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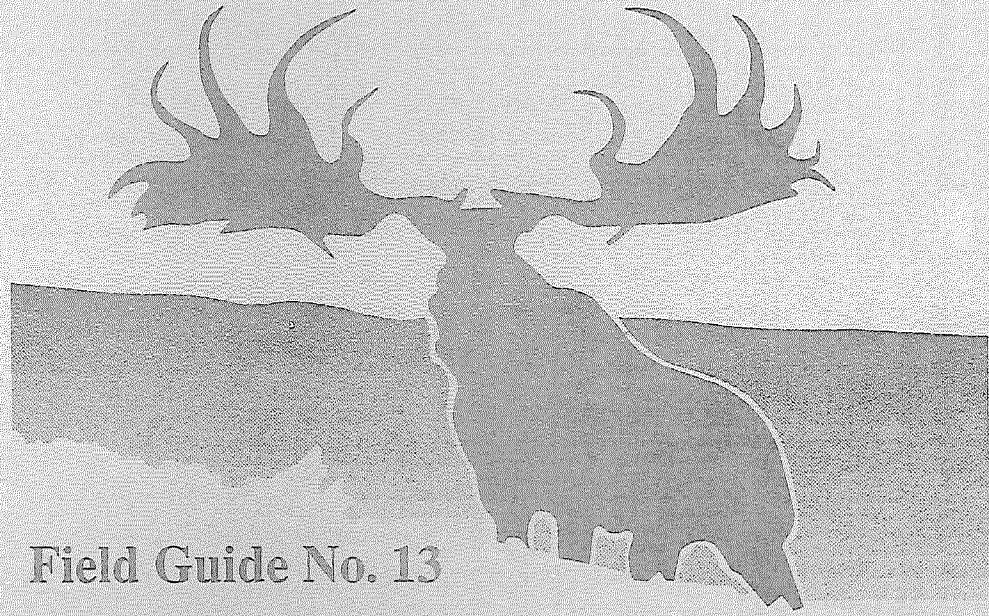

Field Guide No. 13

NORTH ANTRIM AND LONDONDERRY

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1990

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PREFACE

This field guide describes aspects of and sites relating to the Late Quaternary history of the northern part of Northern Ireland. Although the area has attracted the attention of Quaternary scientists for over 100 years, recent research indicates a far more complex pattern of landscape and coastal evolution than previously envisaged. Moreover, palaeoecological studies are yielding important climatic information and are providing archaeologists with a means of precisely dating prehistoric sites. The field excursion has been designed to incorporate these recent studies and to bring together scientists from different Quaternary disciplines to review and discuss their significance.

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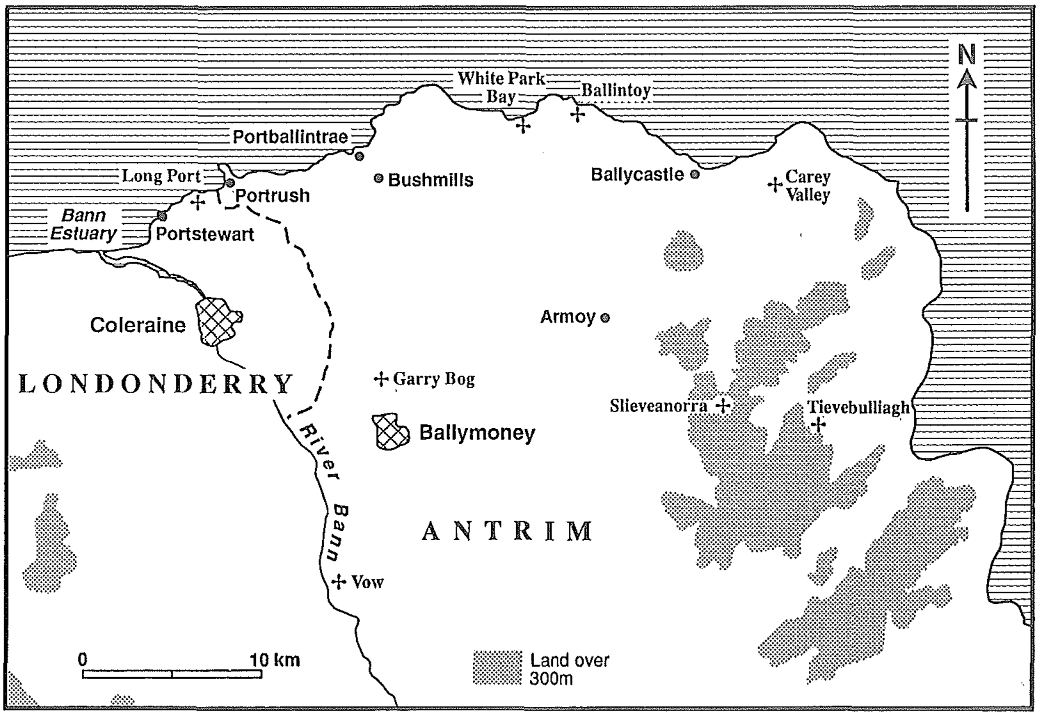

Figure 1. Area covered by the field excursion, showing major towns and locations of sites to be visited.

BEDROCK GEOLOGY (*Graham Nevin*)

While the ancient name for the north-east corner of Ireland - Dal Riada - has attained international geological status as the name given to the group of late Precambrian metasediments stretching from Galway to the east of Scotland, and which form an inlier between Knocklayde and Cushendall, it is the Tertiary basalts of the Antrim Plateau which dominate the geology of north-east Ulster (Fig. 2). These rocks, which occur as a series of horizontally layered lava flows with a total thickness of over 750m, form spectacular cliffs along the north and east coasts, the former area including the Giant's Causeway which has been designated as a World Heritage Site for its cliff scenery and historical importance in the development of the science of geology. The gross outline of the coast is essentially a product of late Tertiary faulting (examples of which can be seen at Ballintoy) and around the coast, movement on these faults has allowed glimpses of the complex geology which lies buried beneath the basalts. These pre-basalt rocks, which range in age from Devonian to Cretaceous, produce fascinating areas of different local geology, and have had an influence on the landscape, both physical and cultural, which outweighs their limited geographical extent.

The Tertiary Volcanic Rocks

The basalt lavas, which cover an area of some 4000km^2, mainly in Co. Antrim, although one of the most striking features of Ulster geology, are but a small remnant of the vast lava fields which covered the north-west of Britain in Tertiary times. Since then, late Tertiary step faulting, which defines the north and east coasts, and considerable erosion of the margins, has isolated the Antrim Plateau and formed the spectacular escarpments around its margins.

The Antrim Lava Group is divided into the Lower Basalt, a widespread formation forming the escarpment overlooking Belfast and the cliffs of the north and east Antrim coast, and the Upper Basalt, which occurs mainly as outliers on the higher ground in the north and east, by an interbasaltic bed of lateritised basalts, residual bauxites and iron ores. In north Antrim, the profile of the hills often shows a prominent step at the position of the Interbasaltic Bed and along this level the brightly coloured spoil tips of old iron ore workings can still be seen. To the north of the Tow Valley Fault (now thought to be a continuation of the Scottish Highland Boundary Fault), a more localised series

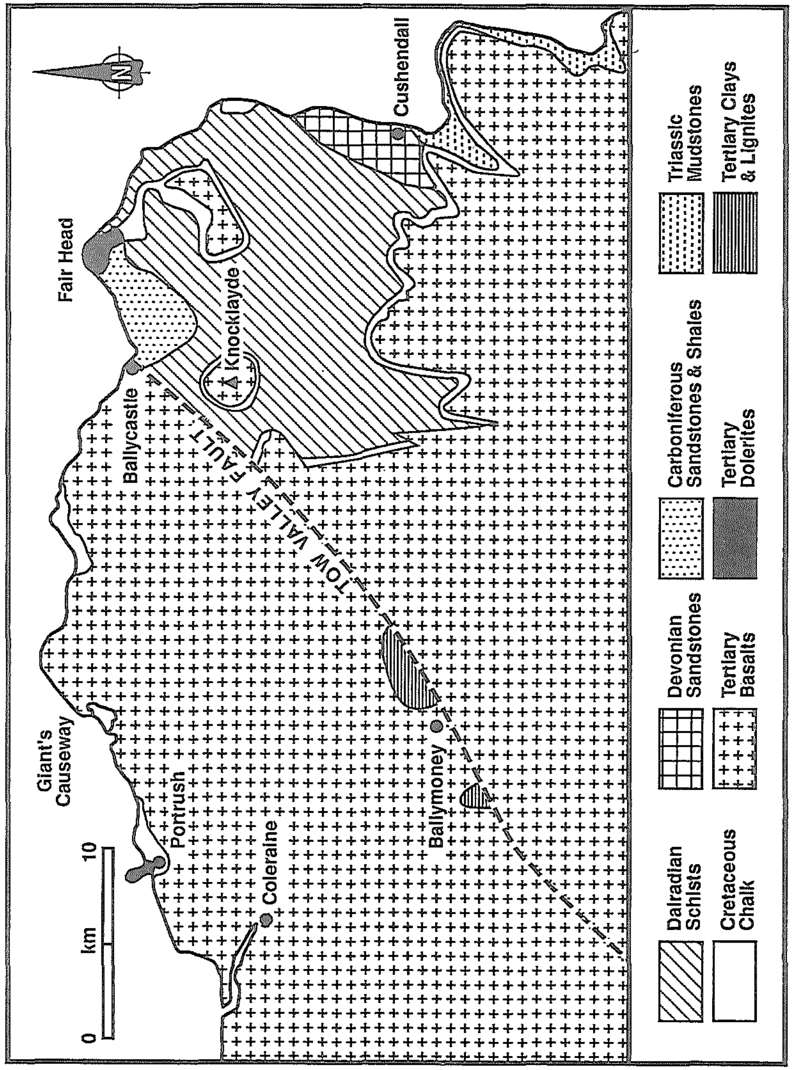

Figure 2. Simplified bedrock geology of the field excursion area.

of basalt flows, the Causeway Basalts, interrupted the interbasaltic hiatus. these basalts are unusually fine grained and exhibit excellent columnar jointing. most spectacularly displayed in the Giant's Causeway.

The lava pile has been built up of very many individual flows ranging in thickness from <1m up to 30-40m. Almost all the flows were erupted subaerially (a few flowed into lakes) and they show a typical three-fold structure of a thin lower rubbly zone, a massive central section and a vesicular top, with numerous small cavities (vesicles) formed as gases released from the fresh lava rose to the surface. Often the top of the flows are marked by a bright red band of weathered lava or volcanic ash, representing palaeosols which, in a few cases, have yielded plant remains. The effect of differential erosion on the alternation of more and less resistant parts of each flow can be seen in the stepped profiles of cliffs, shore platforms and, to a lesser extent, inland as 'trap feature' topography.

The Antrim lavas show a spectacular range of volcanic featues, including a line of vents, running from the White Rocks at Portrush through Carrickarade to Ballycastle, associated with an early phase of explosive activity, producing agglomerates and tuffs. Associated with the extrusive activity are intrusive features - plugs, dykes and sills, including the great dolerite sill of Fair Head, well known for its glacially striated rock pavement, and forming, at the north-eastern tip of Ireland, a promontory so distinctive as to be recognisable even on Ptolemy's charts. The plug at Tievebulliagh is one of several which fed Upper Basalt lava flows; here the conduit passed through the interbasaltic laterites and they have been thermally metamorphosed to a hard, fine grained porcellanite used in Neolithic times for the manufacture of axe heads.

The Pre-basalt Rocks

The older rocks which crop out below the basalt around the coast span a wide range in age and lithology, each producing its own distinctive section of coastline. Dalradian metamorphic rocks form the cliffed coast from Murlough Bay to Cushendun, with Devonian conglomerates, volcanic and pyroclastic rocks forming lower cliffs south from there to Cushendall. The less resistant sediments are found in the bays - Carboniferous sandstones and coal measures at Ballycastle and Murlough Bay, Triassic red sandstone at Red Bay and Jurassic Lias clay at White Park Bay.

The oldest rocks in the area belong to the late Precambrian, Dalradian supergroup, and are a continuation of the Scottish outcrops. The north Antrim inlier is mainly schist and

schistose grit, with an impure crystalline limestone striking inland from Torr Head. These resistant rocks form an important constituent of the glacial gravels of the Carey valley. The area still retains remnants of its Mesozoic cover, which produce unexpected patches of chalk downland within an otherwise barren, peat covered high moorland.

The lava plateau overlies and protects a relatively thin Mesozoic succession of chalk, with local basal greensand, and Lower Jurassic (Lias) marine clays. This latter, although only a few tens of metres thick, plays a significant part in the landscape, forming an important spring line at the base of the chalk and acting as the slide plane for the major rotational slumps along the edge of the escarpment and the source of many active mudflows. The best examples are on the east coast, but they can also be seen in the undercliff at White Park Bay.

