P-2815
Saher, Margot	O-1055, O-3230, O-5060, O-5063, O-5128, O-5130, P-1056
Sahnouni, Mohamed	P-4276
Sahu, Shivam	P-1288
Sahy, Diana	O-1205, O-4037, P-4274
Saifelislam, Nour	O-4048
Saini, Hari Singh	P-2893
Saini, Hari.S.	O-2070
Saini, Jeetendra	<u>P-1439</u>
Saini, Rakesh	<u>O-2105</u> , <u>P-1858</u>
Saitis, Giannis	P-3064
Saito, Fuyuki	P-2489
Saito, Kazuyuki	<u>P-2855</u>
Saito, Yoshiki	O-1079
SAITO, Yoshiki	<u>P-1010</u>
Saiz-Lopez, Alfonso	O-1186, P-4254
Sakamoto, Junya	O-2090
Sakata, Shuhei	P-3457



INQUA 2019  
DUBLIN  
IRELAND

Saklani, Pradeep	O-2069
Sala-Ramos, Robert	O-5025
Salazar, Gary	P-4505
Salazar, Kaleena	P-1434
Salazar, Ángel	<u>O-2195</u> , <u>P-2623</u>
Salem, Alaa	P-3486, P-3829
Salgueiro, Emilia	O-4069
Salgán, Laura	P-1259
Saliu, Francesco	O-1097
Salminen, Sarianna	<u>P-3459</u>
Salomon, Ferréol	O-4056, O-4119
Salomon, Roberto L.	O-2032
Salonen, J. Sakari	O-2029, <u>P-3440</u>
Salonen, Sakari	O-0034, P-1201
Saltanat, Alisher	O-3056
Salter, James	O-4150
Salter-Townshend, Michael	<u>P-4408</u>
Saltre, Frederik	P-3216
Saltré, Frédéric	O-0103
Salvador, Manuel	O-3182
Salvatore, Maria Cristina	O-0013
Salvatore, Peter	P-4818
Salzer, Matthew	P-3614, P-4440
Sampaio, Hugo A	O-1026
Samrat, Rahul	P-4235
Sams, Sarah E.	P-1483, P-3485
Samus, Alina	P-1909
San Román, Manuel	O-1157, P-1262, P-4264
Sana, Hamid	P-3865
Sanchez Goni, Maria Fernanda	P-1802
Sanchez-Goni, Maria Fernanda	O-2038
Sanchez-Goñi, Maria	P-2484
Sanchez-Goñi, Maria-Fernanda	O-4073



INQUA 2019  
DUBLIN  
IRELAND

Sanchez-Montes, Maria	O-2113
Sancho, Carlos	O-3222, P-1226, P-1872, P-2841, P-4451
Sanchèz-Goñi, Maria Fernanda	O-2041
Sander, Lasse	<u>P-3006</u>
Sanders, Diethard	P-1235, P-1871
Sanderson, David	P-2837
Sanderson, Nicole	P-2863
Sandgathe, Dennis	O-0073
Sandoval Ramos, Monica	O-1221
Sandro, Rossato	O-3078
Sanger, Matt	P-1251
Sanhueza, Lorena	O-0143
Sanjurjo, Jorge	O-1151, P-1488, P-2443
Sanjurjo-Sanchez, Jorge	O-2224
Sano, Masaki	P-1422
Santana Sagredo, Francisca	O-0143
Santana-Sagredo, Francisca	<u>P-1017</u>
Santander, Boris	O-4161
Santini, Talitha	P-2601
Santonja, Manuel	P-2899
Santoro, Calogero	O-4004, O-4155, O-4157
Santos, Guaciara M	<u>O-3195</u>
Santos, Luisa	P-4024
Sanyal, Prasanta	O-1120, P-1877, P-2512, P-3452, P-3883, P-4235
Sapelko, Tatyana	<u>P-3606</u> , <u>P-4253</u>
Sapera, Jamie	<u>P-1863</u>
Sapkota, Soma Nath	O-4045
Saqab, Mudasar	P-4001
Sarala, Pertti	<u>O-2144</u> , <u>P-1603</u>
Sarangi, Vijayananda	<u>O-1120</u> , <u>P-1877</u>
Sardans, Jordi	O-2132
Sardella, Raffaele	O-5108
Saresma, Maarit	P-4831



Sarmiento, Alexandra	P-4803
Sarnthein, Michael	O-1086, <u>P-2521</u>
Sarro, Roberto	P-4830
Sarti, Giovanni	<u>P-1013</u>
Sarti, Lucia	P-1607
Sarıkaya, M. Akif	<u>O-1069</u> , <u>P-1889</u>
Sarıkaya, Mehmet Akif	P-2447, P-3817, P-4476, P-4818
Sarış, Faize	P-2462
Sasaoka, Miho	P-1277
Sassoon, Dael	<u>P-1221</u>
Sataev, Robert	P-4234
Satake, Kenji	O-3090, P-3058
Sato, Hiromitsu	O-4140
Sato, Hiroyuki	O-4026
Satoguchi, Yasufumi	O-0118
Satow, Christopher	O-3036, P-4456
Sauer, Daniela	P-3885, <u>P-3887</u>
Sauer, Eberhard	P-3401
Saulnier-Copard, Ségolène	O-1039, P-3875
Saulnier-Talbot, Émilie	O-5035
Saunders, Krystyna	P-4252
Saunders, Krystyna M	<u>O-3183</u> , <u>P-4249</u>
Saunders, Krystyna M.	O-4055, P-3840
Sauter, Marion	P-2270
Sava, Tiberiu	O-4108, P-2459, P-4260
Sava, Tiberiu Bogdan	O-2011
Savard, Martine M.	O-0077
Savarino, Joel	<u>O-5064</u>
Savigny, Wayne	O-2170
Savov, Ivan	O-3115
Sawagaki, Takanobu	P-2444
Sawai, Yuki	O-3008, <u>O-3009</u> , <u>P-3025</u> , P-3029, P-3035
Sawakuchi, André	P-3225



INQUA 2019  
DUBLIN  
IRELAND

Sax, Dov	O-0120
Saxby, Jennifer	O-1113, <u>P-1620</u>
Sayavonkhamdy, Thongsa	P-1452
Sayer, Carl	P-1233
Sañudo, Pablo	P-2202
Sağlam-Selçuk, Azad	P-3842
Scaccia, David	<u>P-2891</u>
Scapozza, Cristian	P-1842, <u>P-4829</u>
Scarciglia, Fabio	<u>O-2046</u> , <u>P-3804</u>
Scardia, Giancarlo	O-2218, O-4066, <u>O-5106</u> , <u>P-3234</u> , P-4443
Scardino, Giovanni	P-3023
Scerri, Eleanor	<u>O-5098</u>
Schaebitz, Frank	O-1036, O-3031, O-4173, P-3805, P-4273
Schaefer, Joerg	O-4164, O-5087, P-2518
Schaetzl, Randall	<u>O-3048</u> , <u>P-1836</u>
Schafer, David	O-4092
Schaffernicht, Erik	O-0009
Schafstall, Nick	<u>O-4062</u>
Schalles, John F.	P-1251
Schanz, Federica	O-2209
Scheder, Juliane	<u>O-0002</u>
Schefuss, Enno	P-1449
Schefuß, Enno	O-0028, O-3109
Scheidt, Stephanie	P-1635
Schenk, Frederik	O-1226, <u>O-4074</u> , O-4087
Schenk, Fredrik	O-1084
Schepanski, Kerstin	P-3803
Schepper, Stijn de	O-1185
Scherer, Sascha	<u>P-4228</u>
Scherler, Dirk	O-1028, <u>O-2221</u> , P-2817
Schettler, Georg	P-3417
Schiestl, Robert	P-3843
Schiller, Christopher M	<u>O-2137</u>



INQUA 2019  
DUBLIN  
IRELAND

Schillereff, Daniel	O-1222
Schillereff, Daniel N.	<u>O-2128</u>
Schimmelmann, Arndt	O-3111
Schimmelpfennig, Irene	O-1053, O-3147, P-2441, P-2443, P-2453, P-2455, P-4482
Schirmer, Wolfgang	P-1628
Schirrmeister, Lutz	P-1215
Schleheck, David	P-4245
Schloemer, Stefan	P-2469
Schloesser, Fabian	P-1401
SCHLOLAUT, Gordon	P-4448
Schlolaut, Gordon	O-3193
Schlunegger, Fritz	P-1898, P-4511
Schläfli, Patrick	P-1898, <u>P-4511</u>
Schlüchter, Christian	<u>O-2191</u> , P-2451
Schlütz, Frank	O-0002, <u>O-0006</u> , P-3210
Schmid, Markus	P-3628
Schmidt, Christoph	O-2043, P-4445, <u>P-4606</u>
Schmidt, Johannes	<u>O-1223</u> , <u>P-1835</u> , P-3208
Schmidt, Sabine	O-3087, O-3188, P-1802
Schmitt, Laurent	<u>O-4056</u> , O-4119, <u>P-3849</u>
Schneider, Birgit	P-3803
Schneider, Christoph	<u>O-4162</u>
Schneider, Heike	P-2212
Schneider, Larissa	O-3137
Schneider, Nathalie	O-4056
Schneider, Raimund	P-3884
Schneider, Ralph	P-1457, P-1458, P-2493
Schneider, Tobias	O-2060
Schoch, Werner	P-2273
Schoeneich, Philippe	<u>P-2453</u> , P-2455, P-2457
Schoenrock, Kate	O-4033
Schofield, James E	<u>O-3027</u>
Schofield, James Edward	O-4033



INQUA 2019  
DUBLIN  
IRELAND

Schokker, Jeroen	<u>O-2193</u>
Scholten, Thomas	P-4228
Scholz, Christopher	<u>O-3112</u>
Scholz, Denis	O-3074, P-1519, P-2482, <u>P-4516</u>
Schomacker, Anders	O-3203, O-5016, P-1894
Schoorl, Jeroen	<u>O-1221</u> , P-1910, <u>P-3837</u> , P-4835
Schoorl, Jeroen M.	P-1839
Schouten, Stan	P-3446, P-4458
Schreuder, Laura T.	O-1045
Schreve, Danielle	O-0037, <u>O-2077</u> , P-1239, P-3217, P-4601
Schroeder, Nils	<u>P-2449</u>
Schröder-Ritzau, Andrea	O-3019
Schröder-Ritzau, Andrea	P-3049
Schubert, Carsten J.	<u>P-3428</u>
Schueler, Lisa	P-2247
Schulte, Lothar	O-2028, O-3007, <u>O-3080</u> , O-3083, O-5073, <u>P-3851</u>
Schulte, Luise	<u>O-1102</u>
Schulte, Philipp	<u>P-1627</u> , P-1628
Schulz, Cameron	O-4094, P-4489
Schulz, Christopher	P-1265
Schulz, Hartmut	O-3036
Schulz, Meike	P-4203
Schumacher, Jens	P-3480
Schumann, R. Randall	O-4215
Schuring, Tim	P-3852
Schuster, Mathieu	P-3806
Schwab, Markus J.	O-4086, P-3436, P-4444, P-4449
Schwab, Valérie F.	O-1228
Schwaiger, Helmut	P-4009
Schwalb, Antje	O-2155, <u>O-3221</u> , O-4074, P-2415, P-2423, P-2510, P-3443, P-4639
Schwamborn, Georg	P-1215, <u>P-3477</u>
Schwardt, Michaela	O-4031



INQUA 2019  
DUBLIN  
IRELAND

Schwarz, Anja	O-1228, O-2155, O-3106, P-2415, P-2423
Schwarzbauer, Jan	P-3054
Schwarzer, Johanna	P-1256
Schweinsberg, Avriel	O-0115, O-1064
Schwenk, Michael	P-4511
Schwenk, Michael A.	<u>P-1898</u>
Schwenninger, Jean-Luc	O-5023, P-1036, P-1052, P-2810, P-4601
Schweri, Lea	P-2446
Schwikowski, Margit	O-2209, P-2264
Schwörer, Christoph	<u>O-0015</u> , O-0099, O-2209, P-1203, <u>P-1205</u> , P-1226, P-4217
Schäbitz, Frank	O-4018, O-4174, P-2421, P-4272, P-4475
Schäfer, Andreas	P-1908
Schäfer, Dieter	P-2273
Schäfer, Joerg	O-1130
Schön, Isa	O-3162
Schön, Isabelle	P-3045
Schöne, Bernd	O-0074
Schöne, Bernd R.	P-2494
Schüler, Lisa	P-1232
Schüpbach, Simon	O-4008
Schüttrumpf, Holger	P-3059
Scifo, Andrea	O-1042
Scoto, Federico	<u>O-1186</u>
Scott, E Marian	O-3190
Scott, E. Marian	O-3191
Scott, George	O-4020, P-4499
Scott, Louis	O-4144
Scott, Reynhout	O-4019
Scott, Shawn	O-4131
Scotti, Oona	<u>O-4120</u> , P-4803
Scourse, James	O-1127, O-3230, O-5060, <u>O-5128</u>
Scourse, James D.	O-1161, P-2494
Scroxtton, Nick	<u>O-1108</u> , O-5124, <u>P-3807</u>