The Lough Neagh Clays

The most recent rocks in the area are the lignite bearing clays of the Oligocene Lough Neagh Group. Although well known around the southern shores of Lough Neagh, and in more recent times from the intensive exploration programme at Crumlin, there was no indication that rocks younger than the basalts occurred anywhere else in Northern Ireland. When, in 1983, grey clays with lignite fragments were recovered from a water well being sunk near Ballymoney, in what was thought to be glacial drift overlying basalt, attention was drawn to the possibility of another post-basalt sedimentary basin in north Antrim. Below 40m of drift, 200m of Tertiary sedimentary rocks similar to those of the Lough Neagh Group, including 70m of lignite in a multiple seam deposit were discovered by a drilling team from the Geological Survey of Northern Ireland. Since then, further exploration by the Geological Survey and latterly by the Australian mining company, Meekatharra, has revealed a series of sedimentary basins along the line of the Tow Valley Fault with reserves of lignite claimed to be capable of supporting a 1000Mw power station. The strata associated with lignites are mainly clays and silty clays with sands and thin conglomerates in the lower part of the sequence; these overlie the deeply weathered top of the basalt lavas. The drift cover averages 40-50m. Exploration is still in progress at the time of writing.

GLACIAL HISTORY (*George Dardis*)

The north coast of Ireland is thought to have been engulfed by two major ice sheets. The earlier glaciation, attributed to the Munsterian Cold Stage, is considered to be of

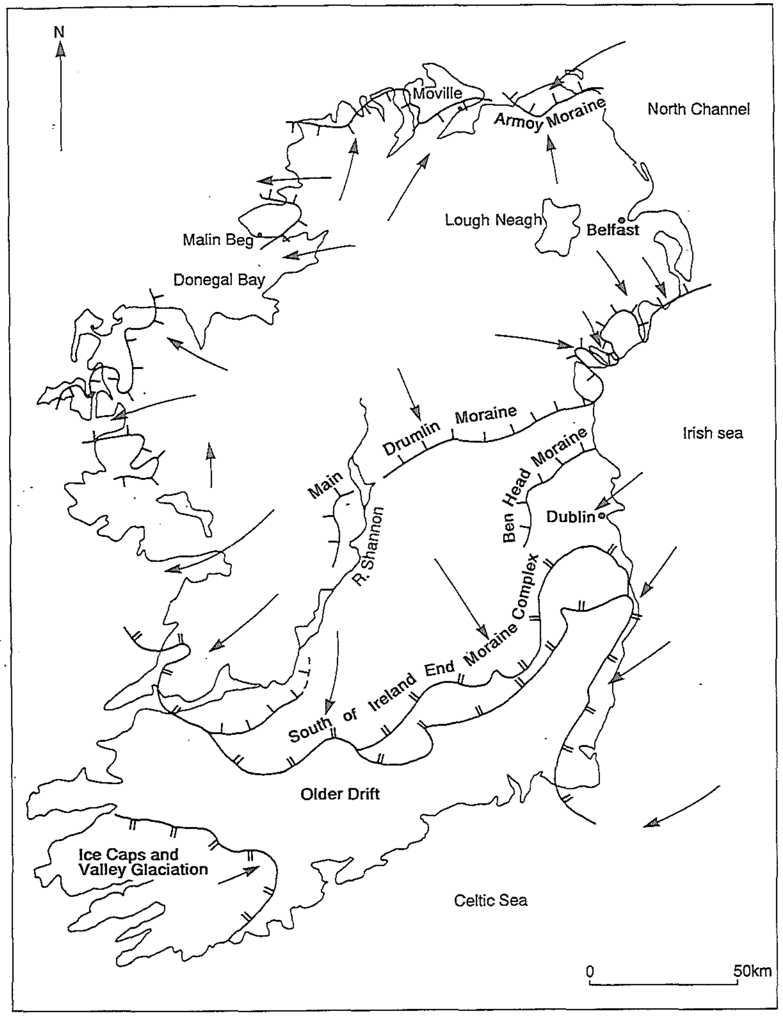

Figure 3. Late Midlandian ice limits and general directions of ice movements in Ireland (modified after McCabe, 1987).

Scottish origin, on the basis of distribution of shelly till lithofacies and Ailsa Craig microgranite erratics found in Quaternary deposits on the coastal fringe of north-east Ireland (Kilroe, 1888; Dwerryhouse, 1923; Charlesworth, 1939). However, erratic carriage shows no set pattern, making the age and regional extent of this ice sheet conjectural (Mitchell *et al.*, 1973; Stephens *et al.*, 1975; Warren, 1985; McCabe, 1985, 1987).

Scottish and Irish ice masses were thought to have been confluent in north-east Ireland during the last glaciation (Dwerryhouse, 1923; Charlesworth, 1939). Later workers believe that the influence of Scottish ice was less marked during the last glaciation (Fig. 3), with Irish ice of sufficient volume and extent to prevent any significant penetration of north-east Ireland by extraneous ice (Hill & Prior, 1968; Stephens *et al.*, 1975). During this glaciation, ice flow in the Bann valley was largely northward, indicated by drumlin orientations and northward carriage of Tardree rhyolite and TIC (Tyrone Igneous Complex) erratics (Hill & Prior, 1968) (Fig. 4). The extent of Antrim Plateau ice cover is conjectural at this stage (Stephens *et al.*, 1975), though glaciated areas of small extent have been mapped in this area and are considered to have been coeval with the late Midlandian ice sheet (Hill & Prior, 1968; Prior, 1968, 1970).

Decay of Irish ice was followed by a widespread readvance of Scottish ice into north-east Ireland (Dwerryhouse, 1923, Charlesworth, 1939), marked on the north coast by a moraine extending east - west cross-country from Ballycastle to Coleraine, via Armoy and Ballymoney. Even though this advance may have overridden and destroyed drumlins on the north coast (Charlesworth, 1939), it is thought to have been coeval with the retreating late Midlandian ice sheet in the Bann valley (Stephens *et al.*, 1975). This latter view is based on detailed examination of till lithology throughout north-central Ulster, and by examination of sedimentary sequences associated with the Armoy glacial limits (Fig. 4) and in linear hummocky moraines in the Bann valley to the south (Creighton, 1974). Extensive glaciolacustrine sequences on the south side of the Armoy glacial limits were attributed to sedimentation within an inter-lobate glacial lake of transient dimensions, formed between Scottish ice of the Armoy Stage and Bann valley ice retreating southwards into the Lough Neagh lowlands (Creighton, 1974). More recent studies have also found evidence of extensive ice-proximal glaciolacustrine sequences (interbedded tills, gravels, sands, silts and laminated clays) associated with the Armoy Stage glacial limits (Shaw & Carter, 1980) which show evidence of extensive glacitectonic deformation (Fig. 5).

Much of the reconstruction of the late Quaternary glacial

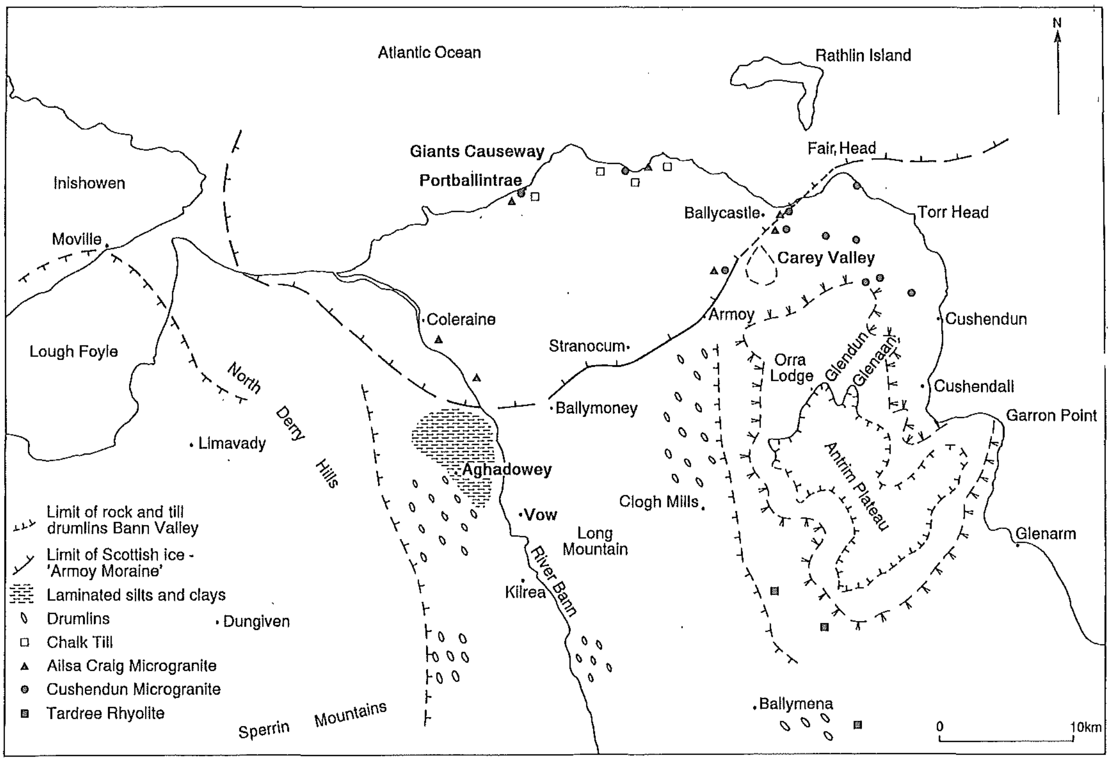

Figure 4. Ice limits in the north of Ireland during the Late Midlandian cold stage (simplified after Stephens et al., 1975; based on field mapping by R.J. Creighton, D.B. Prior, N. Stephens and F.M. Synge).

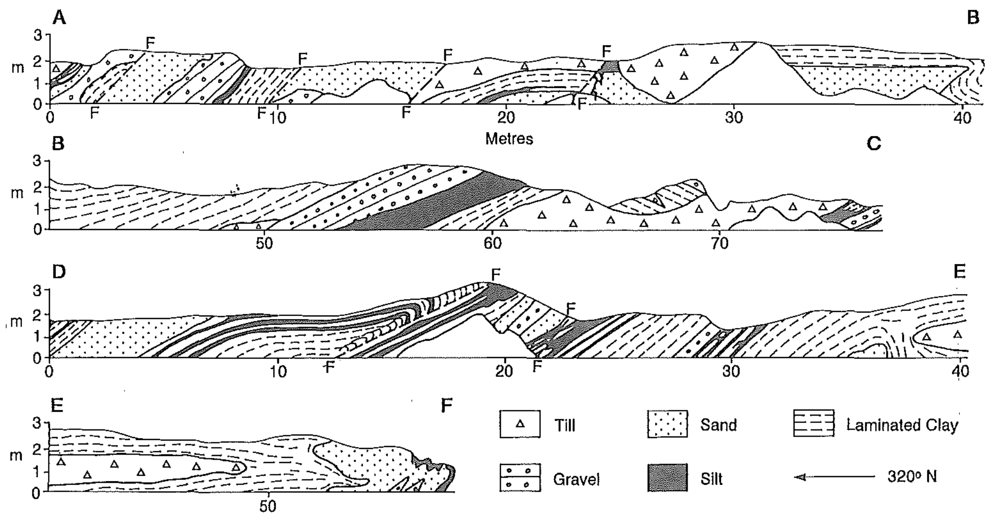

Figure 5. Main lithological units exposed in a road section in the North Antrim (Armoy) End Moraine, August 1978, 1.5km north-east of Ballymoney (redrawn after Shaw & Carter, 1980).

history of northern Ulster is based on litho- and morphostratigraphic evidence (e.g. till lithology, erratic carriage, till macrofabrics, glacial striations, drumlins, end moraines, deltas, etc.) and is not well constrained by datable intra-formational deposits. At Aghnadarragh (south-central Ulster) inter-till organic horizons do occur (McCabe *et al.*, 1987a). The lower till is of pre-Middle Midlandian age (>48000 years B.P.); the upper till (and by inference most drumlin till facies in the Bann valley) post-dates *c.* 40000 years B.P. and is probably a correlative of upper (drumlin) till facies in south-west Ulster, which post-date 30500 years B.P. (Colhoun *et al.*, 1972). Drumlinisation (cf. Dardis, 1985) is thought to have occurred in the north of Ireland at *c.* 17000 years B.P. (McCabe *et al.*, 1986). The age of the Antrim coast advance/Armoy Stage is conjectural and has been nominally placed at *c.* 14000 years B.P. (Stephens *et al.*, 1975).

Much of the morphostratigraphic evidence is liable to re-interpretation (see McCabe & Hirons, 1986). This has led to some debate on the origin and the palaeoenvironmental significance of some of the evidence in this area, particularly the Carey valley succession (McCabe & Eyles, 1988; Eyles & McCabe, 1989; Warren, in press).