Sealy, Judith	P-2235
Sear, David	O-1075, O-3063, O-3117, <u>O-5101</u> , P-4466, P-4467, P-4468, P-4469
Seaton, Tom	O-0062
Sebag, David	P-1876
Sebastián, María	P-1255
Sechi, Daniele	O-1153
Secord, Ross	O-0060
Seddique, Ashraf Ali	<u>O-1006</u>
Seddon, Alistair	O-2034, <u>P-2251</u> , P-4420
Sedov, Sergey	P-3888, P-4847
Seeber, Leonardo	O-3010
Seeber, Peter A.	<u>P-2218</u>
Seeger, Katharina	O-3166
Seeliger, Martin	O-3166, <u>P-3843</u> , P-4014
Sefton, Juliet	O-0116, O-0132, P-1055
Seguel, Roxana	O-3169
Seguinot, Julien	P-1482, P-1890
Sehrt, Melissa	P-2273
Seidenkrantz, Marit-Solveig	O-0038, O-1159, <u>O-1233</u> , O-2185, O-2186, O-2189, <u>P-2490</u> , P-2493, P-2495, P-4441
Seiler, Martin	P-3824
Sejr, Mikael	P-1440
Sejrup, Hans Petter	O-0004, P-4631
Sejrup, Hans-Petter	O-3230
Selby, Katherine	O-4130, P-1014
Self, Angela	O-0125
Selkin, Peter A.	P-1454
Semaan, Lucy	P-4620
Sembroni, Andrea	P-2891, P-2892
Semenova, Ludmila	O-5037
Semikolennykh, Daria	<u>O-3054</u> , <u>P-3608</u>
Semochkina, Anna	P-1911



INQUA 2019  
DUBLIN  
IRELAND

Semon, Anna	P-1251
Seong, Chuntaek	O-4103
Seong, Yeong Bae	<u>P-3026</u>
Sepp, Holar	P-2469
Seppä, Heikki	<u>O-0038</u> , O-2029, O-2187
Sepulveda, Julio	O-1099
Sepúlveda, Julio	O-2188
Seregély, Timo	P-1908
Sergeev, Alexander	O-5127, P-1032, P-2009, P-3005
SERIN--TUIKALEPA, Iale	<u>P-2895</u>
Serna, Alejandro	O-0058
Serodio Domínguez, Andrea	P-2899
Seroussi, Helene	P-4837
Serpelloni, Enrico	P-3021
Serra, Elena	<u>P-2437</u>
Serrano, Oscar	P-2012
Serrano-Ramos, Alexia	O-2166
Servettaz, Aymeric	<u>P-3468</u>
Seto, Koji	P-1018, P-2261
SETO, Koji	<u>P-1019</u>
Settu, Selvaraj	<u>P-3012</u>
Setyaningsih, Christina	<u>O-3136</u> , <u>P-1623</u>
Sevastyanov, Dmitry	P-3606
Severinghaus, Jeffrey	O-1088
Sevilla, Miguel	P-4284
Sevilla-Callejo, Miguel	P-1266, P-2253
Sevillano, Ana	O-2195
Sevillano, Victor	P-2259
Sevink, Jan	P-1616
Seward, Diane	P-3624
Sewell, Lauren	<u>P-4532</u>
Sewell, Lauren C.	P-4529
Sha, Lijuan	P-1496



INQUA 2019  
DUBLIN  
IRELAND

Sha, Longbin	P-2490
Shackelford, Laura	P-1452
Shackleton, Calvin	O-5131
Shackleton, Sarah	O-1088
Shafiq, Muhammad	P-2221, P-4246
Shah, Parth	P-3454
Shah, Rayees Ahmad	<u>O-1112</u>
Shahack-Gross, Ruth	O-2122, P-1254
Shahinian, Samvel	P-1601
Shakun, Jeremy	<u>O-2117</u>
Shakun, Jeremy D.	P-3823
Shalaeva, Evgenia	P-3612
Shalagina, Aliona	O-0135
Shamsipour, Pejman	O-4131
Shang, Xue	<u>P-4210</u>
Shang, Yuan	<u>O-3125</u>
Shangina, Margarita	<u>O-3056</u> , <u>P-2231</u>
Shanhun, Fiona	P-4493
Shanks, Richard	O-4038
Shanmuganathan, Bhavatharini	<u>O-4179</u> , P-1213
Shao, Hai	O-0156
Shao, Konglan	P-3201
Shao, Xuemei	P-1422, P-4536, P-4538
Shao, Yaping	O-0009, P-2229
Shao, Yuexiao	<u>O-1005</u>
Shapiro, Beth	P-2218, <u>Plen02</u>
Sharan, Appu	O-2151
Sharifi, Arash	P-1502
Sharma, Anupam	O-2156, P-3841
Sharma, Choudhurimayum Pankaj Sharma	O-4053
Sharma, Milap	<u>O-1146</u>
Sharma, Milap Chand	O-1013, O-2105, P-1858, P-1896



Sharma, Shubhra	<u>O-2019</u> , <u>P-3831</u>
Sharon, Gonen	O-4202
Shatalova, Angelina	P-4028
Shaw, Helen	<u>O-1062</u> , <u>P-4285</u>
Shaw, John	O-5062
Shaw, Robert	O-0150, P-1033
Shaw, Tim	O-3213
Shaw, Timothy	<u>O-0081</u> , <u>P-1057</u> , P-1062
Shawler, Justin	O-1007
Sheard, Malcolm J.	O-1117
Sheehy, Michael	O-1197, O-2192
Sheffield, Justin	P-4467, P-4468
Sheinkman, Vladimir	P-3888, <u>P-4846</u> , <u>P-4847</u>
Shekhar, Mayank	P-4290, P-4534
Sheldon, Christina M.	P-2490
Shelef, Eitan	P-2821
Shelepaev, Roman	O-0056
Shen, Caiming	<u>O-1033</u> , P-2409
Shen, Chuan-Chou	O-0025, O-3219, O-5108, P-3033, P-3058
SHEN, Chuan-Chou	<u>O-0027</u>
SHEN, Ji	P-3426, <u>P-3456</u>
Shen, Ji	P-1500, P-2249, P-2406
Shen, Wei	P-4292
Shennan, Ian	O-0132, P-1059
Shennan, Stephen	O-5078
Shepherd, Francis	O-1161
Shepherd, Lara	P-4465
Sheremetskaya, Elena	O-4191, P-1909, P-1911, P-3854
Sherriff, Jenni	O-1180, O-1181, <u>P-1287</u> , P-1601, P-1602, <u>P-2615</u> , <u>P-4270</u>
Sherriff, Sophie	O-1145
Sherriff-Tadano, Sam	O-1085, <u>P-1411</u>
Shi, Pilong	P-2821
Shi, Xiaoxu	P-3482



Shi, Xuefa	P-1408
Shields, Graham	P-2911
Shilobod, Nika	O-1213, O-4060, P-4287
Shilova, Olga	P-4637
Shimada, Seiichi	P-1827
Shimada, Yumi	O-3008, P-3025, <u>P-3029</u>
Shimizu, Yuta	O-1006
Shin, Kyung-Hoon	O-4073
Shin, Seungwon	P-1606
Shindo, Lisa	P-4533
Shiner, Katarena	<u>P-4219</u>
Shinker, Jacqueline	O-3214
Shinozaki, Tetsuya	O-3008, P-3035
Shinozuka, Yoshitsugu	O-2161
Shiple, Benjamin	O-2135
Shirai, Masaaki	<u>P-3868</u>
Shirazi, Sabrina	Plen02
Shishikura, Masanobu	O-3008, P-3029
Shishkina, Yulia	P-3854
Shishkina, Yuliya	P-1909
Shkatova, Valentina	P-2622
Shnaider, Svetlana	O-3056, P-2231, P-2239
Shoocongdej, Rasmi	O-0123
Shorkunov, Ilya	P-1909, P-1911, P-3854
Shotter, Lauren	<u>O-1040</u> , <u>P-2869</u>
SHU, Jun-Wu	<u>P-1020</u>
Shu, Peixian	P-1498, <u>P-2836</u>
Shuaifei, Ping	P-2877
Shukla, Anil	O-2019, P-3831
Shulmeister, James	O-3146, O-4111, O-5086, <u>P-1484</u> , P-1487, P-1854, <u>P-2601</u> , P-2607, P-3501, P-3503
Shulmeister, Jamie	O-1148, O-1158
Shuman, Bryan	O-0021, P-1499



INQUA 2019  
DUBLIN  
IRELAND

Shuman, Bryan N.	O-5081
Shumilovskikh, Elena	P-3213
Shumilovskikh, Lyudmila	<u>O-1061</u> , O-3136, P-2871, <u>P-3213</u>
Shuster, David L.	P-1860
Siani, Giuseppe	P-2521
Sichanthongtip, Phonephanh	P-1452
Sicre, Marie-Alexandrine	P-2490
Sidorchuk, Aleksey	<u>O-3207</u> , <u>P-4825</u>
Siekacz, Liliana	P-4440
Sienkiewicz, Elwira	<u>P-4238</u>
Sier, Mark	O-4212
Sierpień, Paula	O-1204, <u>P-4523</u>
Sierra, Maria Jose	P-4254
Sierra-Fernández, Carlos	P-4256
Sierro, Francisco	O-1090
Sierro, Francisco J.	<u>O-3071</u> , O-3076, O-3154, O-4069
SIERRO, FRANCISCO, J.	<u>O-2118</u>
Sifeddine, Abdelfettah	O-3074, O-3109, P-1496
Sigfúsdóttir, Thorbjörg	O-1052, P-1866
Sigl, Michael	O-2209, <u>O-3113</u> , O-4014, P-2264, <u>P-2505</u> , P-4434, P-4437, P-4439, P-4452
Sigurðsson, Gunnar	O-3202
Sigurðsson, Oddur	O-3202
Sihanam, Daovee	P-1452
Sikorski, Jarosław	O-4181
Silva Sanchez, Noemi	O-2131
Silva, Ana Nobre	O-3088
Silva, Francisco	O-4056
Silva, Pablo G.	P-3497, P-4802, <u>P-4804</u>
Silva, Pablo Gabriel	P-2889
Silva, Sabrina Barroso	<u>P-2011</u>
Silva-Sánchez, Noemí	P-2873
Silvester, Ethan	<u>P-4438</u>



INQUA 2019  
DUBLIN  
IRELAND

Sim, Thomas	<u>O-2130</u> , O-2202
Siman-Tov, Lior	O-1206
Sime, Louise	<u>O-1089</u> , O-3183, O-3185, P-4403, P-4506, <u>P-4513</u> , <u>P-4517</u> , P-4517
Simkins, Lauren	<u>O-5059</u> , P-4005
Simmons, Kathleen R.	O-4215, P-2605
Simms, Alexander	<u>P-4005</u>
Simms, Alexander Ray	<u>O-0132</u>
Simms, Michael J.	<u>P-1063</u>
Simon, Blockley	P-4442
Simon, Dirk	O-0061
Simon, Krista	O-2096, P-1487
Simon, Margit	P-4495
Simon, Margit H.	P-1417
Simon, Quentin	P-3225
Simonsen, Marius Folden	O-2015
Simpson, Gavin	O-2060, <u>O-2061</u>
Simpson, Guy	P-3060
Simón, Jose Luis	O-1139
Sinclair, Anthony	P-4274
Singarayer, Joy	<u>O-3033</u> , O-4143, O-4145, P-4513
Singarayer, Joy S.	O-3206
Singh, Atul Kumar	<u>P-2900</u>
SINGH, EKTA	<u>O-2069</u>
Singh, Pramod	O-5014
Singh, Randheer	<u>O-2002</u> , O-2156
Singh, Ravindra	O-2148, O-2151
Singh, Satish	O-1118
Singh, Utsa	P-4534
Singh, Vikas	O-2148
Singh, Vikram	P-4535
Singh, Vivek	<u>O-2064</u>
Singhal, Saurabh	O-4053



INQUA 2019  
DUBLIN  
IRELAND

Singleton, Drake	P-4821
Sinha, Rajiv	P-3419, P-3859
Sinitsyn, Andrei	<u>O-0053</u>
Sinnl, Giulia	<u>P-4455</u>
Sinometti, Renato	P-4017
Sinopoli, Gaia	P-2477
Sion, Brad	O-1067
Sipos, György	P-2616
Sirakov, Nikolay	O-0052
Sirakova, Svoboda	O-0052
Sirbu, Flavius	P-2845
Siringan, Fernando	O-2010
Sirocko, Frank	<u>O-3220</u> , <u>P-1518</u> , P-3879
Sivarajah, Branaavan	O-5075
Siřuch, Marcin	P-4224
Sjögren, Per	O-1100
Sjögren, Per Johan	O-1105
Sjölander, Mattias	O-5120
Sjöström, J.K.	O-2128
Sjöström, Jenny	O-2127, P-2873
Sjöström, Jenny K	<u>O-2131</u>
Skaar, Katrine	P-1442
Skaar, Katrine Sandnes	O-1185
Skelton, Alasdair	O-1084
Skinner, Fiona	<u>P-4215</u>
Skinner, Luke	O-4211, P-3618
Skip, Gary L.	P-2605
Skoglund, Pontus	P-2234
Skolasińska, Katarzyna	P-1867
Skonieczny, Charlotte	O-5102
Skurzyński, Jacek	O-1190, <u>O-1196</u> , <u>P-1631</u> , P-1634
Skyllberg, Ulf	P-4438
Slaymark, Charlotte	<u>P-4447</u>