It is appropriate, therefore, to focus attention on glacial sequences on the north coast and to consider some of the unresolved issues that have arisen from recent studies. This area affords an opportunity to examine one of the few places in Ireland where drumlinised substrates have been overridden by subsequent glacier advances, thus providing unique insights into possible morpho-sedimentologic responses of drumlinised sediments (cf. Dardis & McCabe, 1983; Dardis, 1985; McCabe & Dardis, 1989a) to post-depositional overriding. Studies of this nature may provide new insights into the nature of deformational suites formed on soft glacier beds (Sharp, 1988; Hubbard & Sharp, 1989), and may be critical to resolving a number of the current problematic issues concerning drumlin genesis and controls on rapid northern hemisphere ice sheet disintegration during the late Quaternary (McCabe & Dardis, 1989b).

SEA LEVEL AND COASTAL EVOLUTION (*Bill Carter*)

The north coast of Ireland falls within an isostatic sea level zone (Carter *et al.*, 1989). Immediately following deglaciation around 15000 years B.P., sea level would have been relatively high (perhaps locally around 25m above present water level), although as the land rose the water level fell steadily to a low point of perhaps -30m about

11000 years B.P. At this time Ireland may have been linked to Scotland across the North Channel (Devoy, 1985). Towards the beginning of the Holocene (10000 years B.P.), sea level began to rise rapidly - perhaps at rates of 10-20mm/year - flooding into the valleys of the Bann and the Foyle, and peaking at a level 2-3m above the present day around 6000 years B.P. (Carter, 1982). Much of the present coastal scenery derives from the period immediately after this sea level peak, as sediment was transferred through the wave zone onto the shore. Perhaps the most spectacular feature to form was the beach ridge plain of Magilligan at the mouth of Lough Foyle; however, the beach ridges and dunes at Portstewart, Portrush, Runkerry and White Park Bay all date from this period, as does the raised shoreline found fronting the cliffed coast between Portstewart and Portrush, around the Giant's Causeway and further east near Dunseverick and Ballintoy Harbour.

Coastal evolution has been largely limited to onshore-offshore sediment exchanges driven by long-period Atlantic swell waves, with few long term changes in evidence. One interesting feature is the dependence of many beach sites on the dynamics of the river mouths, which serve to cycle material within small coastal cells. Much of the natural erosion and deposition along the coast is linked to river mouth processes (Carter & Bartlett, 1990).

QUATERNARY SHORE PLATFORMS (*John McKenna*)

A consistent theme in much of the Quaternary literature in both Ireland and Scotland has been the confident use of raised Late Pleistocene and Holocene erosional landforms to reconstruct earlier shoreline positions (e.g. Stephens, 1963; McCann, 1966; Sissons, 1981). More recently, misgivings have been expressed about the validity of this type of relative sea level (RSL) reconstruction based, as it is, almost entirely on the elevations and tilts of coastal landforms. Carter (1983) points out that shoreline studies frequently fail to take account of the inherent vertical range and longshore variation of the processes which create the shoreline morphology. Usually only morphometric data are available, because the hostile marine environment has prevented the acquisition of process data. Unfortunately, this over-reliance on morphometry has sometimes led to spurious interpretations of process/form relationships.

On the north coast of Ireland the intensity and vertical range of contemporary erosion have been consistently underestimated. This has led to the contention that the wider and higher platforms must have been eroded during earlier and higher sea level stands. Wilson & Manning (1978) assume that the Portrush shore platforms are 'raised' because of their elevation and they assign a pre- or infra-glacial age on the basis that the Holocene transgression was too short to plane platforms of such width. Davies & Stephens (1978) also assume that the platforms are elevated and assign a Late Pleistocene or Holocene age, although they concede that contemporary processes have played some part in modifying the inherited morphology.

In fact, the basalt platforms of north Antrim and Londonderry show every indication that they relate to contemporary processes. On an 'optimum' geology erosion is ongoing and active, and recent erosion scars are evident on many platform surfaces that are several metres above O.D. The remarkable scarcity of surficial debris below obviously active cliffs and the rapid dispersal of tracer blocks indicates that high energy wave action regularly sweeps platforms that stand well above mean sea level (MSL).

Quaternary scientists who use shore platforms tend to equate the cliff base elevation with that of approximate MSL at the time of platform development. This is invalid in the context of the north coast because the dominant flow top control of wave quarrying results in a considerable vertical range in the elevation of the cliff/platform junction, from some distance below MSL to 5-6m above. Even on regular platforms the cliff base is a very unreliable indicator of MSL position (Wright, 1970). (Indeed on the the local sub-horizontal platforms the outer plane has a much more consistent relationship to MSL position).

Sea level on the north coast has remained in the approximate range 0-4m O.D. for the last 5000 years. The shore platform literature contains estimates of very rapid planation rates for platforms up to 200m in width, in similar or shorter time periods, e.g. Trenhaile (1972). Given the known vertical range of contemporary wave processes, it is clear that the local shore platforms have been within the zone of effective wave erosion for a sufficient length of time to account for their formation entirely within the latter half of the Holocene stage.

While it is unnecessary to have recourse to RSL variations to account for the north coast shore platforms, it is possible that some of the present morphology is inherited from an earlier phase (or phases) of erosion at a similar stand of sea level; this possibility presents another formidable obstacle to those attempting to use platform elevations to elucidate RSL changes.

Even where there is indisputable evidence for a Holocene shoreline, there are many problems in using its elevation to infer an exact RSL position. There are two such locations along the north coast, at Seaport, immediately west of

Portballintrae, and at Port Gallen, east of Portstewart; at both locations contemporary platforms are being cut into the seaward edges of dissected raised platforms, the latter backed by degraded raised cliffs. At Seaport, the base of the abandoned cliff to the west is at 7.8m O.D. but the elevation of the raised platform falls eastwards with the dip of the basalts from 7.5m to *c.* 3.0m O.D. in a distance of 160m. At Port Gallen, the base of the abandoned cliff, actually a vegetated shore platform, falls from 9.3m to 7.3m O.D. in a longshore distance of 170m. Thus, the raised platforms which form the Holocene shoreline demonstrate the same structurally-controlled longshore variation as the contemporary platforms. As a consequence, the local tilt of a raised shore platform cannot be assumed to be due entirely to isostatic influences.

The main problems in using shore platforms in palaeo-shoreline studies can be summarised as follows:

1. They may be metachronous and so could have been formed at any time.

2. The local relief variation is often much greater than the conjectured change in RSL elevation and the perceived or measured tilts.

PALAEOECOLOGY (*Jon Pilcher & Mike Baillie*)

There has been an interest in north Antrim and in particular in the large area of blanket peat, since the early days of pollen studies. Jessen (1949) looked at two blanket bog sites, and Mitchell (1951) investigated two more. Morrison (1958) and Dimbleby (1962) both looked at the Goodland site where blanket peat covered prehistoric settlements. Goddard (1971) made the first detailed survey and analysis of Co. Antrim blanket peats with an emphasis on understanding their origins. Sam Hanna, now a Ph.D. student at Queen's is continuing work on Antrim blanket peats, particularly on higher summits. Few sites other than blanket peat have been studied. A small area of valley peat at Altnahinch was investigated by Goddard (1971) providing a general vegetational history for the area. The Garry Bog site (see this guide) provides the most detailed, dated, pollen profile from a raised bog. In 1980 Francis carried out detailed pollen and sediment studies on a lake deposit at Lough na Trosk and on coastal deposits at Carnlough, providing further ^{14}C dated vegetational history for the area.

ARCHAEOLOGY (*Jim Mallory*)

Mesolithic (*c.* 7000-3500 years B.C.)

The primary evidence for Early Mesolithic (*c.* 7000-5500 years B.C.) settlement is in the lower Bann valley and the major Irish Early Mesolithic site, Mount Sandel near Coleraine, occurs here (Woodman, 1985). Along the north coast of Antrim there are only a handful of potential Early Mesolithic sites, generally identified from material collected in the past century from around the Giant's Causeway. The heavier broad-bladed industries of the Later Mesolithic (*c.* 5500-3500 years B.C.) are a bit better represented in the form of butt-trimmed 'Bann' flakes at Portrush, Ballintoy and Ballycastle. From an environmental point of view almost all sites are either riverine or coastal with virtually no evidence of upland exploitation. As the main elements of the economy appear to have been fish (salmon, eel) and hunting pig, this is hardly surprising.

Neolithic (*c.* 4000-2000 years B.C.)

The remains of early farming settlements are not abundant anywhere in Ireland (other than the north Mayo field systems) and the most famous actual Neolithic settlement in north Antrim is probably the Goodland site near Murlough. This consisted largely of pits filled with charcoal, stones, lithics and pottery and traces of a ditch. No animal bones were recovered but we know that during the Irish Neolithic farmers exploited cattle, pig, and much lesser amounts of sheep/goat and grew both wheat and barley. The Goodland site has been a continual enigma and its excavator suggested that it typified a particular form of ritual site in Ireland associated with fertility rites in the face of growing boglands and soil deterioration.

The most visible surface remains from the Neolithic are the megalithic tombs of which a number of different types can be found in north Antrim. The two best preserved court tombs are Ossian's Grave (Cloghbrack or Lubitavish) near Cushendall (unexcavated) and Doey's Cairn, Ballymacaldrack, which is famous due to Estyn Evans' excavations of a long 'cremation trench' where one would normally expect to find the stone gallery of the tomb. The north Antrim passage tombs make up a well-known group and are all quite small and generally simple (compared with New Grange) and have recently been assigned to the earliest phase of passage tomb building in Ireland by Alison Sheridan. Only a few examples of the other two tomb types - portal tombs and wedge tombs - are known from the area.

Assuming that settlement may be associated with the distribution of tombs, it has been observed that they are often located either at or beyond the present range of cereal cultivation. It has long been argued that early farmers selected sites on well-drained soils and this accounts for their distribution in upland regions during the Neolithic.

Finally, north Antrim boasts the two known sources of porcellanite, one of the primary stones employed in the manufacture of polished stone axes. The presumably lesser site is at Brockley on Rathlin Island while the major source would appear to have been Tievebulliagh near Cushendall.

The Early Bronze Age (*c.* 2000-1000 years B.C.)

As a period, the Early Bronze Age is primarily represented by burials and stray finds of bronzes. The earliest evidence we have for this period is compatible with the Beaker period (*c.* 2500-1800 years B.C.). North Antrim yields (in Irish terms) a fairly localised group of Beakers along the coast and also the overwhelming majority of archers' wrist-bracers are confined to Co. Antrim. All successive periods are primarily marked by graves - either stone-lined 'cists' or simple earthen pits with typical Early Bronze Age funerary ware, of which collared urns are particularly typical of Co. Antrim.

In terms of settlement, extrapolation from cemetery locations reveals a tendency towards glacial gravels. Reasons proposed for this include both population pressure and/or environmental change in upland regions and the introduction of the plough that permitted exploitation of the somewhat heavier soils of the more low lying regions. One area of possible Bronze Age settlement is White Park Bay where Knowles and others recorded a linear alignment of 20 huts. Here, and elsewhere along the north coast, are a series of sand dunes that have periodically yielded ceramics and lithic material from the Neolithic through the Early Christian period.

The Later Bronze Age (*c.* 1000-300 years B.C.)

This period is primarily artifactual with very little evidence for settlement in this particular region and even evidence for burials is lacking (there are only about three Later Bronze Age burials identified for all of Ireland).

The Iron Age (*c.* 300 years B.C. - 400 years A.D.)

This period is also largely artifactual with some slight traces for Iron Age settlement on the fringes of the excursion area, e.g. an Iron Age shell-midden at Ballymulholland, on Magilligan Foreland, and Iron Age hearths and stake-holes at Bay Farm near Carnlough. The destroyed site of Lisnacrogher, alternatively interpreted as a crannog or ritual site, yielded an unparalleled assortment of Iron Age objects, especially weapons such as swords, scabbards and spear-butts. There is a presumption that some of the promontory forts that occur along the north coast, e.g. Lurigethan near Cushendall, may date from the Iron Age but there is no hard evidence for this and they may be Early Christian.

Early Christian (*c.* 400-1177 years A.D.)

As elsewhere in Ireland, north Antrim is dotted with the ubiquitous rath or ringfort, the typical enclosed farmstead of the presumably upper class landowners of this period. The most spectacular rath excavation, at Deer Park Farms near Glenarm, just outside the field excursion area, was completed only a few years ago. This site yielded total preservation of wicker huts and other organic remains that provided a unique insight into life in the Early Christian period. Larrybane promontory fort on the north coast was excavated by V. Gordon Childe and revealed settlement from around 700-900 years A.D. This site and cave sites in the Port Bradden area have yielded faunas indicating the exploitation of both livestock and marine resources during this period. Another Early Christian monument, the souterrain, a stone-lined underground refuge, is also well-recorded in the north Antrim region, with a very dense distribution between Coleraine and Ballycastle. Finally, one of the more spectacular crannogs can be seen at Lough na Cranagh, at Fair Head.

Mediaeval (*c.* 1177-1700 years A.D.)

For this period most attention is directed to the stone castles of the north coast - e.g. Dunluce, Dunseverick and Kenbane. Most of these show evidence of construction from the 14th through the 17th centuries although some, such as Dunseverick, were clearly occupied in some other form at much earlier dates, (Dunseverick is recorded to have been sacked by the Vikings). Also, adjacent to Dunluce are the remains of a deserted village, the house-platforms still visible in pasture land. Another site of interest is Ballylough, near Bushmills, where a possible crannog, a motte, a towerhouse and a 17th-18th century estate suggests the continuity of estate settlement from the period of the English conquest through the Scottish incursions up through the quasi-plantation activities of the Earl of Antrim. Much of the castle activity as well as ecclesiastical, e.g. Bonamargy Friary, Ballycastle, can be credited to the MacQuillans and MacDonnells.

SOILS (Peter Wilson)

The most extensive soil types found in north Antrim and Londonderry are the 'basalt soils'. These comprise gleys and gleyed brown earths, most commonly developed on clay-rich tills, and slightly gleyed and freely drained brown earths, on loamy tills and sands. They are of medium to high base status and are highly suitable for grassland farming. The latter category of soils has the widest range of agricultural use and the highest potential productivity. Above *c.* 300m O.D. and also in some lowland areas, peaty gleys and peats occur. These soils are of limited agricultural value and in the uplands are used extensively for coniferous forestry. Where lowland peats have been almost entirely cut-over, land drainage has enabled the development of productive grassland (e.g. Garry Bog).

Non-basalt soils are of very restricted extent but occur in north-east Antrim on glacial sands and gravels and also where schist and chalk crop out. Well-developed podzols occur on schist at Breen Wood Nature Reserve and on coarse textured deposits associated with ice wastage. Shallow calcareous soils are found west of and overlooking Torr Head.

PORTSTEWART STRAND AND THE BANN ESTUARY (*Bill Carter & Peter Wilson*)

The beach, dunes and river mouth between Castlerock and Portstewart (Figs. 6 & 7) form a single physiographic unit that has evolved over the last 6000-8000 years. Around 9000 years B.P. sea level began to rise and to flood what was then a major re-entrant river mouth/bay, with marginal freshwater wetlands and lagoons, between basalt outcrops 4km apart (Hamilton, 1985). The river mouth itself is underlain (at about -6m O.D.) by freshwater marls and peats. A peat sample has been ^{14}C dated to 8960$\pm$110 years B.P. (Beta-34315). The sea probably rose about 2-3m above the present level around 6000 years B.P. before falling back (Carter, 1982; Carter *et al.*, 1989). The large volume of glacial sediment stored offshore was sorted and resorted by wave action and transferred onshore, first as a series of gravel beaches, and later as aeolian dunes.

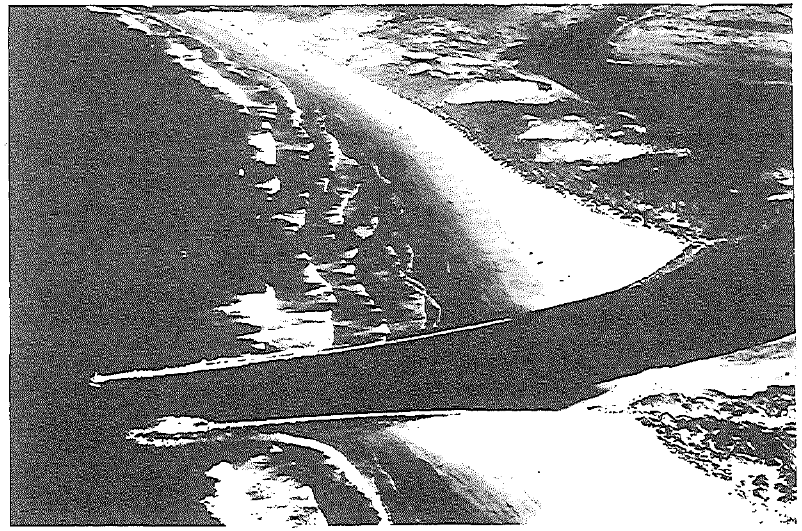

Figure 6. Portstewart Strand and the Bann estuary.

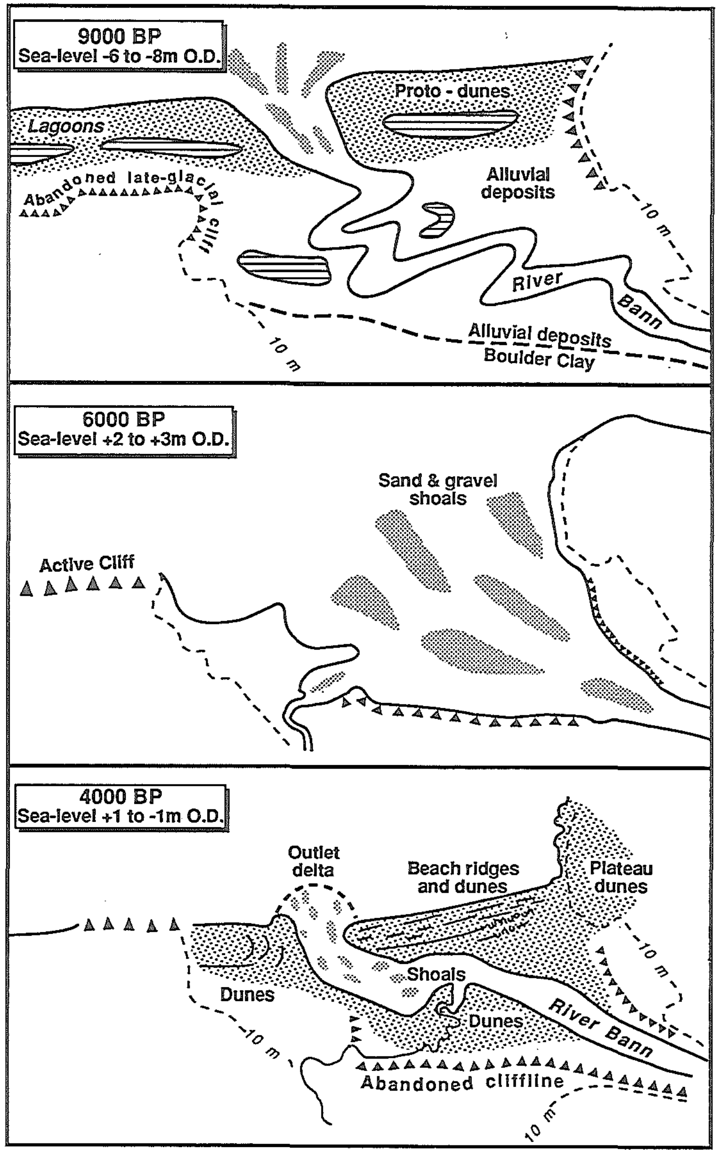

Figure 7. Stages in the Holocene evolution of the Bann Estuary.

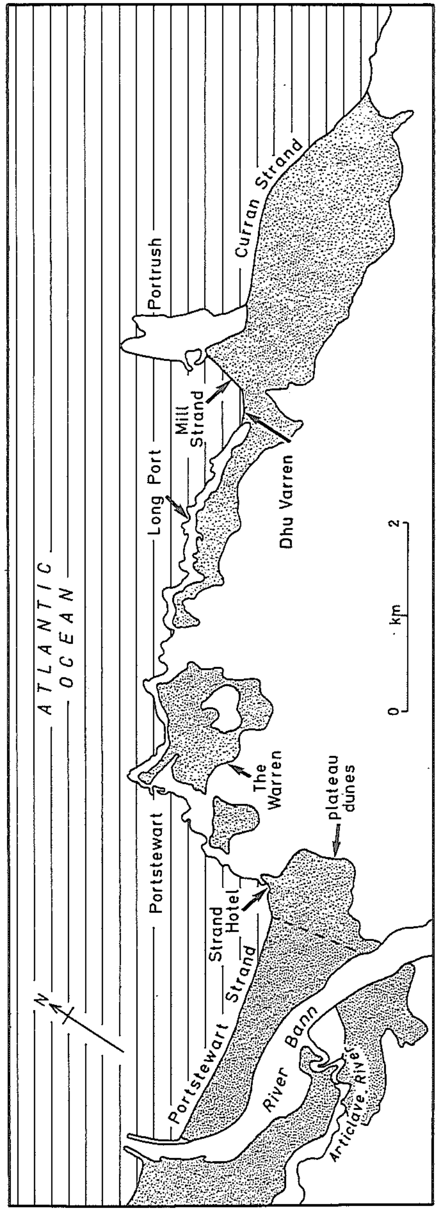

Figure 8. Sand deposits between the River Bann and Portrush, and locations of field excursion sites.

The earliest unequivocal date we have for dune formation is 5315±135 years B.P. (UB-937) from an organic-rich deposit interbedded in dune sands from south of the Bann estuary at the mouth of the Articlave River (Fig. 8; Hamilton & Carter, 1983). This date represents the earliest minimum age for Holocene dune development in Ireland. Buried and modern soil horizons in the overlying sands testify to three subsequent phases of aeolian sand accumulation and stability, but these have not been dated. The dunes on both sides of the Bann estuary have long been known as sites of early human occupation and have produced an abundance of artifacts from the Neolithic to Mediaeval periods (Coffey & Praeger, 1904; May & Batty, 1947). Stratigraphic evidence from the dunes north of the estuary indicates three phases of dune formation; one pre-dating the Neolithic and two post-dating the Bronze Age. The pre-Neolithic dunes are tentatively correlated with those recognised by Hamilton & Carter (1983) as pre-dating *c.* 5300 years B.P.

The present near[illegible] beach-foredune system at Portstewart is remarkably stab[illegible]arly given the high energy wave environment [illegible]age wave height is about 2m). Seasonal beach changes, shown through cut and fill sequences, are rarely more than 0.5m, and the backshore area is scarped only on rare occasions. Even then the volume of material exchanged between foredune and beach is only in the order of a few thousand cubic metres for the entire strand. Part of the stability derives from the arrangement of two sets (inner and outer) of crescentic nearshore bars, with wavelengths in the order of 250-450m. These bars act to reduce the level of wave energy actually reaching the shoreline by 80-95% (Carter & Balsillie, 1983). They also determine the pattern of inshore water movements, particularly the position of rips (strong, seaward flowing currents).

The exposed intertidal beach is rarely dry enough to supply much sand to the foredunes, while the backshore is relatively narrow, and to some extent sheltered from the dominant south-west winds, by local topography. As a consequence the foredune system is relatively static, and inspection of historical records reveals no major coastal changes over the last 150 years (Carter, 1990). On occasions some blown sand does accumulate on the seaward dune faces, but much of this returns to the beach by gravity-induced slides, or during the aforementioned occasional marine undercutting.

The narrow foredune rapidly gives way to large established, transverse dunes - at right angles to the shore. It is clear that these dunes have formed as a result of secondary aeolian processes, probably as a result of man-related destabilisation. The transverse dunes comprise loose, granular, windward faces, with stable well-vegetated lee

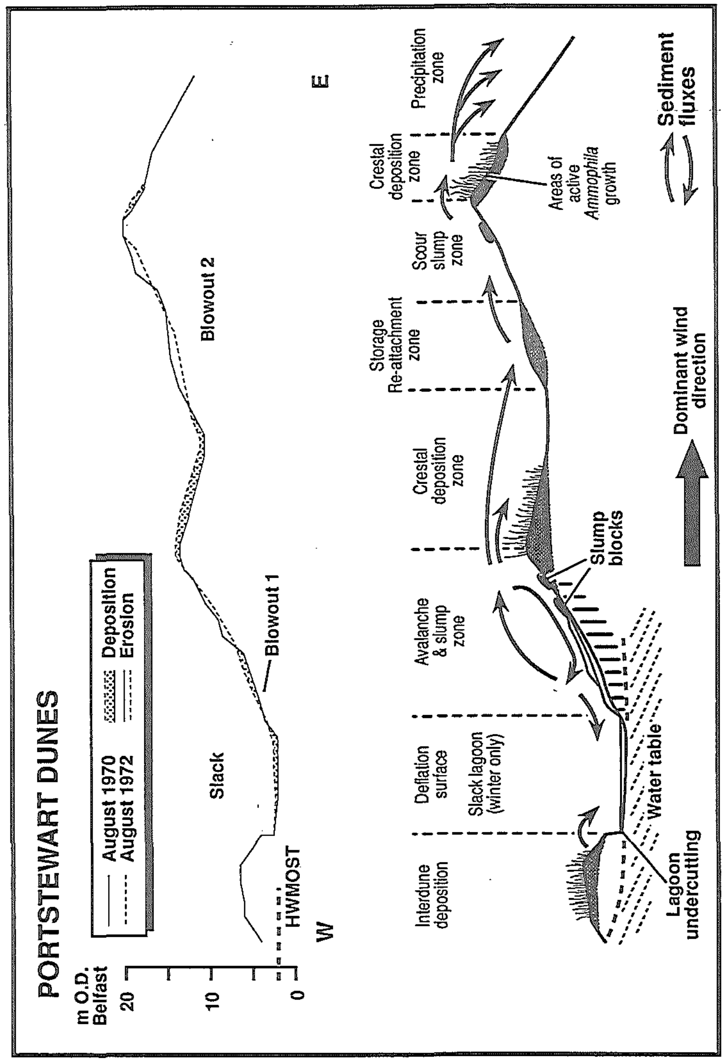

Figure 9. Profiles and proposed depositional model for wind-normal dune slopes at Portstewart.

slopes (Fig. 9). This unusual 'reverse' pattern is largely the result of very low rates of material transfer, producing a distinctive erosional dune form (Carter *et al.*, 1990). Sections in the dunes reveal a preponderance of low-angle concave bedding, interrupted in places by steeper avalanche structures. The dunes have been dissected by wind erosion (exacerbated by human damage), leaving a range of blowout forms, including 'saucers' (low relief hollows), 'basins' (deep, enclosed hollows) and 'corridors' (longitudinal, canyon-like features). In one or two places blowouts are 'stacked' on top of each other, as non-uniform wind flow engendered by a lower form leads to development of an upper one (see Carter *et al.*, 1990).