Slee, Adrian	<u>P-1895</u> , <u>P-2613</u> , P-3500
Sloane, Hilary	O-1205
Sloss, Craig	<u>O-3070</u> , <u>P-3024</u>
Slotte, Tanja	P-1201
Slowinski, Michal	<u>P-1816</u>
Small, David	O-1055, <u>O-3228</u> , O-3230, O-5128, P-2435
Small, Jonathan	<u>P-2232</u>
Smedile, Alessandra	<u>P-3040</u>
Smedley, Rachel	O-1127, O-3230, <u>O-4167</u> , O-4168, O-5128
Smedley, Rachel K	P-4478
Smedley, Rachel Katie	O-2095, O-4163
Smik, Lukas	O-1189, O-4073, <u>P-1443</u>
Smith, Ben	O-5010
Smith, Carol	<u>O-3045</u>
Smith, David	O-4030, O-5079, P-1886
Smith, Felisa A.	<u>O-3176</u>
Smith, James	O-4127, O-4133
Smith, Karen	P-1251
Smith, Larry	<u>O-2223</u>
Smith, Mark	O-2197
Smith, Rebecca	<u>O-1114</u>
Smith, Richard J.	O-3140
Smith, Rod	O-0127, <u>O-5047</u> , <u>P-1270</u>
Smith, Tanya M.	<u>O-0071</u> , O-0072
Smith, Victoria	<u>O-1042</u> , O-1114, <u>P-3629</u>
Smol, John	O-5074, O-5075, P-3437
Smol, John P.	P-4248
Smoot, Joe	O-3110
Smyth, Jessica	<u>O-2023</u>
Snelling, Andrea	<u>O-5031</u>
Sniderman, Kale	P-2802
Sniderman, Kale	O-2076, O-3069, P-3501, <u>P-4491</u>
Snowball, Ian	O-1233



INQUA 2019  
DUBLIN  
IRELAND

Soares de Oliveira, Priscilla	P-1042
Soares, Warley	O-4069
sobczyk, artur	<u>P-1912</u>
Sobczyk, Artur	P-1902, P-2422, <u>P-4640</u>
Sobiech, Marcin	P-1847
Sobkowiak-Tabaka, Iwona	<u>O-1020</u>
Sobol, Magdalena	<u>O-4144</u>
Sobolowski, Stefan	<u>P-4495</u>
Sobrero, Franco Sebastian	<u>O-4185</u>
Sociats, Ona	P-4241
Sohar, Kadri	<u>O-2081</u>
Sohbati, Reza	O-2223, P-2452, P-2456
Sohlenius, Gustav	P-4842
Sokolov, Sergey	<u>O-3128</u>
Sokolova, Natalia	P-4028
Sokołowski, Robert Jan	<u>P-1855</u> , <u>P-4834</u>
Solari, Marcelo	P-3048
Sole, Andrew	P-1049, P-1849
Sole, Andrew J.	O-0043
Soler, Vicente	P-4531
Soligo, Michele	P-2891, P-2892
Solomina, Olga	<u>O-2020</u> , <u>P-3631</u>
Sommer, Christian	O-4135, P-1246, P-4207
Sommer, Michael	P-4609
Sommer, Philipp S.	<u>O-5121</u>
Son, Chang Soo	P-4016
Son, Moon	P-4805, P-4816
Song, Chunhui	P-1804
Song, Gao	P-2404, <u>P-3415</u>
Song, Yang	P-1423, P-3878
Song, Yougui	P-2501, P-2508, P-2836, <u>P-3424</u> , <u>P-3881</u>
Sonke, Jeroen	O-0094
SONODA, Takeshi	P-1019



INQUA 2019  
DUBLIN  
IRELAND

Sonoda, Takeshi	P-1018
Sookdeo, Adam	O-3194
Sookhan, Shane	<u>O-1202</u> , <u>P-1841</u> , <u>P-4836</u>
Soressi, Marie	P-3214
Soriano, Josep	P-2851
Sorokin, Valentin	O-3053, P-3602
Sosa, Numa N.	P-4524
Sosdian, Sindia	O-1189
Soteres, Rodrigo	O-4019, P-2518
Soteres-García, Rodrigo	P-1885
Soto, Maria	O-5025
Soto-Rogel, Pamela	P-4475
Sottile, Gonzalo	<u>O-4059</u> , <u>P-2254</u>
Souhel, Abdellatif	O-0160
Souhir, Mohamed	O-5025
Souksavatdy, Viengkeo	P-1452
Soulet, Guillaume	P-1405, P-4402
Sousa, Leandro	P-3233
Southon, John	O-3190, P-3218, P-4617
Souza, Adriana	P-4026
Souza, André	<u>P-2879</u>
Souza, Simmon	P-4015
Spadano Albuquerque, Ana Luiza	O-0028
Spagnolo, Matteo	<u>O-1133</u> , O-2143, O-5058, P-1846, P-1884, P-2439
Spahni, Renato	O-2052
Spaleta, Karen	O-0063
Spektor, Valentin	P-4636
Spektor, Vladimir	P-4636
Spencer, Daisy	O-4160
Sperisen, Christoph	P-1205
Spiegel, Cornelia	O-4163
Spielhagen, Robert	O-1187
Spielhagen, Robert F.	<u>O-2183</u> , P-1479



INQUA 2019  
DUBLIN  
IRELAND

Spies, Thomas	P-3863
Spiess, Volkhard	O-0133
Spiridonov, Andrej	P-2487, P-4216, P-4848
Spiridonova, Elena	O-3205
Spiske, Michaela	<u>O-3167</u>
Spizzichino, Daniele	P-4820
Spolaor, Andrea	O-1186
Spooner, Nigel	O-3064
Spooner, Nigel A.	P-4277
Sprafke, Tobias	O-3044, P-1627, P-1633, P-4443
Sprague, Dale	O-5075
Spötl, Christoph	O-2074, O-3222, O-4146, O-4216, P-1235, P-1519, P-2482, P-4451, P-4457, P-4473, P-4507, P-4516
Sridhar, Alpa	<u>O-3006</u>
Srinivas, Akash	<u>O-2065</u>
Srivastava, Aayush	<u>P-2839</u>
Srivastava, Jyoti	<u>P-1456</u>
Srivastava, Pradeep	<u>O-4053</u>
Ssemmanda, Immaculate	P-2504
St George, Scott	P-4423
St-Onge, Guillaume	O-5035
St. Onge, Guillaume	P-2495
Stachowicz-Rybka, Renata	O-1165, P-2205, P-2422, P-2427, P-4640
Stadmark, Johanna	O-1003
Staff, Richard	O-2078, O-3193, O-4091, P-3433, P-3620, <u>P-4453</u>
STAFF, Richard	P-4448
Stafford, Jr., Thomas W.	O-3176
Stahle, Daniel	P-2238
STAHLE, LAURIE	P-4282
Stahlschmidt, Mareike	O-2073
Stammen, Sarah	P-3840
Stammler, Florian	P-2218
Stampanoni Bassi, Filippo	P-3234



INQUA 2019  
DUBLIN  
IRELAND

Stan - Sion, Cătălin	P-2459
Standovár, Tibor	P-2213
Stanislaus, Glen	P-1404
Staniszewska, Kasia	O-2213
Stankevič, Robertas	P-2487
Stančikaitė, Miglė	<u>P-1035</u> , <u>P-2487</u>
Stap, Lennert	P-1478
Starkel, Leszek	O-1152
Stattegger, Karl	P-3018
Stauch, Georg	<u>O-1110</u> , O-4114
Staurset, Sigrid	O-5026, P-3801
Steele, Teresa E.	O-0073
Stefan, Lauterbach	P-4442
Stefani, Cristina	O-5041
Stefaniak, Krzysztof	P-2205, P-2422, P-3873, P-4640
Steffen, Holger	P-3863
Steffensen, J.P.	O-4014
Stegner, Allison	O-1211, P-2251
Stegner, M. Allison	<u>O-2059</u>
Steig, Eric J.	O-0076
Stein, Rudiger	O-1187
Stein, Ruediger	P-1442
Stein, Rüdiger	P-1439
Steinberger, Bernhard	P-3018
Steinbichler, Mathias G.	O-4190
Steinemann, Olivia	<u>P-2905</u> , P-2908
Steinhoff, Christoph K.	<u>P-4621</u>
Steininger, Florian	O-2153
Steinke, Stephan	P-1250
Steinhorsdottir, Margret	O-4090
Stekelenburg, Martin	P-1509
Stele, Andreas	P-1835
Stella Maris, Moreiras	O-4194



INQUA 2019  
DUBLIN  
IRELAND

Stemberk, Jakub	P-3865
Stepanova, Anna	O-4214, P-3004
Steph, Silke	P-4499
STEPHAN, PIERRE	<u>O-3165</u>
Stephan, Pierre	P-1029
Stepišnik, Uros	P-3817
Stern, Charles	O-1114
Sternes, Alison	P-3024
Steup, Raphael	<u>P-1908</u>
Stevens, Rhiannon	O-3181, P-4215, P-4427
Stevens, T	P-1639
Stevens, Thomas	O-0098, <u>O-1191</u> , P-1425, P-2603, P-3808
Stevens, Todd	O-1161
Stevenson, Janelle	O-3058, P-1823
Stevenson, John	O-1040, P-2869
Stewart, Brian	O-3034, <u>O-5027</u>
Stewart, Brian A.	O-5022
Stewart, Heather	O-1198, <u>P-4002</u>
Stewart, John R.	P-4529
Stewart, Joseph	O-4037
Stewart, Margaret	P-1068, P-4002
Stiller, Mathias	Plen02
Stimpson, Christopher	P-3230
Stimpson, Ian	P-4833
Stimson, Andrew	P-2434
Stivrins, Normunds	O-5004
Stocchi, Paolo	O-1235, <u>O-5133</u> , P-1064, P-3014
Stock, Friederike	P-4009
Stock, Michael	P-3629
Stocker, Benjamin	O-2052
Stocker, Thomas	O-4014
Stockhecke, Mona	O-3221, O-4169, P-3412, P-3428, P-4278
Stojakowits, Philipp	O-1154



INQUA 2019  
DUBLIN  
IRELAND

Stoker, Ben	O-0046
Stoker, Benjamin	O-5048
Stoker, Benjamin James	<u>P-1891</u>
Stokes, Chris	O-0127, O-1237, P-1884, P-4840
Stokes, Chris R	P-4843
Stokes, Chris R.	O-4132
Stokes, Martin	O-1218, <u>O-3092</u> , P-2883, P-2896, <u>P-2898</u>
Stolze, Susann	<u>O-0124</u>
Stolzenberger, Sophie	O-4197
Stone, Abi	P-2484, <u>P-2837</u> , <u>P-4274</u>
Stone, George	<u>O-3212</u>
Stone, Jeffery	P-2238, P-3422
Stone, Tim	P-1012
Stoner, Joseph	O-5091, P-2223
Stoof-Leichsenring, Kathleen R.	O-1022, O-1028, O-1102, P-1208, P-1215, P-1441
Storms, Joep	O-3159
Storrar, Robert	<u>O-0046</u> , O-0047, P-1884, <u>P-3819</u>
Storrar, Robert D.	O-0043, O-0045, P-1843
Stouthamer, Esther	O-0001, P-3845, P-3852
Straile, Dietmar	P-4245
Strandberg, Gustav	O-5010
Strandberg, Nichola	<u>P-4466</u>
Strani, Flavia	P-2207
Strasser, Michael	O-2093, O-3010, O-3011, O-4046, P-1464, P-2272, P-2273, P-2828, P-3862
Stratmann, Theresa	O-0105
Strecker, Manfred R.	P-1058
Street-Perrott, Alayne	P-2870
Streeter, Richard	O-1119, P-4233, P-4425
Streletskaya, Irina	P-1638, P-1639, P-1911
Stringer, Chris	P-4456
Strobel, Paul	P-3480, <u>P-4530</u>
Stroeven, Arjen P	O-1070



INQUA 2019  
DUBLIN  
IRELAND

Stroeven, Arjen P.	P-1420, P-1483, P-1890, P-3485
Strom, Alexander	<u>P-3867</u> , P-3870
Strouhalová, Barbora	P-1630
Stroup, Justin	O-3110
Struck, Julian	<u>P-3480</u> , P-3884, P-4530
Strukova, Tatiana	O-5110, P-1224, P-2811
Strzelecki, Mateusz	P-3011
Stuart, Fin	O-3092
Stuart, Finlay	P-1477
Stuart, Finlay M	O-1070
Stuart, Finlay M.	P-1483
Stuchlik, Evzen	P-3627
Stuchlík, Evžen	O-5109
Stuhne, Gordan	P-3407
Stuijts, Ingelise	P-4220
Stutz, Jamey	O-3187
Stuut, Jan-Berend	<u>O-0092</u> , <u>P-4490</u>
Styring, Amy	O-5009
Stéphan, Pierre	P-1016, <u>P-4011</u>
Støren, Eivind	P-3853, P-4433, P-4435
Støren, Eivind W.N.	O-3114
Støvern, Leif E.	P-1209
Stürmane, Amanda	P-2906
Su, Chih-Chieh	O-1071, O-1074
Su, Qianqian	<u>P-2485</u>
Su, Teng	O-5117
Suarez, Serge	O-3165, P-1016
Subetto, Dmitriy	P-4028
Subetto, Dmitry	O-5021
Suchora, Magdalena	P-4244
Suchánek, Vladimír	<u>P-1237</u>
Sue, Christian	O-4186
Sueoka, Shigeru	O-4036