Except in the active blowouts, the dunes are well-vegetated, notably by *Elymus farctus*, *Ammophila arenaria*, *Festuca rubra*, *F. ovina*, *Thymus drucei* and *Lotus corniculatus* (Hamilton, 1989). The presence of the invasive shrub sea buckthorn (*Hippophae rhamnoides*) is leading to management problems. The shrub was planted in the 1930s for erosion control and to deter access (Carter, 1987), but has spread extensively throughout the dune system, crowding out native species. The buckthorn communities are extremely difficult to eradicate.

The mouth of the River Bann is probably located at a point originally initiated and occupied by a major rip channel. Until the late-nineteenth century the river mouth was a naturally dynamic system, with a number of sand shoals serving to exchange material between the river, the nearshore and the beach. However, a series of river 'improvements', including the building and rebuilding of the jetties (in 1889 and 1941), dredging and discharge regulation have radically altered the picture (Carter & Rihan, 1976; Carter, 1990). At present about 40000m³ of material are dredged from the river and deposited in an EC-designated dumping ground some 4.5km to the north-west (Carter & Bartlett, 1990). This represents a finite loss of material to the coastal sediment budget, and concerns have been expressed about the long-term geomorphic stability of the Bann Mouth.

PORTSTEWART - STRAND HOTEL (*Peter Wilson*)

Much of Portstewart is underlain by sand that extends from near the coast to the higher ground above the town at *c.* 30-40m O.D. North-east of Portstewart, sand occurs along the cliff-top for about 4km to Portrush (Fig. 8). These sands were considered by Wilcock (1976) and Wilson & Manning (1978) to be mid-Holocene aeolian deposits related to a higher stand of sea level. More recently, Carter *et al.* (1989) have suggested that the sands may represent reworked coastal dunes resulting from the increased frequency of storms between the 11th and 13th centuries.

Due east of Portstewart Strand, Wilcock (1976) recognised an area of sand that was continuous with the dunes of the Strand but differed in surface morphology, grain size characteristics and $CaCO_3$ content. These so-called 'plateau dunes' (Fig. 8) were said to consist of 'low-relief, shallow sand deposits' and are occupied by a golf course and housing.

Recent structural alterations at the Strand Hotel (Fig. 8) have provided a section in the plateau dunes (Fig. 10) which indicates that sand accumulation was more complex than previously envisaged. The section is between *c.* 13.5–15.5m O.D. and stands above and a little way inland of a Holocene marine cliff and platform. At least two major phases of sand deposition, separated by a period of landscape stability and pedogenesis, and two minor phases of sand deposition have been recognised.

The sequence of soil horizons developed in the sands, along with some chemical properties, are shown in Fig. 11 and grain size distributions are given in Table 1. The sands rest on a basalt-rich diamicton which is enriched in organic matter and contains frequent vegetation stems throughout its upper 10cm; distinctive mottling occurs beneath the organic horizon. This soil is interpreted as a buried stagnogley. A humus podzol developed in *c.* 1.4m of sand occurs above the stagnogley. The sand is predominantly of fine size and is very well sorted. Abundant stems are present in the bBh2 horizon and thin (<0.5cm) convolute bands, containing slightly more organic matter than the surrounding sand, occur in both bBh horizons. A 2cm thick peat band is present within the bAh/Ea horizon. The podzol is acidic throughout, displays slight enrichment in organic matter in the bB horizons but has negligible amounts of iron extractable by pyrophosphate (Fe_p) and dithionite (Fe_d). A few well-rounded basalt and flint clasts have been found in the upper part of the bAh/Ea horizon. The podzol is buried by *c.* 0.5m of iron-stained sand with grain size characteristics that are indistinguishable from those of the podzol. Made ground *c.* 0.3m thick completes the section.

Evaluation of the morphology, chemical properties and grain size characteristics suggests the following history for the site:

1. Prior to sand deposition a basalt-rich diamicton containing a stagnogley soil existed at the site. The organic-rich horizon of this soil can be sub-divided on the basis of grain size into a lower horizon (3bAh), with grain size distribution similar to that of the underlying diamicton, and an upper horizon (2bAh), whose grain size is

Figure 10. Section in plateau dunes at the Strand Hotel, showing podzolised sands.

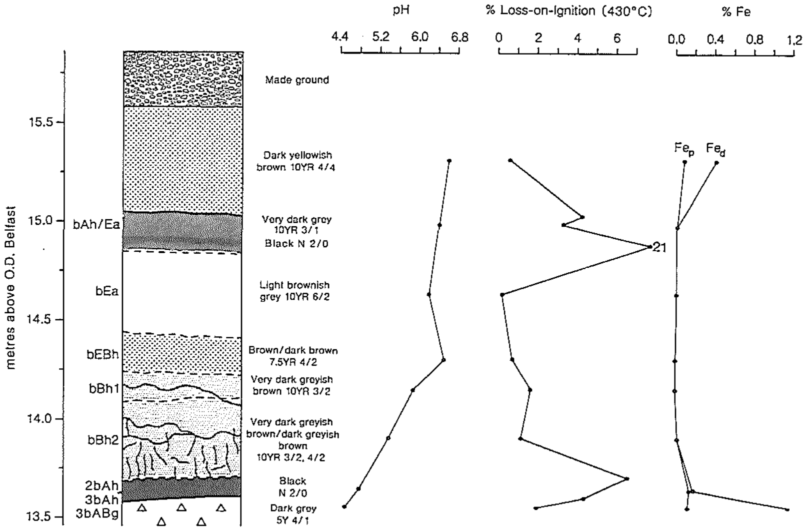

Figure 11. Sequence of soil horizons and some chemical properties for the Strand Hotel section.

Table 1. Grain size characteristics for sediments at the Strand Hotel.

Sample/ horizon	%SAND VC	C	M	F	VF	%SILT	%CLAY	TEXTURAL PARAMETERS $Mz\phi$	$\sigma_I\phi$	Sk	K_G'
Upper sand	-	0.01	3.92	92.28	2.94	0.09	0.76	+2.46	0.26	-0.29	0.47
bAh/Ea	0.03	0.16	4.74	82.91	3.61	6.00	2.55	+2.46	0.29	-0.24	0.50
bEa	-	0.02	6.52	88.61	2.00	1.83	1.02	+2.41	0.27	-0.28	0.46
bEBh	-	0.03	4.13	90.45	2.73	1.77	0.89	+2.45	0.26	-0.26	0.47
bBh1	-	-	3.74	90.03	3.19	2.04	1.00	+2.46	0.27	-0.20	0.47
bBh2	-	-	2.15	92.58	3.19	1.17	0.91	+2.48	0.25	-0.19	0.51
2bAh	-	0.26	5.18	71.44	6.26	9.21	7.65	+2.54	0.35	-0.24	0.62
3bAh	0.76	1.54	14.82	36.57	8.79	20.32	17.20	+2.38	0.69	-0.20	0.56
3bABg	0.62	3.22	28.57	24.53	6.49	20.29	16.28	+2.06	0.73	+0.14	0.54

SAND: VC very coarse -1 to 0ϕ, C coarse 0 to $+1\phi$, M medium +1 to $+2\phi$, F fine +2 to $+3\phi$, VF very fine +3 to $+4\phi$.
SILT: +4 to $+9\phi$.
CLAY: $>+9\phi$.
TEXTURAL PARAMETERS (calculated for sand fraction only): Mz mean size, σ_I sorting, Sk skewness, K_G' kurtosis.

intermediate between that of the diamicton and the overlying sand (Table 1). This probably reflects the deposition of small amounts of wind-blown sand and its incorporation, by faunal activity, into the organic horizon of the stagnogley.

2. The occurrence of vertical and sub-vertical stems indicates that, at least in its early stages, deposition of the overlying sand was gradual and the vegetation continued to grow up through the sand. More rapid sand deposition probably then occurred and was followed by a substantial period of surface stability marked by vegetation growth and soil development; this land surface is delimited by the thin peat band within the bAh/Ea horizon. Soil formation culminated in a humus podzol that extends through the full thickness of the sand and is considerably thicker than similar buried soils described by Wilson & Bateman (1986) in coastal sands at Magilligan, 15km to the west. A thin layer of sand was then deposited across the peat surface and soil forming processes 'welded' the sand to the profile. A few clasts occur within this sand unit.

3. Podzolisation was terminated when the soil was buried by *c.* 0.5m of sand.

The height above O.D., the general absence of clasts and the lack of large shell valves (which are common in raised marine sands of the north coast) suggests that the sands are probably aeolian. The clasts that occur in the bAh/Ea horizon of the podzol are thought to relate to human activity, given the long history of sand dune settlement.

The events outlined above may be site-specific rather than applying to all the higher level sands between Portstewart and Portrush. For example, at the Warren (Fig. 8) up to 2.5m of sand rests on a basalt-rich diamicton but buried soils are absent from the sand.

PORTSTEWART-PORTRUSH COAST (*John McKenna*)

Basalt shore platforms of various width occur along the north coast of Antrim and Londonderry. Elsewhere in Ireland shore platforms are far from ubiquitous. Edwards (1941) and Trenhaile & Layzell (1980) consider shore platforms in terms of a narrow range of morphogenic and geologic conditions. Edwards suggested that the optimum lithology for platform development is a rock of medium hardness like Tertiary basalt. On the basalts of the north coast morphogenic and geologic environments combine to provide conditions necessary for shore platform development. Significantly, platforms have not developed on the hard dolerite of the Portrush Sill, suggesting that geology is the critical factor.

The coast has a general WSW-ENE trend (Fig. 8) and is probably fault controlled; in plan it consists of a series of low amplitude embayments and headlands. Cliff heights range between 9m and 23m, averaging *c.* 13m, and heights increase eastwards. Embayment cliffs are degraded and vegetated, with slopes of 30-35°, although frequently displaying a free face buttress in their upper sections. In contrast, headland cliffs are steep and possess complex systems of fractures and joints. These cliffs are generally active.

Shore platforms are found flanking the headlands, but some of the most extensive examples occupy the inner part of embayments. Platform topography is characterised by a high relative relief and ruggedness which is regarded as a product of wave-quarrying. In many cases the term 'platform' is a misnomer; these erosional landforms are often uneven and are dotted with residual rock knobs that extend several metres above the surrounding surface. However, most of the platforms do display broadly planar surfaces for at least part of their width. The fine relief detail is often characterised by a furrow-and-cobble topography that is controlled by the polygonal joint pattern of the basalts. On very exposed sites the joints form deep clefts giving a pavement effect to the platforms.

The plan detail is also highly irregular and indented. Platform orientation corresponds closely with two of the three regional tectonic joint sets described by Roberts (1976). These joints trend 330° and 345° and coincide with the direction of maximum fetch and the most effective wave attack and it seems reasonable to conclude that this element of the local geology has helped to optimise shore platform development.

The platforms are broadly sub-horizontal with minor overall dips of <3° to seaward (although occasionally to landward) and extensive planar sections of <1°. These low angle planes may relate to the narrow tidal range, or may reflect the attitude of the bedding. It is likely that both of these factors operate, although horizontality may also be aided by the unidirectional mode of erosion. On their seaward margins the platforms invariably terminate in a steep low-tide cliff dropping to *c.* 10m below water level. The platforms fit neatly into the micro/meso-tidal group in the classification of Trenhaile & Layzell (1980).

The cliff/platform junction usually coincides with a basalt flow top. In some cases residuals of flow top material still remain on the inner surface of the platform. A shore-parallel cliff base gully with abraded, rounded surfaces is also characteristic. Occasionally a narrow cliff bench occurs between the cliff and the main platform. These

benches may result from infrequent storm wave attack along particularly friable flow tops. Several platforms have high level ramparts rising steadily seaward from the general surface elevation. These sloping ramparts are a function of the local landward dip of an eroding basalt unit. It could be argued that such ramparts are modified remnants of higher platforms, but the dominant bedding control typical of basalt platforms makes this explanation unlikely.

LONG PORT (*John McKenna & Peter Wilson*)

At several locations along the north coast, sloping vegetated terraces extend between the landward margin of the storm beach and the degraded cliff to the rear. Wilson & Manning (1978) speculated that they represented the surviving remnants of Holocene raised beaches but recent field examination has revealed that during major storms a layer of marine sand is deposited on some of the terraces. This suggests that the terraces may be landforms created primarily by storm sedimentation at contemporary sea level. Two terraces, at Long Port and Port Gorm, have been investigated in detail in order to determine their mode of formation.

At Long Port (Fig. 8), *c.* 2km west of Portrush, a supratidal terrace occurs landward of the contemporary storm beach. The terrace surface is vegetated and rises at 11° towards the base of a degraded cliff. A 2.5m high scarp has been cut into the seaward edge of the terrace. The stratigraphy of the scarp is shown in Fig. 12 and four main sedimentary units are apparent:

1. A basal unit consisting of beach cobbles in a matrix of silty sand.

2. A zone of interbedded peat and silty sand with occasional rounded clasts.

3. A unit composed predominantly of peat with occasional rounded clasts.

4. A sand unit that underlies the terrace surface.

The presence of the peat horizons makes this backshore terrace unique in the coastal area covered by this meeting.

Grain size distributions of material >-1ϕ for samples 1-10 (Fig. 12) are given in Table 2. Details of an additional sand sample (No. 11) from 3-4m above the scarp exposure and a sample of colluvium (No. 12) from the eastern end of the bay are also included. Textural parameters were calculated

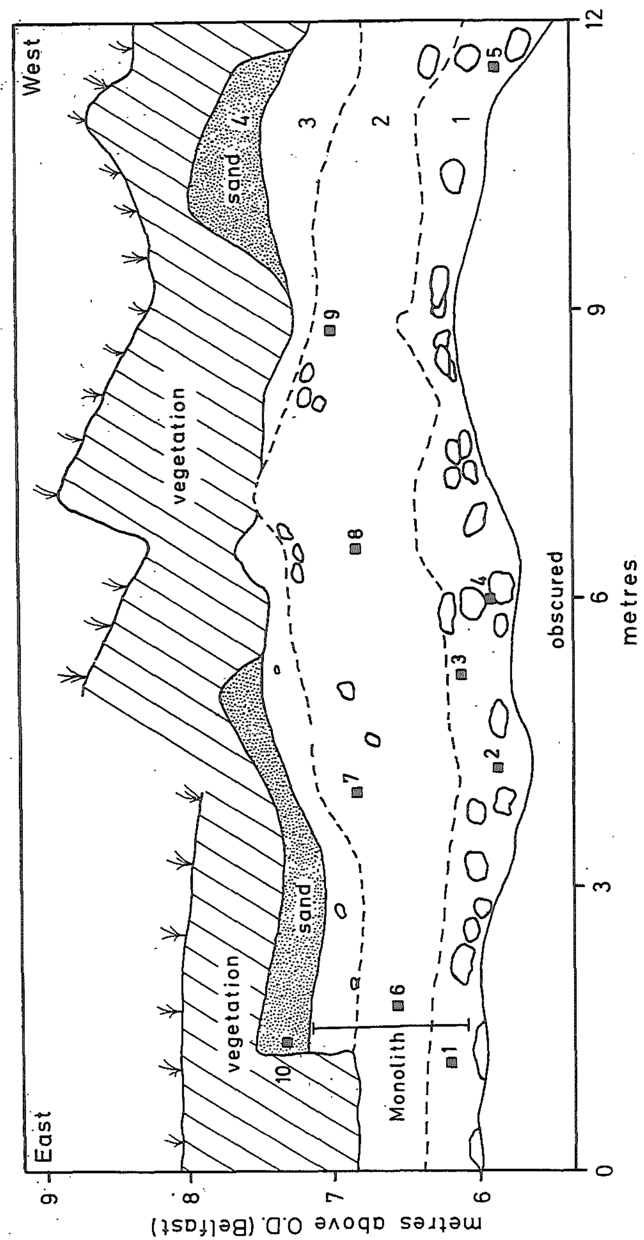

Figure 12. Terrace scarp exposure at Long Port.

Table 2. Grain size characteristics for sediments at Long Port.

UNIT	SAMPLE	%SAND	%SILT	%CLAY	TEXTURAL PARAMETERS			
					$Mz\phi$	$\sigma_I\phi$	Sk	K_G'
1	1	68.35	15.05	16.60	+1.87	1.13	−0.45	0.53
	2	60.81	35.08	4.11	+1.06	1.50	+0.20	0.42
	3	59.26	37.87	2.87	+1.40	1.57	−0.04	0.40
	4	61.60	38.25	0.15	+1.37	1.59	−0.01	0.39
	5	63.86	33.38	2.76	+1.47	1.54	−0.12	0.41
2	6	67.51	22.33	10.16	+2.03	1.02	−0.31	0.55
	7	69.19	23.61	7.20	+1.80	1.16	−0.25	0.53
	8	66.34	21.65	12.01	+1.91	1.20	−0.32	0.52
	9	67.19	23.63	9.18	+1.36	1.28	−0.23	0.43
4	10	95.98	2.32	1.70	+1.90	0.57	−0.23	0.48
	11	99.12	0.31	0.57	+1.90	0.60	−0.03	0.49
Colluvium	12	50.72	37.06	12.22	+0.49	1.32	+0.52	0.47

SAND: −1 to $+4\phi$, SILT: $+4$ to $+9\phi$, CLAY: $>+9\phi$.

TEXTURAL PARAMETERS (calculated for sand fraction only): M_z mean size, σ_I sorting, Sk skewness, K_G' kurtosis.

for the sand fraction only. All of the samples from units 1 and 2 consist of poorly sorted medium sands. Skewness is variable in unit 1 but all samples from unit 2 are negatively skewed. Samples 10 and 11 have similar characteristics to sand deposits in a thick exposure at Dhu Varren, Portrush, and form part of the cliff-top sands that occur between Portstewart and Portrush. The sample of colluvium consists of coarse sand that is poorly sorted and positively skewed.

Most of the clasts in the scarp show a high degree of rounding and little surface deterioration, which suggests they have been shaped by marine processes. Some clasts have decomposed and their former outline is marked by a strong orange ferric oxide stain. The silt and clay components of the terrace sediments are probably best regarded as alteration products of the sand and gravel.

Organic matter determination and pollen analysis were carried out by Dr. Ken Hirons on a monolith taken at the eastern end of the scarp (Fig. 12). Loss-on-ignition shows clearly the alternating sequence of organic-rich and organic-poor layers (Fig. 13). Unfortunately the pollen was in very poor condition and was also rather sparse, especially tree and shrub pollen. The predominant pollen

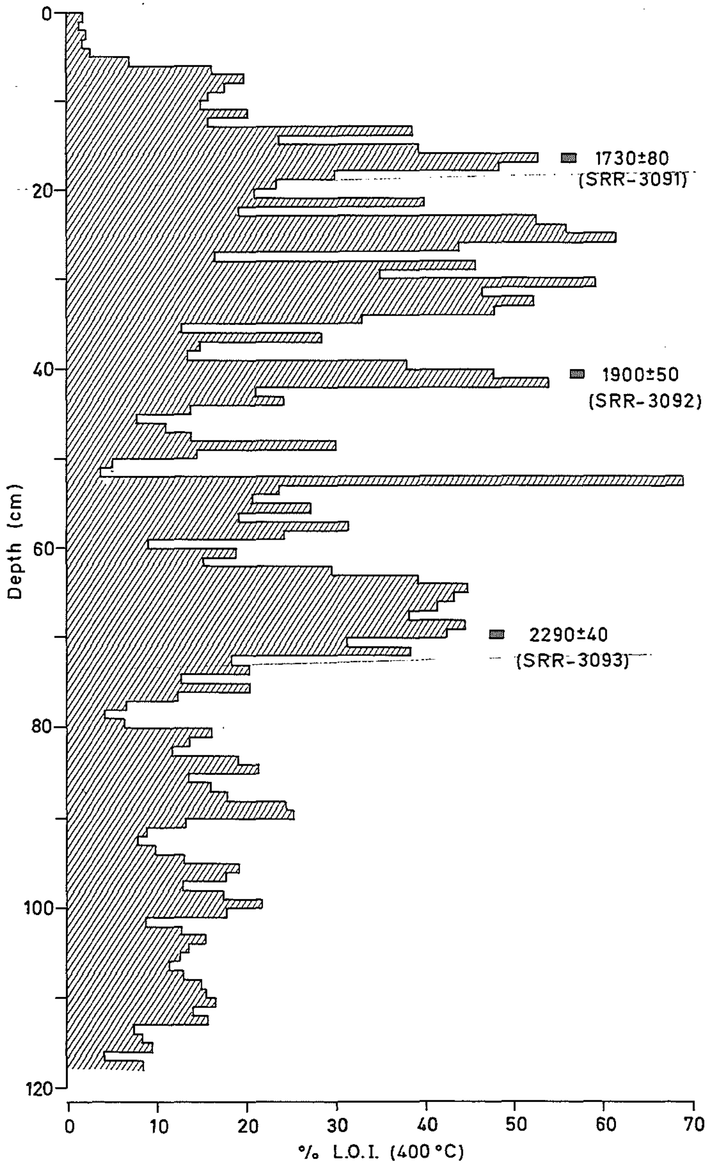

Figure 13. Loss-on-ignition and radiocarbon dates for the Long Port monolith.

types were those of herbaceous plants such as Graminae, Compositae (esp. *Artemisia*) and *Plantago lanceolata, P. maritima* and *P. coronopus*, suggesting a very open environment. *Plantago maritima* and *P. coronopus* are indicative of coastal localities while the presence of Cyperaceae and *Calluna* together with the occurrence of *Sphagnum* spores suggests a wet and oligotrophic environment. The abundance of deteriorated pollen grains may indicate the periodic drying and oxidation of the peat surface during the course of accumulation.

Three ^{14}C dates have been obtained and are given in Fig. 13. These indicate that peat formation commenced before *c.* 2300 years B.P. and terminated after *c.* 1700 years B.P. The earliest date gives a minimum age for deposition of the underlying beach gravels and the youngest date provides a maximum age for deposition of the overlying sand unit.

The simplest explanation for the terrace stratigraphy is that the interbedded peats and sands accumulated in a depression cut off from the sea by a storm ridge barrier, (the peats are unlikely to have formed with the present free-draining scarp in existence). A model for terrace development is outlined in Fig. 14 although it must be emphasised that certain elements of the model remain conjectural.

Stage A in Fig. 14 shows a gravel barrier and a backslope depression in which peat is accumulating. The elevation of the upper peat horizon in the terrace demands a crest elevation for the barrier of at least 7.2m O.D. and a depression depth of *c.* 1m is indicated by the thickness of the interbedded peats and sands. Given that none of the contemporary gravel storm beaches reach 7m O.D. it seems likely that the barrier was related to a sea level slightly higher than that of today. The barrier was probably formed by the rising Holocene sea as it rolled nearshore shelf sediments landwards. These sands and gravels may have grounded on the embayment headlands, thereby creating a depression between the barrier and the backshore cliffs.

Vegetation growth and peat accumulation in the depression were interrupted repeatedly by inputs of sand (stage B). These sands, with occasional rounded clasts, are inferred to represent discrete storm events in which barrier overwashing/overtopping processes were active. This inference is based on: (a) the similarity in grain size characteristics between the interbedded sands and the sand fraction in the underlying beach gravels, (b) the presence of crude laminations in the sands, (c) the rounding of the clasts, (d) the distortion to the sands where clasts have impacted and, (e) the lack of correspondence between the sands and the colluvium, indicating that the sands are not derived from weathering and erosion of the backshore cliff.