INQUA 2019  
DUBLIN  
IRELAND

Suganuma, Yusuke	<u>O-0118</u> , O-1232, P-1001, P-2444, P-2479
Sugden, David	P-1477
Sugita, Shinya	O-1080, O-4058, O-5008, O-5010, O-5012, O-5013, O-5014, O-5083, P-1007
Sugiyama, Cohe	O-3086
Sugrañes, Nuria	P-1259
Sun, Aizhi	P-1497, P-4422
Sun, Chunqing	<u>P-1611</u> , P-3621
Sun, Dong	O-0156
Sun, Jimin	O-2160, P-3425
Sun, Qifa	O-1033
SUN, Weiwei	P-3456
Sun, Weiyi	O-5070
Sun, Wenfeng	O-1229
Sun, Xuefeng	P-2206
Sun, Youbin	P-1424, P-1444, P-1503, P-2483
Sun, Zhilei	O-2178, P-2499
Sunal, Gürsel	P-3605
Sundriyal, Y.P	P-2461
Sundriyal, YP	O-4053
Sunyé-Puchol, Ivan	O-1042
Superson, Józef	O-1152
Suraprasit, Kantapon	O-0123
Surić, Maša	<u>O-3075</u> , P-2803
Surányi, Gergely	P-3625
Susini, Davide	O-5036
Sutherland, Jenna	<u>O-5086</u> , <u>P-1854</u>
Sutinen, Raimo	<u>O-4126</u>
Suuroja, Sten	P-1046
Suwargadi, Bambang	P-3019
Suzuki, Akihiko	<u>P-2001</u>
Suzuki, Takehiko	O-3042, <u>P-1608</u> , P-3629
Svanning, Jens-Christian	O-0126



INQUA 2019  
DUBLIN  
IRELAND

Svecova, Eva	O-5109, P-3627
Svendsen, John Inge	O-1050, <u>O-1130</u> , O-1162, O-5019, P-1892, P-3481
Svendsen, John-Inge	O-0039, O-1100
Svenning, Jens-Christian	P-2218
Svensen, Henrik	P-4433, P-4435
svensson, anders	O-2015
Svensson, Anders	O-3042, O-3196, <u>O-4014</u> , P-4455, P-4460
Svistunov, Mikhail	O-3054, P-1639, <u>P-3609</u> , P-3610, <u>P-4234</u>
Svitavska Svobodova, Helena	O-2207, O-4062
Svitoch, Alexander	O-3052
Svoboda, Miroslav	O-4062
Svobodova-Svitavska, Helena	P-3627
Swann, George	O-2204, <u>O-4076</u> , O-5031
Swart, Peter K	P-1502
Sweeney, Mark	<u>O-3049</u>
Swennen, Rudy	O-1210
Swift, Darrel A.	P-1900
Swindles, Graeme	O-2130, O-2197, <u>O-2202</u> , O-3115, P-2849, <u>P-2858</u> , <u>P-2863</u>
Swindles, Graeme T.	O-0077, O-2027
Swingedouw, Didier	O-2038, P-2470
Swinnen, Ward	<u>O-2200</u> , P-2862, <u>P-2868</u>
Switzer, Adam	P-1065, P-3019
Sychev, Nikita	P-3607
Syiemlieh, Hiambok Jones	O-1013
Sylvestre, Florence	O-3221, P-3806
Symons, William	O-3130
Synal, Hans-Arno	P-2905, P-4617
Synolakis, Costas	P-3064
Syromyatnikov, Igor	P-4636
Syrykh, Liudmila	P-4028
Szabó, Péter	O-4070
Szabó, Zoltán	O-0122, P-4299
Szafrańiec, Joanna Ewa	<u>O-4054</u>



INQUA 2019  
DUBLIN  
IRELAND

Szalai, Zoltán	P-2609
Szameitat, Annika	P-3865
Szczerba, Agnieszka	P-4244
Szczuciński, Witold	O-3162, P-1816, P-1867, P-3061
Szczygieł, Jacek	P-2805, P-2806
Szeberényi, József	O-1195, P-1629, <u>P-2614</u> , P-3625
Szeliga, Marcin	P-1243, P-4224
Szidat, Sönke	O-2148, P-2273, P-4505, P-4619
Sztein, Ester	<u>P-4428</u>
Szuman, Izabela	O-1201
Szymanek, Marcin	P-3486, P-3829
Szádovszky, Luca	P-4299
Sánchez-Goñi, Maria-Fernanda	O-1018
Sáez, Alberto	O-3174, O-4106, P-1495
Sági, Tamás	P-3625
Sánchez Goñi, Maria Fernanda	P-2488
Sánchez Goñi, María Fernanda	<u>P-2471</u>
Sánchez, Nieves	O-2195
Sánchez-Bandera, Christian	P-2204
Sánchez-García, Carlos	<u>O-3083</u>
Sánchez-Goñi, María Fernanda	O-2040
Sánchez-Moya, Yolanda	O-3079
Sánchez-Vizcaíno, Jesús	P-2851
Sæle, Tone H.	O-1050
Sémah, Anne-Marie	O-5102
Söderlindh, Jenny	O-1084
Søndergaard, Anne Sofie	<u>O-3197</u>
Sørensen, Søren Anker	O-1159
Süle, Tamás Gábor	P-1629
Sławińska, Joanna	P-1492
Słowińsk, Michał	O-2080
Słowiński, Michał	O-2140, O-4086, O-4087, P-2266, P-4449
Ta, Thi Kim Oanh	O-1079, P-1022



INQUA 2019  
DUBLIN  
IRELAND

Taberlet, Pierre	P-1204
Tabor, Clay	O-0010
Tachikawa, Kazuyo	O-2120, O-3208, P-3225, P-3806
Tackney, Justin	P-1211
Tada, Ryuji	O-1111, P-1024
TADA, Ryuji	P-4448
Tafelmaier, Yvonne	O-5024
Tagami, Takahiro	O-4036
Taimagambetov, Zhaken	O-0135
Takac, Marian	O-5109, P-3627
Takada, Hideki	P-4226
Takakura, Jun	<u>P-4268</u>
Takao, Makoto	P-4803
Takashimizu, Yasuhiro	P-3041, P-3051
Takata, Hiroyuki	P-1018
Takeshita, Yoshihiro	O-0118
Takeuchi, Gary	P-3218
Tal, Irit	O-2117
Talamo, Sahra	O-3194, P-3873
Taldenkova, Ekaterina	O-4214, P-3004
Tammelin, Mira	<u>P-2260</u>
Tamura, Toru	O-0051, <u>O-1079</u> , O-3008, <u>P-1022</u> , P-1277
Tan, Liangcheng	<u>O-0025</u> , O-4011, <u>P-1503</u>
Tan, Ning	P-1422
Tandon, S.K.	P-3419
Tang, Hui	<u>P-3050</u>
Tang, Lingyu	O-1033
Tang, Yongjie	P-2852
Tang, Zhihua	P-1005
Tang, Zihua	<u>O-0145</u> , P-1913, <u>P-2245</u> , P-4503
Tanigawa, Koichiro	O-3008, P-3035
Tankersley, Kenneth	<u>P-4432</u>
Tanner, David	O-4189



INQUA 2019  
DUBLIN  
IRELAND

Tanttu, Heidi	<u>P-2250</u>
Tao, Shichen	O-3168
Taormina, Rebecca	<u>O-1216</u>
Tapias, Fernando	P-2889
Tarasov, Lev	O-2197
TARASOV, Pavel	P-4448
Taratunina, Natalia	<u>P-1638</u> , <u>P-1639</u>
Tardif, Jacques	P-4440
TARI, Ufuk	<u>O-3131</u> , <u>P-3605</u>
Tarique, Mohd	P-4025
Tarriño, Andoni	O-5025
Taschetto, Andrea	O-4211
Tassi, Francesca	O-1026
Tassier-Surine, Stephanie	O-0033
Tavares, Alexandre	P-1040
Taylor, David	O-0089, <u>O-1023</u> , O-1175, O-5076, P-4251
Taylor, Karen	O-4160
Taylor, Liam	P-2858
Taylor, R. E.	P-1276
Taylor, Sheila	P-4618
Taylor, Timothy	P-2272, P-2273
Team Members, HSPDP	O-4169
TEAM, ASTER	O-2020
Team, Aster	O-1142
Team, ASTER	O-2016, O-3147, P-1859, P-1862, P-2441, P-2443, P-2455, P-4482
teams 2016/17 and 2018/19, "Once Upon a Time"	P-2246
Tegner, Christian	P-3628
Telfer, Matt	P-2898
Temme, Arnaud	P-4609
Tempest, Kirsten	<u>O-1009</u>
Terayama, Satoshi	P-1608



Terekhov, Anton	P-1032
Terpiłowski, Sławomir	P-1888, P-4638
Terry, James	P-3044
Terry, Karisa	<u>O-4028</u>
Terwilliger, Valery	P-4288
Tesakov, Alexey	O-3128, O-5040, O-5107
Tesakov, Alexey S.	O-3132
Tessadri, Richard	O-2093
Tessone, Augusto	O-0143, P-1262
TESTÉ, Marc	<u>P-4229</u>
Tetard, Martin	P-3219
Tetzner, Dieter	<u>P-3472</u>
Thackray, Glenn	O-0042, O-1064, O-1148, <u>O-4047</u> , P-1484, P-1487
Thalmeier, Belen	<u>O-3005</u>
Thamó-Bozsó, Edit	P-3855
Thebaudeau, Benjamin	P-4001
Theiling, Bethany	O-4175
Theuerkauf, Martin	<u>O-5080</u> , <u>P-4286</u> , P-4295, P-4420
Thibodeau, Benoit	<u>O-1091</u>
Thiel, Christine	P-3625
Thiele-Bruhn, Sören	P-3884
Thomas, David	O-2151, O-3122, P-1626, P-2839, P-3475
Thomas, David Hurst	P-1251
Thomas, David S.G.	<u>O-5026</u> , <u>P-2606</u>
Thomas, Elizabeth	O-1099, <u>P-3467</u> , <u>P-3469</u>
Thomas, Geoff	O-1127
Thomas, Liz	O-3185, P-3472
Thomas, Maik	P-3018
Thomas, Shan	O-4179, P-1213
Thomas, Stevens	P-3812
Thomas, Zoe	O-2110
Thomas, Zoë	P-3464
Thompson, Polly	O-1119, <u>P-1613</u>



INQUA 2019  
DUBLIN  
IRELAND

Thompson, Victor	<u>P-1251</u>
Thompson, Warren	P-3609
Thomsen, Corrina	O-3177
Thordarson, Thor	O-2188, P-1622
Thornalley, David	O-1086
Thornalley, David J	O-4085
Thornalley, David J.	P-1472
Thorndycraft, Varyl	O-3144, P-4471, P-4472
Thorndycraft, Varyl R.	O-4166, P-4862
Thorne, Peter	O-0091
Thorsteinsson, Thorsteinn	O-2017
Thouveny, Nicolas	P-3225
Thébaudeau, Benjamin	<u>O-2173</u>
Tian, Chengjing	P-1005
Tian, Fang	P-4296
Tian, Yanyan	<u>O-2150</u>
Tian, Zhiping	O-2084
Tianyang, WANG	P-4021, P-4230
Tibby, John	O-3067, <u>O-3184</u> , O-4094, O-5032, P-1513, P-2498, P-3413, P-4489
Tichá, Anna	O-2206
Tiedemann, Ralf	P-1441, P-2521, P-4499
Tiedemann, Ralph	P-1208
Timar-Gabor, Alida	P-2813
Timm, Ingo	O-4134
Timm, Ingo J.	O-4135, O-4136, P-4204
Timmerman, Axel	P-4469
Timmermann, Axel	O-0024, O-2115, P-1401
Timmins, Madeleine	P-2863
Timmreck, Claudia	P-4434, P-4437
Timms, Rhys	O-1180, O-1181, O-2078, O-2100, <u>O-3041</u> , P-1601, P-2416, P-4270, P-4456
Timpany, Scott	O-5005, <u>P-1048</u>



INQUA 2019  
DUBLIN  
IRELAND

Tims, Stephen	O-4020, P-3466
Tinacba, Erin Joy	O-2010
Tindall, Joanna	<u>P-2416</u>
Tiner, Rachel	P-4496
Ting, Wang	<u>P-2412</u>
Tinner, Willy	<u>O-0017</u> , O-0099, O-2032, O-2140, O-2206, O-2209, O-4084, O-4089, O-5004, P-1203, P-1205, P-1226, P-1258, P- 1806, P-2264, P-4217, P-4291, P-4511
Tipping, E	O-2128
Tipping, Richard	P-1247
Tipton, John	O-5121
Tisdall, Eileen	<u>O-1157</u> , O-2078, P-1247, <u>P-1281</u>
Tisnérat-Laborde, Nadine	P-3490
TISSOUX, Hélène	P-2895
Tissoux, Hélène	<u>P-1833</u>
Titov, Vadim	O-3055, O-5040, <u>O-5107</u>
Titton, Stefania	O-2166
Tiwari, Nupur	<u>O-2068</u>
Tjallingii, Rik	<u>O-1076</u> , O-1212, O-1228, O-3093, O-4086, P-3436, P-3438, P-3839, P-4444, P-4449
Tjiputra, Jerry	O-2042
Tkach, Nikolai	<u>P-3607</u>
Tkacheva, Elena	O-5127
Toberman, H.	O-2128
Tobolski, Kazimierz	P-2866
Tocino, Stéphane	P-4450
Todisco, Dominique	P-4264, P-4476
TOKO IMOROU, Ismaïla	<u>O-5136</u>
Tokunaga, Tomochika	P-1827
Tolu, Julie	O-2083
Toma, Alina	P-2459
Tomczyk, Aleksandra	O-0046, P-1830, P-1850, <u>P-3231</u> , P-3819, <u>P-4849</u>
Tomiak, Peter	P-4618
Tomić, Nemanja	P-3621



INQUA 2019  
DUBLIN  
IRELAND

Tomić, Nemanja	P-1423
Tomkins, Matt	<u>P-2434</u>
Toms, Phillip	O-4050
Tomé, Catalina P.	O-3176
Tonello, Marcela S.	O-4059, P-2254
Toney, Jaime	P-4447
Toney, Jaime L.	O-3151, P-3493
TONG, Haowen	<u>P-1219</u> , <u>P-2201</u>
Toohey, Matthew	O-3113, P-4434, P-4437
Toonen, Willem	O-3216, P-3852
Tooth, Stephen	O-4178
Torgovkin, Nikolai	<u>P-4636</u>
Tornero, Carlos	P-2808
Tornqvist, Torbjorn	<u>O-0079</u>
Torrejón, Fernando	P-3840, P-4856
Torres, Jimena	O-1157
Torres, Vladimir	P-3235
Torres-Elgueta, Jimena	P-1017
Torri, Paola	P-2477
Toucanne, Samuel	O-1111, O-2220, O-3204, <u>P-1405</u> , <u>P-4401</u> , P-4402
Tourlière, Bruno	P-1833
Tourte, Bernard	P-4473
Touzeau, Alexandra	P-3468
Tołoczko-Pasek, Anna	<u>P-1862</u> , P-3486
Trabucho, Nikki	O-2193
Trachsel, Mathias	<u>O-5081</u>
Trainor, Paul	O-2035
Tramelli, Andrea	P-1235
Trauth, Martin	O-1036, O-4174, P-4272
Trauth, Martin H.	O-4173, P-1208, P-3805, P-4273
Travassos, Daiana	O-4001
Traylor, Wolfgang	<u>O-0105</u>
Treble, Pauline	O-4092, P-2507, P-4488



Tremblay, Emy	O-3179
Tremblay, Marissa M.	P-1860
Tremblay, Tommy	<u>P-1861</u> , P-1881, P-2820, <u>P-4844</u>
Tri Hascaryo, Agus	P-1610
Trias, Sergio	<u>P-3495</u>
Trifonov, Vladimir	<u>P-3037</u>
Trigo, Ricardo M	O-3174, P-1495
Trikhunkov, Yaroslav	<u>P-3612</u>
Triller, Benno	O-2100
Tringali, Giorgio	O-4044
Tripaldi, Alfonsina	<u>P-2610</u> , <u>P-2832</u>
Trnka, Miroslav	O-0085
Trobajo, Rosa	P-4024
Trobec, Ana	<u>P-1041</u>
Troch, Matthias	<u>P-3838</u>
Troiani, Francesco	P-3836
Trombino, Luca	O-3121
Troncoso, Andrés	O-0143, O-3169
Trucchi, Emiliano	O-1026
Tsai, Hsien-Chen	O-3219
Tsai, Victor C.	<u>O-1012</u>
Tsakiridou, Margarita	<u>O-1123</u> , <u>P-1818</u>
Tsanova, Tsenka	<u>O-0052</u>
Tseng, Chia-Han	P-2886
Tsirtsoni, Zoï	P-1261
Tsujimoto, Akira	P-1018, P-1028
Tsukamoto, Sumiko	O-4036, <u>O-4117</u> , P-3863, P-4624
Tsutsumi, Hiroyuki	P-3033, P-3058
Tsutsumi, Takashi	O-4100
Tsutsumi, Yukiyasu	O-2070
Tsydenova, Natalia	<u>O-4026</u>
Tubalado, Edrian	P-3058
Tucci, Mario	<u>P-3443</u> , P-4639



INQUA 2019  
DUBLIN  
IRELAND

Tuccimei, Paola	P-2891, P-2892
Tucholka, Piotr	O-3209, O-3210, P-3404
Tucker, Bryan	P-1251
Tuckwell, Dr George	O-1200, P-1047
Tudryn, Alina	<u>O-3204</u> , O-3205, O-3209, O-3210, <u>P-3404</u>
Tuittila, Eeva-Stiina	O-2187
Tuittila, Eeva-stiina	P-2857
Tunno, Irene	<u>O-4041</u> , <u>P-3431</u>
Tuovinen, Juha-Pekka	P-2857
Turcq, Bruno	O-3109
Turkelboom, Francis	P-1242
Turner, Angie	<u>P-4833</u>
Turner, Charles	<u>O-5111</u>
Turner, Derek	O-2212, P-1481
Turner, Falko	P-2510
Turner, Fiona	<u>P-4403</u>
Turner, Jonathan	<u>P-3857</u>
Turner, Rebecca	O-1126
Turney, Chris	O-2012, O-2110, O-3059, O-3067, O-3194, P-3464
Turney, Christian	O-3190, O-4204
Turney, Lovina	O-3214
Turq, Alain	O-0073
Turu, Valenti	<u>P-2440</u>
Turu, Valentí	P-1885, P-2851
Tuset, Jordi	O-3004, P-3846
Țuțuianu, Laurențiu	O-4108, P-2230
Twesigye, Charles	<u>O-3062</u>
Twesigye, Elvaida Agnes	P-2242
Twigg, Will	P-3819
Tyler, Jonathan	O-1005, O-3067, O-3184, O-4094, O-4095, O-5032, O-5053, P-1507, P-1513, P-2498, P-3501
Tylmann, Karol	<u>O-1053</u> , <u>P-2816</u>
TYLMANN, Wojciech	O-3188



Tylmann, Wojciech	O-5002, P-1474, P-3421, P-3450, P-4244, P-4250
Tzedakis, Chronis	O-1164, P-4454
Tzedakis, Polychronis	O-4211
Tzedakis, Polychronis C.	O-4213, P-1802
Tzigounaki, Anastasia	O-4029
Tábořík, Petr	P-3865
Tîrlă, Laura	O-1207
Tóth, Zsuzsanna	O-0133, O-2013
Tõnisson, Hannes	<u>O-1080</u> , P-1007, P-1046
Tüysüz, Okan	O-3131
Ubillá, Martín	<u>P-1489</u>
Uchiyama, Takashi	<u>P-3030</u>
Uemoto, Shinji	O-3086
Ufrecht, Wolfgang	P-1519
Ugalde, Paula	<u>O-4155</u> , O-4157
Ulbricht, Arlett	P-4206
Ulm, Sean	O-0103, O-1047, P-3024
Ulner, Laerke-Corinn	P-2490
Ulner, Lærke-Corinn	P-2493
Unger, Lillian	O-5032
Unneberg, Per	P-1201
Urabe, Atsushi	<u>P-3041</u> , <u>P-3051</u> , P-3617
Urban, Brigitte	O-5111, P-3443, P-4639
Urbina, Ximena	P-1262
Uribe, Carlos	O-4161
Uribe, Mauricio	O-0026, O-4157
Urrego, Dunia	P-1509
Urrutia, Roberto	O-3188
Usami, Kazuko	O-3010
Ustaszewski, Kamil	O-4048
Ustimenko, Aleksandr	P-2426
Utida, Giselle	<u>O-3109</u>
Utkina, Anna	P-4855



Utsugawa, Takako	P-3868
Utting, Daniel	P-1845
Uuganzaya, Munkhjargal	P-2419
Uusitalo, Joonas	P-4214
Uxa, Tomáš	<u>O-5114</u>
Uzunidis, Antigone	P-3491
Vaasma, Tiit	O-1080, P-1007
Vacchi, Matteo	<u>O-0083</u> , O-2120, P-1053, <u>P-3021</u>
Vachula, Richard	<u>O-1043</u> , <u>P-3223</u>
Vadsaria, Tristan	P-2481
Vaiani, Stefano Claudio	O-1082
Vaikmäe, Rein	<u>P-2469</u>
Vaikutiene, Giedre	P-3061
Vainer, Shlomy	<u>O-2219</u> , <u>P-1859</u>
Valbuena-Carabaña, Maria	O-2032
Valcárcel, Marcos	P-1486
Valdes, Julio	P-2506
Valdes, Paul	O-2197, O-3029, O-3206, O-4072, P-1412
Valdivia Manchego, Mario	O-4184
Valenzano, Eliana	<u>P-3023</u>
Valenzuela Saavedra, Marcela	O-4158
Valenzuela, Daniela	O-4157
Valenzuela, Pablo	O-1151, P-1488
Valero- Garcés, Blas Lorenzo	<u>O-1139</u>
Valero-Garces, Blas Lorenzo	<u>P-4241</u>
Valero-Garcés, Blas	O-3007, O-4158
Valero-Garcés, Blas L.	P-1266, <u>P-3848</u>
Valero-Garcés, Blas Lorenzo	P-4254
Valezio, Éverton Vinícius	<u>P-2881</u>
Valla, Pierre G.	P-1860, P-2437
Vallelonga, Paul	O-1186, O-2015, O-4014
Vallè, Francesca	O-1168, P-3430
Van Asch, Nelleke	P-4227



INQUA 2019  
DUBLIN  
IRELAND

van Asch, Nelleke	O-1098, P-2417
Van Crimpen, Fleur	O-0092
Van Daele, Maarten	O-2109, O-3011, P-2828, P-3028
Van Damme, Dirk	P-4227
van de Velde, Sabrina	P-3604
van de Wal, Roderik	P-1478
van de Wiel, Marco	P-1910
van den Bogaard, Christel	O-1041
van den Bos, Valerie	<u>O-4012</u> , <u>P-3470</u>
Van den Bos, Valerie	P-4492
Van der Bilt, Willem	P-3853
van der Bilt, Willem G.M.	O-3114
van der Bilt, Willem Godert	<u>O-1234</u>
Van der Does, Michèlle	O-0092
van der Knaap, Pim	P-2212, P-4420
van der Knaap, Willem Oscar	P-3627
van der Maas, Daniel	P-1828
van der Made, Jan	P-4276
van der Meer, Jaap J.M.	<u>O-0130</u>
Van der Meeren, Thijs	O-2109, <u>O-2111</u> , <u>P-3806</u> , P-4227
van der Meij, Marijn	<u>P-1828</u> , <u>P-4609</u>
van der Meulen, Bas	<u>O-3082</u>
Van der Meulen, Michiel	O-2193
Van der Plicht, Johannes	P-4835
van der Plicht, Johannes	O-3190, O-3196
van der Putten, Nathalie	P-4458
Van der Putten, Nathalie	O-0094
van Dijk, Evelien	<u>P-4437</u>
van Eijk, Arjan	P-4458
van Gorp, Wouter	O-1221, <u>P-1616</u> , <u>P-1910</u>
van Hardenbroek, Maarten	O-1104, O-3100, O-3101, P-1273, P-3204
Van Hardenbroek, Maarten	O-3099
Van Heteren, Sytze	O-2193



INQUA 2019  
DUBLIN  
IRELAND

van Kolfschoten, Thijs	O-5111
Van Landeghem, Katrien	O-3230, O-5060, O-5063, O-5128
van Lanen, Rowin	O-1098
van Leeuwen, Jacqueline	O-2206, P-2212, P-3627, P-4420, P-4511
van Leeuwen, Jacqueline F. N.	O-5004
van Leeuwen, Jacqueline FN	O-3174
Van Loo, Maarten	O-2049
Van Loon, A.J. (Tom)	P-1879
van Loon, Sydney	P-2890
van Niekerk, Karen	O-3017
Van Nieuwenhove, Nicolas	P-2490
Van Overmeiren, Preben	O-0093
Van Peer, Philip	O-3019
van Vugt, Lieveke	<u>P-4217</u>
van Woerkom, Anne	O-1101
van Wyk de Vries, Benjamin	P-3224
Vanacker, Veerle	O-1065
Vandam, Ralf	O-2049
Vandekerkhove, Elke	O-3157, <u>O-4055</u> , <u>P-3840</u>
Vandel, Egert	O-1080, <u>P-1007</u>
Vandenbergh, Jef	P-1444
Vander Linden, Marc	O-5009
Vandergoes, Marcus	O-3145, O-4020, O-5007, P-3470, P-4492, P-4499
Vandermaelen, Nathan	<u>O-1065</u>
Vanderstraeten, Aubry	<u>O-0093</u> , P-1435
Vandiver, Pamela	<u>O-4023</u>
Vandyk, Thomas	P-2911
Vane, Christopher	O-3008, P-2221, P-4246
Vanni�re, Boris	P-1258, <u>P-2212</u>
Vanormelingen, Pieter	P-1242
Varga, Gy�rgy	O-1194, O-3032, <u>O-3047</u> , <u>P-2609</u> , P-2614
Vargo, Lauren	P-3466
Vartanyan, Sergey	P-1229



Vasconcelos, Alessandra	P-3232
Vasiliu, Dan	O-3127
Vassallo, Riccardo	O-4186
Vassiljev, Jüri	P-2859
Vasskog, Kristian	P-3060
Vaughan, David	<u>P-1074</u>
Vazquez Riveiros, Natalia	O-2038, P-1405
Vecchio, Antonio	P-3021
Vega, Rodrigo M	P-4479
Vegas, Juana	P-2623
Veiga-Pires, Cristina	O-5124
Veit, Heinz	O-1149
Veklych, Yuiy	P-4206
Velasquez, Patricio	P-1482, <u>P-4298</u> , <u>P-4414</u>
Velay-Vitow, Jesse	<u>P-3407</u>
Veldkamp, A.	P-1839
Veldkamp, Tom	O-1220, O-1221, P-3837
Veloso, Mario	O-2095
Velázquez, Gonzalo	O-3172
Velázquez-Bucio, María Magdalena	<u>P-4806</u>
Vennemann, Torsten	O-4070
Vercammen, Erika	P-2862
Verdin, Florence	P-1016
Veres, Daniel	<u>O-2203</u> , O-4091, P-1614, P-1626, P-1635, P-2813, P-3620, <u>P-4445</u>
Veres, Matthew	O-5123
Verhegge, Jeroen	<u>O-1215</u>
Verheyden, Sophie	P-1505
Verheyden, Wim	P-1242
Verhoeven, Marcus	P-3230
Verleyen, Elie	P-2250
Verlova, Tatyana	P-3854
Vermaire, Jesse	O-2035, <u>O-5075</u> , P-4247