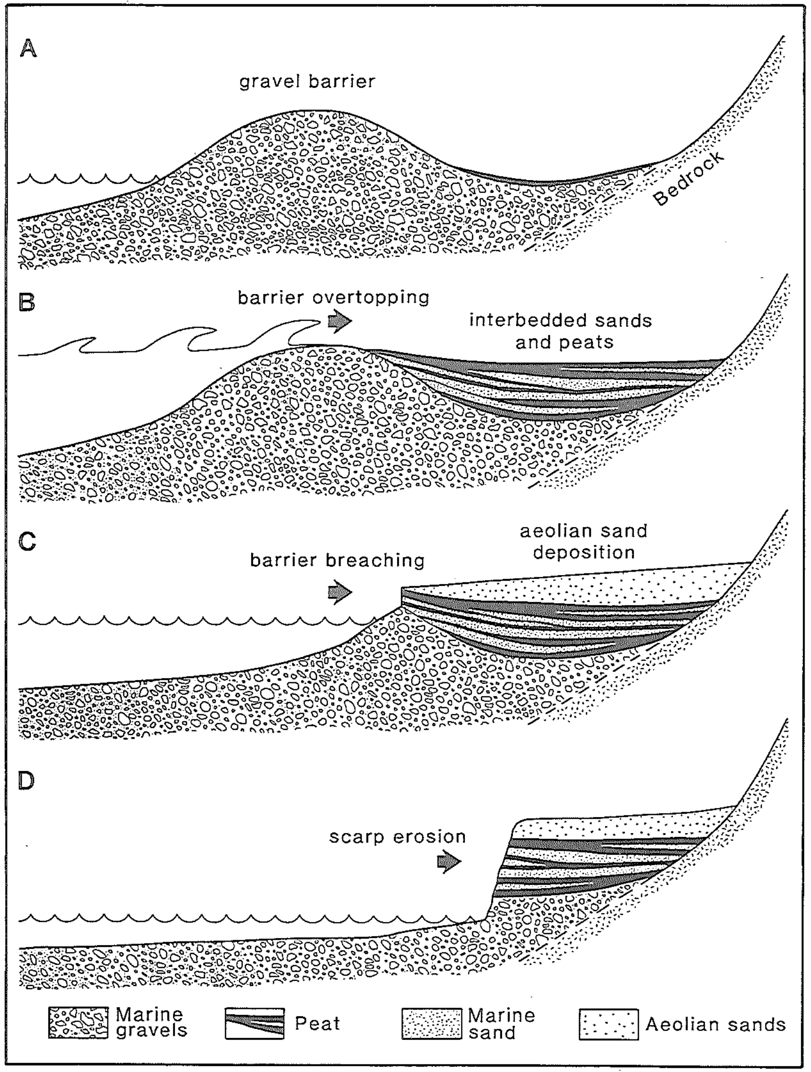

Figure 14. Model for terrace development at Long Port.

It is not necessary to postulate a sea level slightly higher than that of today for the operation of barrier overwashing/overtopping processes. The interbedded sands occur within the range of modern depositional processes and may relate to a sea level similar to that of today. Contemporary examples of barrier overwashing/overtopping in south-east Ireland are given by Orford & Carter (1982).

Peat formation may have terminated as a result of barrier breaching, which allowed drainage of the depression (stage C). Earlier, temporary barrier breaching may account for the drying phases, oxidation and destruction of the pollen within the peats. Aeolian deposition of the upper sand unit may also have caused termination of peat growth, but it is not clear whether this sand pre- or post-dates barrier breaching.

The present-day section at Long Port (stage D) is considered to represent the remnants of a more extensive back-barrier depression in which marine and terrestrial sediments accumulated over the last 3000 years. It is proposed that the build-up of the terrace sands is the result of storm-wave sedimentation at or near contemporary sea level. The underlying beach gravels are earlier deposits related to a slightly higher sea level.

PORTRUSH - MILL STRAND (*Peter Wilson & Bill Carter*)

The outcrop of peat at Mill Strand, Portrush, (Fig. 8) was mentioned briefly by Coffey & Praeger (1904) and Erdtman (1928), but the most detailed work to-date is that of Jessen (1949). Since Jessen visited the area in the 1930s the site has undergone considerable change. The sand cliff containing the peat has been covered by a sea wall and promenade, and landscaping has destroyed the dune topography. Depending on the state of the tide and the beach, peat outcrops can sometimes be seen in the inter-tidal zone (Figs. 15 & 16).

The stratigraphy of the section investigated by Jessen is shown in Fig. 17. Four units were identified from the surface downwards as follows:

1. Light grey blown sand, several metres thick and built up into dunes rising to 15m O.D.

2. Reddish yellow laminated beach sand without shells. Scattered stones present at the south-western end of the section.

3. Highly-compressed peat containing abundant wood.

Figure 15. Exposure of inter-tidal peat, Mill Strand, Portrush.

4. Blown sand without shells or stones.

The lower sand was reported to be of considerably finer grain size than either of the upper sand units and, because it rose into two low ridges, was thought to represent an old dune system. From pollen analyses and macro-fossil identifications Jessen regarded the peat as of late Boreal - early Atlantic age, as did Erdtman (1928), and to have formed in dune depressions in response to impeded drainage associated with a rising sea level. At the maximum of the transgression the peat was buried by a thick layer of beach sand that indicates marine activity up to 5m O.D. Following the subsequent regression, dunes formed on the raised beach.

Below the section described by Jessen, Wilson & Manning (1978) reported the presence of a 0.4m thick peat at 4.5m below beach level in the area north of Castle Erin (Fig. 16). This lower peat has not yet been investigated.

Recent re-culverting of the stream that enters the sea towards the southern end of Mill Strand (Fig. 16) provided temporary exposures in the upper peat and overlying sands both seaward and landward of the railway embankment. On the

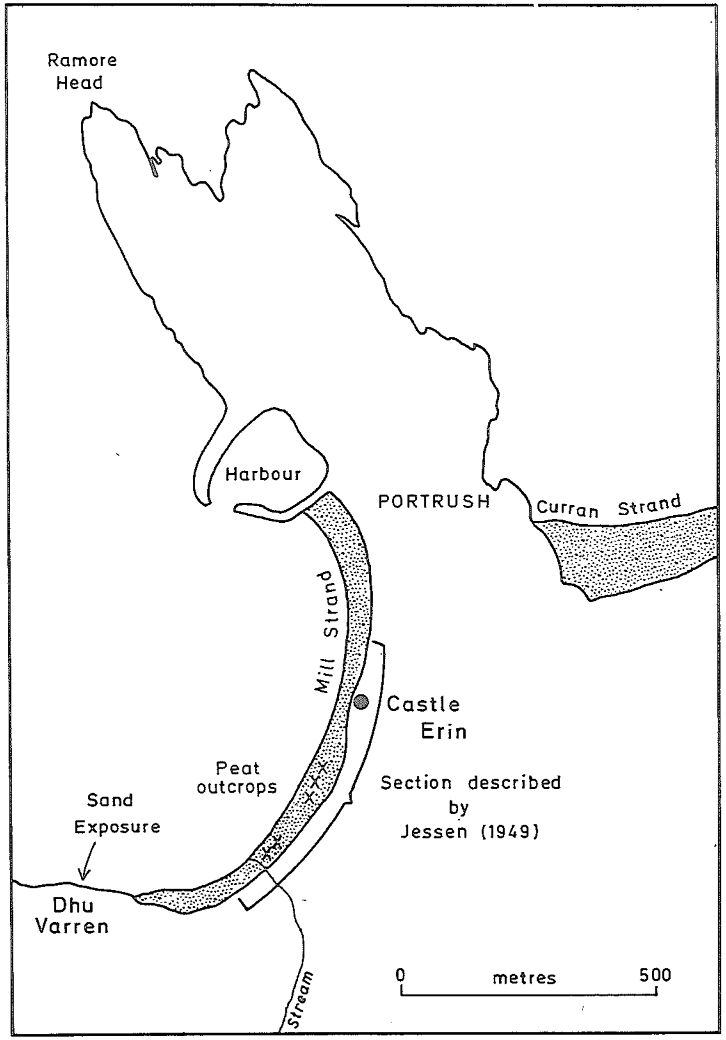

Figure 16. Location of inter-tidal peat at Mill Strand and sand exposure at Dhu Varren.

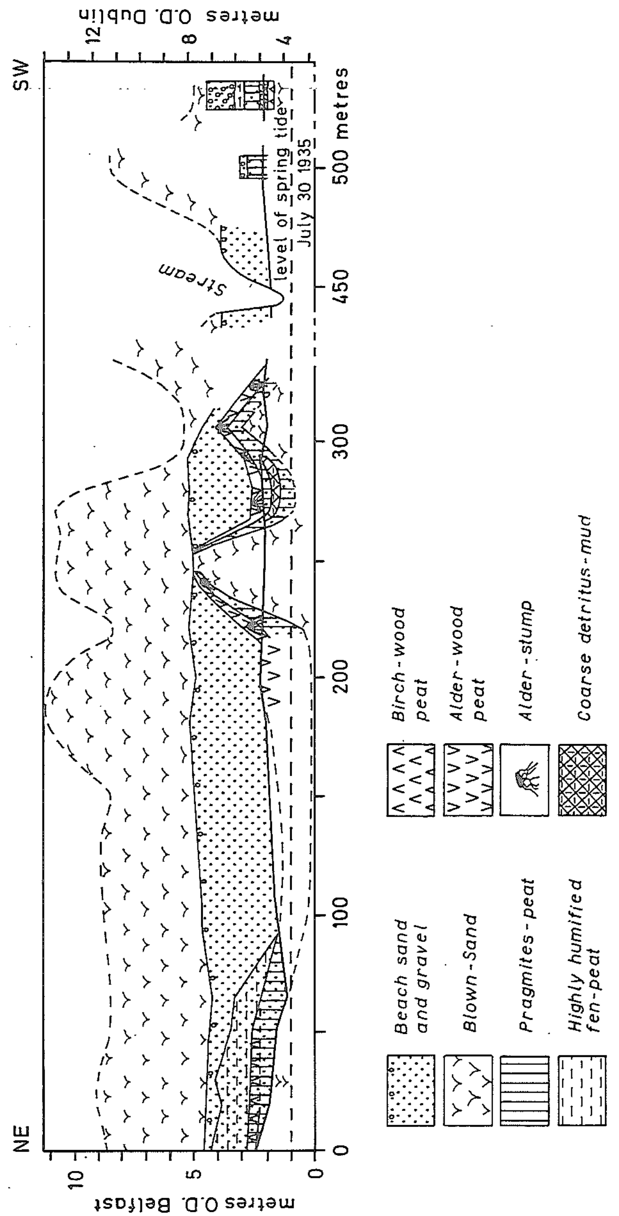

Figure 17. The sedimentary sequence at Mill Strand, Portrush (redrawn after Jessen, 1949).

seaward side of the railway the overlying sand was *c.* 1m thick and was of predominantly medium sand size (65-75%, Mzø +1.5-+1.82), well sorted (σ_Iø 0.35-0.48) and negatively skewed (Sk -0.04 to -0.15). Gravel was absent. Landward of the railway, 1.37m of peat occurred below sand that contained gravel in its lowermost part (sand 65%, gravel 35%). The bulk of the gravel (28%) was of fine size (0.2-0.63cm) the rest was of medium size (0.63-2cm). The sand fraction was dominated by medium and fine sand (46% and 32% respectively, Mzø +1.54), was moderately sorted (σ_Iø 0.87) and negatively skewed (Sk -0.37). The base of the peat was not seen but samples from the top and the bottom of the observed peat thickness were ^{14}C dated to 5920±80 years B.P. (Beta-36943) and 7310±100 years B.P. (Beta-36944) respectively.

These dates indicate that the peat probably relates to the period immediately prior to the peak of the Holocene marine transgression, around 6000 years B.P., as suggested by Jessen.

PORTRUSH - DHU VARREN (*Peter Wilson & Richard Bateman*)

A short distance west of the southern end of Mill Strand, a sand cliff exposure (Fig. 16) displays three buried soils and six iron-enriched horizons (Figs. 18 & 19). This exposure is of interest and significance in its own right, as well as in relation to the section described by Jessen (1949) at Mill Strand. The buried organic horizons indicate periods of landscape stability, vegetation growth and pedogenesis separating phases of sand accumulation. The iron-enriched horizons reflect mineral decomposition and translocation.

Sand and soil characteristics were assessed by analyses of 34 samples taken from three profiles (A-C, Figs. 18 & 19). The sand is acidic throughout (pH <6.0) and lacks shell fragments. Loss-on-ignition values for the organic horizons are low (1-5%) and dithionite-extractable iron values for the iron-enriched horizons are moderate to high (0.8-13.5%). Sand sized particles comprise at least 95% by weight of all horizons sampled; combined amounts of silt and clay never exceed 5% and gravel is absent. Medium and fine sand dominate most horizons (39-74% and 2-54% respectively) though some horizons of profile C are unusually rich in coarse sand. Mean sand size ranges from +0.97ø to +1.76ø in profile C and from +1.67ø to +2.05ø in profiles A and B. Sorting values show no systematic variation, all samples are either well sorted or moderately well sorted (0.43-0.55ø) and skewness varies from positive to negative (+0.10 to -0.26). The section lacks visible sedimentary structures.