Vermaire, Jesse C.	P-1809, P-4261
Verniers, Jacques	P-4227
Verrecchia, Eric P.	<u>P-1876</u>
Verschuren, Dirk	O-2109, O-2111, P-2250, P-3806
Versendaal, Alice	P-1839, P-3837
Vershinina, Alisa	Plen02
Verstraeten, Gert	O-2049, O-2200, P-1242, P-2862, P-2868, P-3236
Vervacke, Laura	P-2862
Vescovi, Elisa	P-4511
Veski, Siim	P-2859
Vespremeanu - Stroe, Alfred Ionuț	P-2459
Vespremeanu-Stroe, Alfred	<u>O-4108</u> , P-2230, P-4260
Vettoretti, Guido	O-4098
Vezzolli, Giovanni	P-2429
Viau, Andre	P-2506
Vibrans, Alexander	P-3226
Vicente de Vera, Alejandra	O-1139, <u>P-1266</u> , P-4241, <u>P-4254</u>
Vickers, Kim	O-3026
Vidal, Céline	O-1036, O-4173, O-4174, P-3805, P-4272, P-4273
Videla, Javiera	O-4165
Viehberg, Finn	P-3805, P-4272
Vignola, Cristiano	P-1267
Vignoni, Paula	<u>P-3438</u>
Vilanova, Isabel	P-4023, P-4480, <u>P-4497</u>
Vilaverde, Joana	O-3174
Villa Martinez, Rodrigo	O-4019
Villa, Javier	P-1885
Villa-Martinez, Rodrigo	P-4497
Villa-Martínez, Rodrigo	<u>P-4480</u>
Villada Paredes, Fernando	P-4819
Villagrán, Carolina	O-1150
Villalba, Ricardo	O-3172, P-4482
Villamor, Pilar	P-4803



INQUA 2019  
DUBLIN  
IRELAND

Villanoy, Cesar	O-2010
Villarosa, Gustavo	P-4218
Villarías-Robles, Juan J.R.	P-4019
Villaseñor, Amelia	O-3176
Villaseñor, Tania	P-3847
Villavicencio, Natalia	<u>O-0102</u>
Vilumaa, Kadri	O-1080, P-1007
Vincent, Brice	P-1253
Vincze, Ildikó	O-0122
Vink, Judith	P-3500
Vinnepand, Mathias	P-1628
Vinther, Bo	O-2015
Vinther, Bo M.	O-4014
Vinuesa, Ricardo	O-4074
Viranta, Suvi	O-2166
Virtanen, Tarmo	P-3437
Virág, Attila	O-0122
Viscolani, Andrea	O-4048
Visini, Francesco	<u>O-4124</u>
Vitale, Marcello	P-3498
Vittori, Eutizio	O-4044, O-4123
Viveen, Willem	<u>O-2224</u> , <u>P-4835</u>
Vivoli, Nicola	P-3488
Vizcaino, Miren	O-3227
Vičič, Blaž	O-4048
Vladimorova, Diana	O-2015
Vlaicu, Marius	P-1231
Vockenhuber, Christof	O-1149, O-2018, P-2430, P-2884, P-2905, P-2908, P-3001
Voelker, Antje H.	O-4069
Voelker, Antje H. L.	<u>P-4508</u>
Vogel, Felix	O-4209
Vogel, Hendrik	O-3057, P-1471, P-3442, P-3450, P-4250
Vogels, Marjolein	P-2513



INQUA 2019  
DUBLIN  
IRELAND

Vogelsang, Ralf	O-2102, O-3020
Vohradský, Lukáš	O-5114
Voigt, Carolina	P-2857
VOINCHET, Pierre	P-2895
Volkova, Svetlana	P-2874
Volvakh, Anna	P-2620
Volvakh, Anna Olegovna	<u>P-1637</u>
Volvakh, Nikolay	<u>P-2620</u>
Volvakh, Nikolay Evgenevich	P-1637
von der Lühe, Barbara	P-3885
Von Grafenstein, Ulrich	P-4240
von Grafenstein, Ulrich	P-2262
von Scheele, Alexander	P-4819
von Scheffer, Clemens	P-1431
von Suchodoletz, Hans	P-3803
Vondrak, Daniel	O-5109
Vondrák, Daniel	O-2206, <u>P-3627</u>
Vonhof, Hubert	O-3031, O-4066
Voroshilov, Egor	O-4191
Vos, Vincent	O-3135
Voss, Jochen	P-4506
Vrabec, Marko	O-4048, P-1041
Vuduyagiri, Sindhu	O-2015
Vuille, Mathias	O-3109
Vyazov, Leonid	P-4300
Vázquez-Castro, Gabriel	P-3063
Vázquez-Loureiro, David	O-3174
Vázquez-Selem, Lorenzo	P-2441
Väli, Vivika	O-2029
Väliranta, Minna	O-0034, O-2051, O-2187, O-4074, P-1201, P-2217, P-2853, <u>P-2857</u>
Végh, Tamás	O-1194, O-1195, P-1629, P-2614, P-3625
Völlmer, Johannes	O-2024, P-1835, <u>P-3208</u>



INQUA 2019  
DUBLIN  
IRELAND

Vött, Andreas	<u>O-4029</u> , O-4031, P-1628, P-3039
Wachecka-Kotkowska, Lucyna	<u>O-1152</u>
Wackenheim, Quentin	P-1868
Wacker, Lisa	O-4197
Wacker, Lukas	O-3189, O-3190, O-3194, P-3613, P-3614, P-4630
Wacnik, Agnieszka	O-5002
Waelbroeck, Claire	P-1405, P-3618, P-4413, P-4515
Wagner, Bernd	O-1137, O-1163, O-3150, P-2472, P-2477
Wagner-Cremer, Friederik	<u>P-2513</u>
Wagner-Cremer, Friederike	<u>O-4090</u> , P-1509, P-2263, P-3446
Wagnon, Patrick	O-1142
Wainer, Ilana	P-3465
Wainwright, John	O-1219, O-1220
Waite, Richard	<u>O-3002</u>
Wake, Leanne	O-0116
Walczak, Maureen	P-4490
Walder-Hoge, Zoe	P-4288
Waldmann, Nicolas	O-3035, <u>O-4199</u> , <u>P-3060</u> , P-3489
Walgraeve, Christophe	O-0093
Walk, Janek	O-4114
Walker, Bernard	P-2613
Walker, J Douglas	O-1066
Walker, Jacob	O-5006, <u>P-2503</u>
Walker, Michael	P-4453
Wall, Alexander F.	<u>P-4487</u>
Wallace, Kristi	P-1612, P-3619
Waller, Richard	<u>O-5046</u> , P-4833
Wallinga, Jakob	O-3159, P-3858, P-4609, P-4835
Walsh, Amy A.	<u>P-3449</u>
Walsh, Ella	<u>P-3475</u>
Walsh, Kevin	P-1203, P-1258
Walters, Richard	P-3226
Wan, Qiuchi	P-2852



Wan, Xiaoqiao	P-2405, P-2408
Wang, Can	O-3104
Wang, Chung-Ho	P-1514
Wang, Fei	O-4185
Wang, Guoan	<u>O-5050</u>
WANG, Guoan	P-4502
Wang, Hailei	<u>P-2404</u> , P-3415
Wang, Hanlin	O-1229, P-3812
Wang, Hong	<u>P-1498</u> , P-2836
Wang, Jia	O-5050
Wang, Jian	O-1167, <u>P-3205</u> , P-4223
Wang, Jiehua	O-3103
Wang, Junbo	<u>P-2402</u> , P-2423, P-2510
Wang, Ke	<u>P-1024</u>
Wang, Liang-Chi	<u>P-1461</u>
Wang, Lisheng	O-2178, <u>P-2499</u>
Wang, Long	<u>P-1062</u>
Wang, Longsheng	P-3434
Wang, Luo	O-2005, <u>O-2079</u> , P-2215, P-2408, P-2409, P-2411, P-3878
Wang, Ning	O-3168
Wang, Ningsheng	P-1895
Wang, Pei-Ling	O-1074
Wang, Qian	<u>O-5033</u>
Wang, Rong	P-2255
Wang, Shejiang	P-2206
Wang, Sirui	O-2055
Wang, Sumin	P-2406
Wang, Tao	O-4027
Wang, Wei-Ming	<u>O-2101</u>
WANG, XIAOHUA	P-3811
Wang, Xu	<u>O-2176</u> , O-2177, P-4503
Wang, Xueye	O-0145, <u>P-1913</u>
Wang, Yao	P-2621



INQUA 2019  
DUBLIN  
IRELAND

Wang, Yi	<u>O-3158</u>
Wang, Yichao	O-1229
Wang, Ying	O-2142
Wang, Yinghui	O-3168, O-4180, P-4603
Wang, Yiya	<u>P-1426</u>
Wang, Yong	O-4065
Wang, You-Ping	P-4608
Wang, Youjun	P-3411
Wang, Youpeng	O-4049
Wang, Youping	<u>O-4104</u>
Wang, Yuchen	O-3090
Wang, Yuchong	P-2911
Wang, Yue	O-1211, <u>O-2135</u>
Wang, Zhanghua	P-1062
Wang, Zongli	P-1248
Wanyama, Daniel	P-1836
Ward, Brent	<u>O-2212</u> , P-1481, <u>P-3224</u> , P-4832
Ward, Brittany Marie	<u>P-4498</u>
Ward, Ingrid	<u>O-2087</u> , <u>P-3043</u>
Ward, Sophie L.	O-1161
Ware, Roselyn	O-1103
Ware, Rosie	O-4030
Warken, Sophie	<u>P-2482</u>
Warren, Graeme	O-2023
Wary, Mélanie	<u>O-4073</u> , O-4077
Wassenburg, Jasper A.	O-3074, P-1496
Wasson, Robert	O-1029
Wasson, Robert J	O-4053
Wastegård, Stefan	O-1114, <u>O-3038</u> , O-5015, P-1468, P-3623, P-4446, P-4867
Watanabe Nara, Fumiko	O-0051
Watson, Ben	P-1819
Wattanapituksakul, Athiwat	O-0123
Wattrus, Nigel	O-3199, P-4853



Watts, Hannah	<u>P-2438</u>
Waweru, Veronica	O-2099
Webb, Gregory	O-4093
Weber, John	P-3026
Weber, Michael E.	<u>O-1010</u> , <u>P-1454</u>
Weber, Mike	O-3226
Weber, Yuki	P-3455
Webster, Cole	O-3151, P-3493
Weckström, Jan	P-3437
Weckström, Kaarina	O-1159, O-1184, P-1440, <u>P-4441</u>
Weckwerth, Piotr	<u>O-0049</u> , O-4083, <u>P-4213</u>
Weedon, Graham	P-4539
Wehmiller, John F.	O-3131
Wei, Dong	P-1913
Wei, Dongyang	O-3149
Wei, Kuo-Yen	<u>P-3215</u>
Wei, Mingjian	O-2150
Wei, Wang	O-0121
Wei, YE	P-4021, P-4230
Weidenfeller, Michael	P-3884
Weij, Rieneke	<u>O-2076</u>
Weilbach, Kasper	O-1055
Weiser, Jens	P-1439
Weiss, Harvey	<u>O-0108</u>
Weiss, Marcel	P-3873
Weiss, Robert	P-3050
Weisscher, Steven	O-1078
Weitzel, Nils	<u>O-4149</u> , <u>P-4405</u>
Weiß, Marcel	P-3874
Welc, Fabian	P-3486, P-3829
Wells, Greta	<u>O-4052</u>
Welsh, Katharine	<u>O-1222</u>
Welsh, Kevin	<u>O-4093</u> , P-2601



INQUA 2019  
DUBLIN  
IRELAND

Welte, Julian	O-4048
Weltje, Gert Jan	O-1077
Wen, Ruilin	O-2084, P-2403
Wen, Wenwen	P-1222
Wenau, Stefan	O-0133
Wenchao, Zhang	O-1030
Wendt, Jenny	P-1511
Weng, Chengyu	<u>O-1107</u> , P-1250
Weniger, Gerd-Christian	O-5024, P-2229
Weniniger, Bernhard	P-3803
Wennrich, Volker	O-2203, O-3016
Werban, Ulrike	O-2024, P-1835, P-3208
Werner, Martin	O-5124
Werner, Vera	O-4029, O-4031
Werritty, Alan	P-1283
Werther, Lukas	O-1223, P-1835, P-3208
Wesselingh, Frank	P-3604
Wessman, Anna	O-0146
Wesson, Rob	P-3020
West, Allen	P-2429
West, Dr Jared	O-1200, P-1047
West, Martin	O-2113
Westaway, Kira	O-0121, <u>P-1218</u> , P-1225, P-1452, P-4485
Westaway, Robert	P-2878
Westgard, Adele	P-1404
Westley, Kieran	<u>P-1264</u>
Weston, Dorothy	O-3041, <u>P-3626</u>
Wetter, Oliver	O-3080
Weyrich, Laura	O-0103
WG, EMERGE0	<u>P-4822</u>
Wheeler, Andrew	O-0133
Wheeler, Andrew J.	O-2013
Wheeler, Charlotte	P-1265



INQUA 2019  
DUBLIN  
IRELAND

Wheeler, Lucy	P-4618, <u>P-4631</u>
White, Chris	O-1081
White, Dustin	P-4456
White, James W. C.	O-0076
White, Mark	O-1019, O-1059, O-1217, P-1271, P-1290
White, Mark J.	O-3161
White, Tom	P-2234
Whiteford, Erika	P-4866
Whitehouse, Nicki	O-1104, O-1213, O-3099, O-3100, O-3101, O-4060, O-4062, <u>O-5009, P-4287</u>
Whitehouse, Pippa	O-0082, O-0113, O-1232, O-3228, P-1051, P-2435, P-3020, P-4005
Whitley, Thomas	O-2087
WHITLOCK, CATHY	P-4282
Whitlock, Cathy	<u>O-0019</u> , O-2137, P-4218
Whitmore, Ross	O-3187
Whitney, Bronwen	O-3173, <u>O-4063</u> , P-4209
Whittaker, Alex	O-1220
Whittaker, John	P-1036
Whittle, Alasdair	O-1213
Wholey, Heather	O-0067, <u>O-0152</u>
Wick, Lucia	O-1168
Wickert, Andrew	O-1235, O-4072, P-1402
Wickert, Andrew D.	O-2017
Wickert, Andy	P-1412
Wickham-Jones, Caroline	P-1048
Wickler, Stephen	<u>O-3023</u>
Widga, Chris	O-0041
Wieczorek, Dariusz	O-1152
Wieczorek, Małgorzata	P-1632
Wieler, Nimrod	P-2821
Wiemer, Stefan	O-3085
Wienhues, Giulia	<u>P-4250</u>



INQUA 2019  
DUBLIN  
IRELAND

Wiesendanger, Emily	<u>P-1239</u>
Wiggs, Giles	O-0094
Wilby, Robert	O-0091
Wilcken, Klaus	O-2096, O-3146, P-1487
Wilcken, Klaus M.	P-2447
Wilcox, Patrick	O-2220
Wilcox, Paul	<u>O-2074</u> , <u>P-4507</u>
Wilczyński, Jarosław	P-3873
Wilhelm, Bruno	O-3080, P-3848
Wilhelms, Frank	O-4014, P-4455
Wilken, Dennis	O-4031, P-1628, P-3039
Wilkins, Jayne	P-2235
Wilkinson, Clive	O-0090
Wilkinson, Keith	O-1180, O-1181, P-1287, P-1602, P-2615, P-4270
Wilkinson, Richard	P-4403
Willeit, Matteo	O-2036, <u>P-1429</u>
Willershäuser, Timo	P-3039
Willesrhäuser, Timo	O-4031
Williams, Alan	O-0103, P-3464
Williams, Charles	P-4513
Williams, Charlie	O-3033, O-4145
Williams, Chris	O-1224
Williams, Ian S.	O-0071, O-0072
Williams, Jack	O-1211, O-5008, <u>P-1819</u>
Williams, John	O-2007, O-2184, P-2251
Williams, John E.	O-0101
Williams, John W.	O-0101, O-2059, O-5081, <u>O-5122</u> , P-3440
Williams, Martin	<u>O-3015</u>
Williams, Park	P-4537
Williams, Rory	P-2832, P-4485
Williams, Sophie	<u>P-1049</u>
Williamson, Daniel	O-4150
Willis, Katherine	<u>Plen06</u>



Willis, Kathy	O-1121, O-1134, P-2251
Willis, Kathy J.	O-2134
Willmes, Christian	O-3019, O-4135, <u>P-4207</u>
Willmes, Malte	<u>O-0147</u>
Willserlev, Eske	P-1204
Wilmshurst, Janet	O-2136, O-3145, O-4012, P-3470, P-4492
Wilmshurst, Janet M	O-2054
Wils, Tommy	P-4537
Wilson, Graham	<u>O-1164</u>
Wilson, Oliver	<u>O-2171</u> , <u>P-3226</u>
Wilson, Paul	O-3202
Wilson, Peter	O-1055, O-3230, O-5128, P-2431
Wimpenny, Sam	O-4125
Winckler, Gisela	O-0008, O-3046, P-2603
Winocur, Diego	O-0143
Winsborrow, Monica	O-2143, O-5059, O-5129
Winsborrow, Monica C. M.	O-5131
Winsemann, Jutta	O-4189, <u>P-3825</u> , <u>P-3863</u> , <u>P-4851</u>
Winstrup, Mai	O-2015, P-4455
Winter, Lara	P-2221, P-4246
Winton, Holly	O-0013
Wirth, Stefanie	<u>O-5073</u>
Wirth, Stefanie B.	O-3080
Wise, Erika	<u>O-1225</u>
Wittmann, Hella	O-1220
Wißing, Christoph	P-1231
Wiśniewski, Andrzej	<u>P-3873</u>
Woelders, Lineke	P-3446
Wohlfarth, Barbara	O-0025, O-1051, O-4074, P-1201
Woida, Kathleen	O-0033
Wolf, Annabel	P-1506
Wolf, Daniel	O-3032, <u>O-3223</u> , <u>P-1602</u> , P-2815
Wolf, Dennis	P-4610



Wolf, Kyra	O-0021
Wolfe, Stephen	O-2035
Wolff, Christian	O-2109
Wolff, Eric	O-4009, <u>Plen01</u>
Wolpert, Tilmann	P-1602, <u>P-2815</u>
Wolters, Steffen Wolters	P-4420
Wong, Corinne	O-2117
Wong, Henri	P-2480
Wood, Jamie R	O-2054
Wood, Susie	O-5007
Woodbridge, Jessie	<u>O-5078</u> , O-5079, P-2212
Woodhead, Jon	O-2076, P-2480, P-2802, P-4486, P-4491
Woodroffe, Sarah	<u>O-0116</u> , <u>P-1055</u> , <u>P-2257</u>
Woods, Arielle	O-5091, P-2223
Woodward, Craig	O-1047, O-3146
Woodward, Jamie	O-2096, P-3827
Woodworth, Philip	P-1056
Wooller, Matthew	O-0062, <u>O-0063</u> , O-2201, Plen02
Wooller, Matthew J.	O-0058
Woolley, John-Mark	O-4204, P-4492, <u>P-4493</u>
Woronko, Barbara	O-1128, <u>O-2211</u> , P-1855, P-1879, P-2822, <u>P-2824</u> , P-2827, P-3829, P-4641, P-4834
Woszczyk, Michał	P-4411, P-4412
Wotzka, Hans-Peter	O-3097
Woźniak, Piotr P.	O-1053
Woźniak, Piotr Paweł	<u>P-2827</u>
Wright, Joshua	P-3214
Wright, Joshua	O-0142
Wu, Bin	P-2215
Wu, Fuli	P-1804, <u>P-3425</u>
Wu, Haibin	O-5011, <u>P-1497</u> , P-2206, P-3878, P-4422, P-4504, P-4526
Wu, Jiang	P-2621
Wu, Jiaying	P-2220



INQUA 2019  
DUBLIN  
IRELAND

Wu, Jing	P-2245, P-2409, <u>P-2411</u> , P-3408
Wu, Naiqin	P-1222, P-2215, P-2409, <u>P-2611</u> , P-3201
Wu, Yan	<u>O-0153</u>
Wu, Yi	O-2163
Wu, Zhipeng	<u>P-2476</u>
Wulf, Gerwin	O-3108
Wulf, Sabine	<u>O-3036</u> , O-3116, O-4087, P-1614, P-4009, P-4444, P-4449
Wunderlich, Jürgen	P-3448, P-3843
Wunderlich, Tina	P-1628
Wunderliche, Tina	O-4031
Wurster, Christopher	<u>O-2112</u> , <u>P-1811</u>
Wyman, D. Allie	<u>O-5100</u>
Wynne, Hollie	O-0150, O-1160
Wyshnytzky, Cianna	O-1148
Wysoczanski, Richard	P-3624
Wysota, Wojciech	O-0049, <u>O-2141</u> , <u>P-1847</u>
Wünnemann, Bernd	P-3477
Włodarski, Wojciech	P-1901
Wörmer, Lars-Peter	P-1511
Xavier, Pedro	P-2899
Xia, Dunsheng	O-0022
Xiang, Lixiong	O-2157, <u>P-4419</u>
Xiao, Jule	<u>O-2084</u> , P-2403
Xiao, Xiayun	<u>P-2406</u>
Xiao, ZHANG	P-4021
Xiaozhong, Huang	P-2414
Xie, Hao	P-4267
Xie, Jiubing	O-2163
Xie, Zhenglan	<u>P-2466</u>
Xin, Yan	P-4223
Xinrong, Zhang	<u>P-2877</u>
Xiong, Haixian	P-3009
Xu, Bing	O-2079, P-2228, P-3878



INQUA 2019  
DUBLIN  
IRELAND

Xu, Chenxi	<u>O-4207</u> , P-1422
Xu, Deke	O-3103, <u>P-2409</u>
XU, Deke	P-2215
Xu, Qinghai	O-5012, P-2403, <u>P-4292</u>
Xu, Sheng	O-4163, O-4167, O-4168, P-4482
Xu, Zhiwei	<u>O-2149</u> , <u>P-3808</u>
Xuan, Chuang	O-3130
Xue, Bin	P-2406
Xue, Gang	<u>O-4011</u> , P-1418
Xue, Jibin	P-4012
Yabi, Ibouraima	<u>P-4257</u>
Yadav, Ram R.	P-4535
Yadava, Akhilesh K.	P-4535
YAGI, Hiroshi	<u>P-3871</u>
Yagi, Masatoshi	O-2090
Yakovleva, Svetlana	P-2622
Yalkovskaya, Lidia	O-5110
Yaltirak, Cenk	P-3605
YAMADA, Kazuyoshi	P-1019
Yamada, Kazuyoshi	O-2161, P-2261
Yamada, Keitaro	<u>P-2428</u> , P-3457
Yamada, Masaki	<u>O-3090</u>
Yamamoto, Akitomo	P-1430
Yamamoto, Shinya	P-3030
Yamoah, Kweku	O-0107
Yamoah, Kweku Afrifa	O-1074
yan, hong	O-1030
Yan, Maodu	P-2515
Yan, Mi	<u>O-5051</u> , O-5070
Yan, Xiaoli	P-1804
Yan, Yan	P-1424
Yan, Yao	P-2405, P-2408
Yanes, Yurena	P-3493



INQUA 2019  
DUBLIN  
IRELAND

Yaneva, Marlana	P-3865
Yang, Bingjie	<u>O-5071</u>
Yang, Dong-Yoon	<u>P-1002</u> , P-1018
Yang, Fei	P-3887
Yang, Hu	P-1444, <u>P-3482</u>
Yang, Qingjiang	<u>P-4223</u>
YANG, Shi-Xia	<u>O-4139</u>
Yang, Shiling	O-2005, <u>O-4064</u> , P-4503
Yang, Shixia	O-2163
Yang, xiangdong	P-2249
Yang, Xiangdong	O-2079, O-5033, P-4242
Yang, Xiaolan	O-4065, P-4279
Yang, xiaoping	P-2833
Yang, Xiaoping	P-2834, P-3478, <u>Plen03</u>
Yang, Xiaoqiang	O-4081
Yang, Xiaoxiao	O-2005
Yang, Xiaoyan	<u>O-4027</u>
Yang, Yan	P-1801
Yang, Zhenrui	P-2911
Yang, Zhenyu	<u>P-3630</u>
Yang, Zhigang	P-2464
Yanina, Tamara	O-3051, O-3052, <u>O-3053</u> , O-3054, P-1638, P-1639, P-2231, <u>P-3602</u> , P-3604, P-3607, P-3608, P-3609, P-3610
Yao, Qiang	O-1083, P-4026
Yasan, Onur	P-2462
Yasuhara, Moriaki	<u>O-1001</u>
Yates, Yurena	O-3151
Yavuz, Vural	O-2018
YE, Wei	<u>P-3435</u> , P-4518
Ye, Wei	P-3411
Ye, Yi Shin	O-3219
Yeakel, Justin	P-3218
Yellich, John	P-1851



Yen, Jiun-Yee	P-2882
Yesilyurt, Serdar	O-1149
Yeşilyurt, Serdar	O-2018, <u>P-2430</u> , <u>P-3001</u>
Yi, Chaolu	<u>P-1880</u>
Yi, Liang	P-2215
Yi, Sangheon	P-1002, P-1228, <u>P-1490</u> , P-2474, P-4525
Yi, Shuangwen	O-4176, <u>P-2621</u> , P-3808
Yilales, Mariana	O-4004
Yin, Bin	O-1033
Yin, Qiuzhen	O-0022, <u>O-3000</u> , P-2215, P-2476, P-2478, P-2485, P-3880
Yin, Zhi-Yong	P-4536, P-4538
Yin, Zhiqiang	<u>O-0156</u>
Ying, HUANG	P-4021
Yoccoz, Nigel G.	P-1209
Yoccoz, Nigel Giles	O-1105
Yohannes, Elizabeth	P-4262
Yokohata, Tokuta	P-2855
Yokoo, Yoriko	O-1006
Yokoyama, Elder	<u>P-2425</u>
Yokoyama, Yuseke	O-5032
YOKOYAMA, Yusuke	P-4448
Yokoyama, Yusuke	O-1011, O-3087, O-5057, P-3615, P-4629
Yoneda, Minoru	O-3086
Yonenobu, Hitoshi	O-2161
YONENOBU, Hitoshi	P-4448
Yoo, Dong Geun	P-3830
Yoo, Dong-Geun	P-1606, P-2003, <u>P-2829</u>
Yoon, Hyun Ho	P-2003
Yoshida, Takehito	P-2261
Yoshimori, Masakazu	O-1085, P-2489
Yost, Chad	O-4169
Youbin, Sun	P-2412
Young, Aythya	<u>P-3221</u>



Young, Benjamin	O-0109
Young, Dylan	P-2863
Young, G.H.F.	O-4042
Young, Giles	<u>O-4210</u>
Young, Joseph	<u>O-5048</u> , <u>P-4858</u>
Yu, Byung Yong	P-3026
Yu, Dorothy	O-3098
Yu, Du	P-2877
Yu, Gao	O-4049
Yu, Hongbin	O-0092
Yu, Kefu	O-3168, O-4180, P-4603
Yu, Lupeng	P-2618
Yu, Shaohua	<u>P-3406</u>
Yu, Shi-Yong	O-3158
Yu, Tsai-Luen	O-0027, O-5108
Yu, Xuefeng	<u>P-1501</u>
Yu, Yanyan	<u>O-5011</u> , P-1497, P-4422, P-4504
Yu, Zicheng	O-2055
Yuan, Baoyin	P-4522
Yuan, Jing	O-0145
Yue, Yuanfu	<u>O-3168</u> , <u>P-2852</u>
Yun, Suk Min	P-1223, P-3008
Yurtaev, Andrey	P-3888
Yildirim, Cengiz	P-2447, P-2897, P-3817, P-4476, <u>P-4818</u>
Zabel, Matthias	P-4530
Zafra, Elena	O-2032
Zagórski, Piotr	P-1243
Zahajská, Petra	O-5030
Zahariev, Nikolay	O-0052
Zahng, Huiping	P-2821
Zaim, Yahdi	P-1610
Zakharov, Andrey	<u>P-3814</u> , P-4845, P-4852, P-4860
Zalat, Abdelfattah	O-1165, P-3486



INQUA 2019  
DUBLIN  
IRELAND

Zan, Jinbo	P-2515
Zanchetta, Giovanni	O-1163, O-2124, O-3150, O-4211, <u>P-1607</u> , P-2472, P-2480, <u>P-3488</u> , P-3810, P-4013
Zander, Anja	O-4114, O-4118, P-3884
Zander, Paul	<u>O-5002</u> , <u>P-4619</u>
Zang, Shuang	O-3041
Zanon, Marco	<u>O-1041</u>
Zaragosi, Sébastien	O-4077, P-1405, P-1449, P-2481
Zaretskaya, Nataliya	<u>P-4637</u> , <u>P-4855</u>
Zarzecka-Szubińska, Katarzyna	P-3873
Zasadni, Jerzy	P-2448
Zastrozhnov, Andrei	<u>P-2622</u>
Zastrozhnov, Andrey	O-5039
Zavala, Bilberto	P-3224
Zawadzki, Atun	P-3423, P-3463, P-4252
Zawiska, Izabela	<u>P-4411</u> , P-4412
Zazo, Caridad	P-3497, P-4531
Zazovskaya, Elya	O-5020
Zazula, Grant	O-0041, O-2213, Plen02
Zbucki, Łukasz	P-4641
Zech, Michael	O-3021, O-3096, P-2253, P-3207, P-3210, P-3480, P-4505
Zech, Roland	O-3223, P-2446, P-3480, P-3884, P-4530
Zech, Wolfgang	P-3207, P-3210
Zeeden, Christian	P-1628, P-2813
Zelenin, Egor	P-3037
Zellman, Mark	O-1064, O-4047
Zeng, Lin	P-2621
Zeng, Linghan	<u>P-4259</u>
Zeng, Xun	P-4811
Zerathe, Swann	P-3224
Zerboni, Andrea	<u>O-2124</u> , O-3018, O-3121, P-1887, <u>P-3802</u>
Zerefos, Christos	P-3064
Zerkal, Oleg	<u>P-3870</u>



Zerkal, Oleg Vladimirovich	<u>P-3869</u>
Zernack, Anke Verena	<u>P-1621</u> , <u>P-3628</u>
Zevallos-Valdivia, Leonardo	O-2224
Zhai, Dayou	O-2084
Zhai, Jixuan	O-2176, <u>O-2177</u>
Zhamoida, Vladimir	O-5127, <u>P-1032</u> , P-2009, <u>P-3005</u>
Zhang, Can	P-1500
Zhang, Chengjun	P-4275
Zhang, Chunxia	<u>P-4526</u>
Zhang, Dan	P-2215
Zhang, Deguo	O-2079, P-2215, <u>P-2834</u>
Zhang, Dongtao	O-2079
Zhang, Enlou	O-2005, O-2079, P-2408
Zhang, Guiling	O-1167
Zhang, Hanzhi	O-1229, <u>P-3812</u>
Zhang, Hongyan	O-1229, P-2206
Zhang, Hucai	O-1033, P-2502
Zhang, Hui	O-2051, P-2853, P-2857
Zhang, Huiling	O-3168
Zhang, Ji-Xiao	O-2101
Zhang, Jia-Fu	<u>P-4608</u>
Zhang, Jianping	O-3103, O-3104, <u>P-3201</u> , P-4225
Zhang, Jiaoyang	P-2405, P-2408
Zhang, jingpeng	P-3406
Zhang, Jun	P-1248
zhang, ke	<u>P-2249</u>
Zhang, Lei	O-0023, P-2228, <u>P-3828</u>
Zhang, Lijun	P-2862
Zhang, Peiqi	<u>O-0139</u>
Zhang, Peng	<u>P-3212</u>
Zhang, Ping	P-1804
Zhang, Qi	<u>P-3434</u>
Zhang, Qiong	O-5010



INQUA 2019  
DUBLIN  
IRELAND

Zhang, Ruchun	P-4279
Zhang, Shengrui	O-2084, <u>P-2403</u> , P-4292
Zhang, Shuang	O-1181
Zhang, Shuhua	O-2177
Zhang, Tingwei	O-4081
Zhang, Weiguo	P-1031
Zhang, Weilin	P-2515
Zhang, Wenchao	<u>P-2206</u>
Zhang, Wenfang	P-1431
Zhang, Wensheng	P-4279
Zhang, Xiaoling	O-0056
Zhang, Xiaoyan	P-4526
Zhang, Xu	<u>O-2114</u> , O-4009, P-1444
Zhang, Xujiao	P-3813
Zhang, Yaze	<u>P-3009</u>
Zhang, Yingqi	O-0121, P-1218, <u>P-1225</u>
Zhang, Yong	<u>P-4536</u>
Zhang, Yueting	P-2215
Zhang, Yunan	<u>P-4211</u>
Zhang, Yurui	P-1447
Zhang, Zeke	<u>P-1515</u>
Zhang, Zhongshi	P-4495
Zhao, Chao	<u>P-1808</u> , P-4223
Zhao, Cheng	<u>P-1500</u>
Zhao, Hailong	P-4275
Zhao, Haiyan	P-1501
Zhao, Jian-xin	O-4093, P-3487
Zhao, Keliang	P-4223
Zhao, Lin	O-1229
Zhao, Yan	O-5012
Zhao, Yanjie	<u>P-2256</u>
Zhao, Yongtao	P-2413, <u>P-3420</u>
Zhao, Yuchao	O-5027



INQUA 2019  
DUBLIN  
IRELAND

Zheng, Hongbo	P-1024
Zheng, Jingyun	O-0087
Zheng, Qian	O-1033
Zheng, Rongzhang	P-4811
Zheng, Xianglin	O-1046
Zheng, Xue	P-4293
Zheng, Yunfei	O-3103
Zheng, Zhuo	O-1124, O-1171, P-2852, P-3009
Zhenjing, Yang	O-2082
Zhilich, Snezhana	O-2003
Zhong, Yafang	O-0115
Zhou, Aifeng	P-3479
Zhou, Bin	O-2112
Zhou, Houyun	<u>P-2804</u>
Zhou, Liping	<u>O-0119</u> , P-4608
Zhou, Weijian	P-1498, P-2836
Zhou, Xinying	O-1167, P-1808, P-3205, P-4223
Zhou, Ye	<u>P-2833</u>
ZHU, Lidong	P-3435, P-4518
Zhu, Lidong	P-3411
Zhu, Liping	<u>O-2001</u> , P-1494, P-2402, P-2415, P-2423
Zhu, Min	P-4503
Zhu, Rixiang	P-4522, P-4526
Zhu, Yun	P-2502
Zhu, Zeyang	<u>P-3408</u>
Zhu, Zhaoyu	<u>O-2163</u> , P-1005
Zhuang, Qianlai	<u>O-2055</u>
Zieglar, Alan	O-4053
Ziegler, Alan	O-1029, P-3044
Ziegler, Martin	P-1473
Zielhofer, Christoph	O-1223, O-2024, <u>O-3073</u> , O-3148, P-1835, P-3208, <u>P-3803</u>
Zieliński, Paweł	P-4638, P-4834
Zieliński, Tomasz	P-4638



INQUA 2019  
DUBLIN  
IRELAND

Zimmerman, Susan	O-4041, O-4141, P-3431, P-3466
Zimmermann, Boris	O-2034
Zimmermann, Heike	O-1102
Zimmermann, Heike H.	O-1022, O-1028, <u>P-1215</u> , <u>P-1441</u>
Zinaye, Bahru	O-3031
Zocchi, Marta	P-3836
Zoeller, Ludwig	<u>P-1625</u> , P-1634
Zoet, Lucas	P-1853
Zolitschka, Bernd	O-1114, O-1154, <u>O-4018</u> , P-3421
Zondervan, Jesse	P-2898
Zong, Xiulan	<u>P-2501</u>
Zong, Yongqiang	P-3009
Zonneveld, John-Paul	P-1610
Zonneveld, Karin	P-4461
Zorita, Eduardo	P-4415, <u>P-4416</u>
Zorzi, Coralie	<u>O-4068</u> , P-1457, <u>P-1458</u>
Zorzut, Valentina	P-4482
Zou, Jianjun	P-1408
Zou, Yafei	O-2079, P-2408
Zouari, Kamel	P-2468
Zreda, Marek	O-1069
Zuffetti, Chiara	<u>P-1906</u>
Zuidema, Paquita	O-0092
Zular, André	O-3109
Zuo, Xinxin	<u>P-4225</u>
Zupan Hajna, Nadja	<u>O-2071</u>
Zupan-Hajna, Nadia	O-1204
Zuraida, Rina	O-1118
Zurbuchen, Julie	P-4005
Zwart, Costijn	P-1811
Zweidorff, Julie	O-5019
Zwinger, Thomas	O-3229
Zwyns, Nicolas	<u>O-0054</u> , O-0139, O-5094



INQUA 2019  
DUBLIN  
IRELAND

Zykin, Vladimir	<u>O-4067</u>
Zykina, Valentina	O-4067, <u>P-2619</u> , P-2620
Zyuganova, Inna	P-4845
Zárate, Marcelo	P-2832
Zêzere, José Luís	P-1040
Zöllner, Ludwig	O-3032, O-3223, P-1636, P-2887
Zăinescu, Florin	O-4108
Álvarez-Vena, Adrián	P-1488
Åkesson, Henning	P-3822
Çiner, Attila	O-1069, P-1889, P-2447, <u>P-3817</u> , <u>P-4476</u> , P-4818
Çilğın, Zeynel	P-2462
Ó Cofaigh, Colm	O-1055, O-5060, O-5061, O-5062, P-4002, <u>P-4838</u>
Ó Dochartaigh, Brighid	O-3202
Ó Drisceoil, Cóilín	P-2234
Ófeigsson, Benedikt	O-3202
Óladóttir, Bergrún Arna	O-3040
Öhrling, Christian	P-2910, P-4842
Özbey, Volkan	P-4818
Özcan, Orkan	P-2897, P-4818
Özgür, Nevzat	<u>O-3210</u>
Özpolat, Emrah	<u>P-1038</u> , <u>P-2897</u>
Újvári, Gábor	O-1191, O-4070, P-1425
Łabęcka, Karolina	<u>P-1888</u>
Łanczont, Maria	<u>P-2885</u> , <u>P-4633</u>
Łokas, Edyta	P-2266
Łuców, Dominika	P-1816
Řezníčková, Ladislava	O-0085
Świąder, Andrzej	P-2448
Şahiner, Eren	O-3129, P-2897, P-3842
Şen, Erdal	O-1069
Şen, Ömer L.	P-1889
Şentürk, Alperen	O-3210
Šeirienė, Vaida	P-1035



INQUA 2019  
DUBLIN  
IRELAND

Šinkūnas, Petras	P-1852, <u>P-4848</u>
Šinkūnė, Eglė	<u>P-1852</u>
Šmuc, Andrej	O-4208, P-1041, P-2262, P-4240
Štorc, Richard	O-5109
Štěpančíková, Petra	<u>P-3865</u>
Šírová, Jolana	O-3155
Țuțuianu, Laurentiu-Florin	<u>P-4260</u>
Żarczyński, Maurycy	O-5002, <u>P-1474</u> , P-4619
Żarski, Marcin	O-1165, P-2407
Žatecká, Michaela	P-1630
Žebre, Manja	P-2842, P-2903, P-3817
Živčić, Mladen	O-4188
Žliobaitė, Indrė	O-2166
Žulkus, Vladas	P-1035