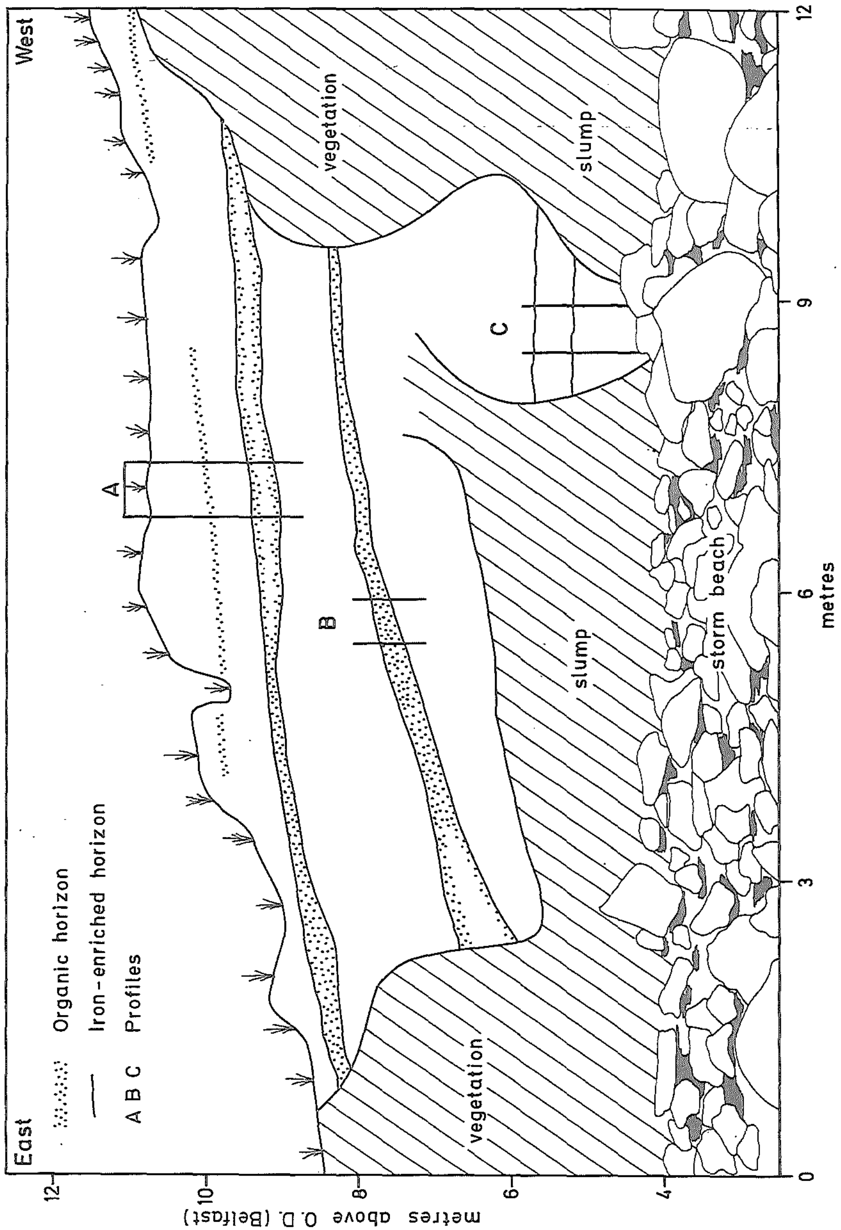

Figure 18. Sand exposure at Dhu Varren, Portrush.

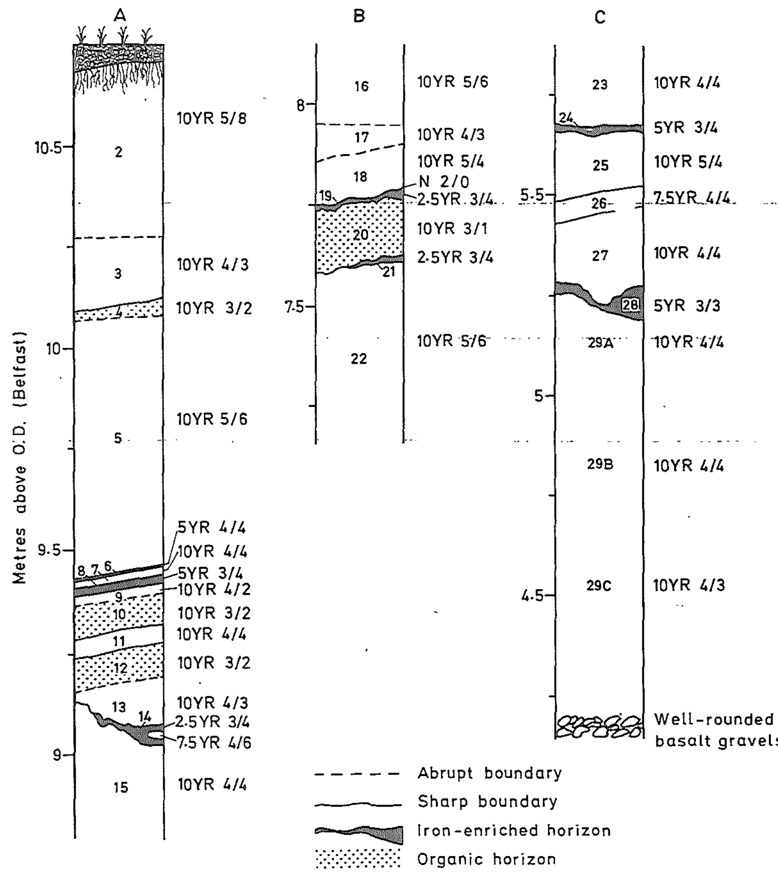

Figure 19. Stratigraphy, unit numbers and Munsell Colours for profiles A, B and C (Fig. 18) at Dhu Varren, Portrush.

The mineralogy of three samples, from horizons 5, 15 and 22 (Fig. 19), shows remarkably little variation, suggesting a more-or-less constant provenance during the deposition of all three units sampled. Quartz and calcic plagioclase dominate the light fractions (*c.* 95%) with subordinate (3-4%) alkali feldspars and traces (<1%) of chert, leucocratic phyllosilicates and glauconites (Table 3A). In the size fraction analysed (3.0-3.5ø), the heavy fractions constitute an exceptionally high proportion (34-47%) of the total sand, and non-opaques consistently exceed opaques.

Table 3. Light (A) and non-opaque heavy (B) mineral data for the fine sand fractions of samples from three depositional units at Dhu Varren, Portrush. Means ($\bar{x}$), sample standard deviations (σ -1) and coefficients of variation (CV%) for Dhu Varren are compared with values for coastal sands at Magilligan, 20km west of Portrush (Wilson & Bateman, 1986, 1987), and for Late Pleistocene tills from the floor of the Irish Sea (Wilson *et al.*, 1981). Size ranges subsampled for mineralogical analysis were 3.0-3.5ϕ (90-125µm) for Dhu Varren and Magilligan, and 2-4ϕ (63-250µm) for the Irish Sea tills. Density separation in tribromomethane followed by the procedures of Bullock & Loveland (1974), and grains were mounted in a clove oil mixture (R.I. 1.538) on glass slides. Grain counts were 600-1100 for each of the light and non-opaque heavy fractions; opaque heavy fractions contained insufficient variables to warrant quantification. The small numbers of samples analysed render dubious the summary statistics for the Dhu Varren deposits and the Irish Sea tills. Mineralogical note: the quartz category includes all calcic plagioclase ($>Ab_{10}$, including labradorite). Leucocratic phyllosilicates are dominantly chlorites. Biogenic and volcanigenic carbonates are not distinguished. Augite includes other related clinopyroxenes such as titanoaugite and aegirine.

(A)

Locality		Light minerals (‰)							(%)	
		Quartz/Plagiocl.	Chert	Alkali feldspars	Leucocratic phyl.	Glauconites	Volcanic glass	Calcite/Aragonite	Non-opaques	Opaques
Portrush samples	5	943	12	34	7	4	-	-	21.8	12.8
	15	947	11	31	11	-	-	-	25.8	21.7
	22	940	7	42	5	4	2	-	20.3	14.1
Portrush (n= 3)	$\bar{x}$	943	10	36	8	3	1	0	22.6	16.2
	σ -1	4	3	6	3	3	-	-	2.8	4.8
	CV(%)	<1	26	16	40	87	-	-	13	30
Magilligan (n=29)	$\bar{x}$	823	18	98	7	2	1	52	4.3	2.2
	σ -1	72	10	28	4	2	-	80	2.2	1.6
	CV(%)	9	56	29	60	104	-	155	52	75
Irish Sea tills (n= 4)	$\bar{x}$	913	19	67	<1	<1	<1	0	0.15	0.12
	σ -1	29	9	21	-	-	-	-	0.07	0.07
	CV(%)	3	50	32	-	-	-	-	49	64

(B)

Locality		Heavy minerals (‰)																			
		Zircon	Anatase	Brookite	Rutile	Tourmalines	Sillimanite	Andalusite	Kyanite	Staurolite	Corundum	Spinels	Garnets	Zoisite/Clinoz.	Epidote	Hypersthene/Brz.	Hornblende	Tremolite/Actin.	Augite	Apatite	Chrysolite
Portrush samples	5	15	-	-	8	6	-	1	1	1	-	-	56	1	35	1	70	7	775	13	10
	15	19	-	-	-	10	-	1	-	1	-	-	42	4	38	1	48	10	806	12	8
	22	17	-	-	1	9	-	3	-	1	-	-	72	1	21	-	53	11	783	11	27
Portrush (n= 3)	$\bar{x}$	17	0	0	3	8	0	2	<1	1	0	0	57	2	31	1	57	9	788	12	15
	σ -1	2	-	-	4	2	-	1	-	-	-	-	15	2	9	-	12	2	16	1	10
	CV(%)	12	-	-	145	25	-	69	-	-	-	-	26	87	29	-	20	22	2	8	70
Magilligan (n=29)	$\bar{x}$	8	<1	<1	3	13	<1	5	1	6	<1	<1	48	8	43	8	126	21	661	11	35
	σ -1	8	-	-	2	6	-	4	1	4	-	-	27	4	12	5	18	8	53	7	29
	CV(%)	98	-	-	70	49	-	74	77	57	-	-	56	51	28	57	14	39	8	61	85
Irish Sea tills (n= 4)	$\bar{x}$	70	0	2	8	86	0	7	7	20	0	0	117	22	21	31	101	11	493	1	2
	σ -1	36	-	3	8	20	-	2	4	8	-	-	34	8	7	8	18	5	58	-	2
	CV(%)	51	-	141	107	23	-	35	56	39	-	-	29	35	34	24	18	43	12	-	115

Non-opaque heavy fractions are strongly dominated by clinopyroxenes (*c.* 80%) with subordinate (3-6%) hornblende, epidote and garnets, and minor (<2%) quantities of 11 other recognisable mineral categories (Table 3B).

Coefficients of variation for the more frequent minerals range from 29% for epidote to remarkably low values of 2% for augite and 1% for quartz, appreciably less than coefficients of variation for the same minerals in sand samples analysed from Magilligan and the floor of the Irish Sea (Table 3). The only significant differences between the three samples from Dhu Varren are the presence of volcanic glass (<1%), greater frequency of chrysolite olivine (3%: 1%) and larger garnets:epidote ratio (3.4: 1.1-1.6) in the lowermost horizon (22) and the presence of rutile (1%) in the uppermost horizon (5). The samples do not exhibit any mineralogical variation that could be ascribed to minor differences in particle size distributions.

The presence of volcanic glass in horizon 22 and of chrysolite and apatite in all three horizons suggests that the sampled horizons have experienced minimal acid pedochemical weathering (cf. Bateman & Catt, 1985; Wilson & Bateman, 1986, 1987), though the data tentatively suggest limited depletion of volcanic glass and chrysolite in horizons 15 and 5, an interpretation supported by low-grade etch features on many of the olivines. These observations tell us nothing about the degree of weathering experienced by horizons closer to successive soil surfaces, as mineral weathering profiles can be very steep, confining intense mineral depletion to the uppermost few decimetres (cf. Bateman & Catt, 1985).

The relationship between this sand sequence and Jessen's section is not clear; he did not report buried soils or iron-enriched horizons in any of the sand units exposed at Mill Strand. The base of the sand has been levelled to 4.2m O.D., within the elevational range given by Jessen for the beach sand. The upper part of the sand lies within the elevational range of Jessen's upper dune sand. However, correlation of the sections on the basis of elevation, without any firm dating control, is probably unwise. Moreover, although Jessen reported that shells were absent from the beach sand and the lower dunes he did not comment on the presence or absence of shell fragments in his upper dune sand. It seems likely that shell material was present in the upper dunes, as these were once continuous with the dunes of Curran Strand (Fig. 8) and dune systems along the north coast of Ireland contain a substantial shell component (5-20%). The absence of shell fragments from the sand exposure militates against correlation with Jessen's upper dunes.

Alternatively, the sand may be part of the cliff-top sand

that extends between Portstewart and Portrush. It has similar grain size characteristics to the sand at Long Port but is significantly coarser and less well sorted than the sand that underlies Portstewart. These variations may reflect the nature of the source materials and/or the mode of sand deposition.

Unravelling the origin, age and correlation of these enigmatic sand deposits would be greatly assisted by a reliable chronostratigraphy based on additional ^{14}C dates.

PORTBALLINTRAE - SEAPORT LODGE (*John McKenna*)

The shore platforms north of Seaport Lodge, Portballintrae (Fig. 1), provide a good example of the juxtaposition of a contemporary and a Holocene platform. The Holocene platform is the much-dissected high-level surface to landward (now vegetated in parts), which dips east towards the bay from *c.* 8m to *c.* 3m O.D. It terminates landward in a degraded Holocene cliff. Contemporary storms occasionally throw cobbles right to the base of this raised cliff. The raised platform is now being replaced on its seaward margin by a contemporary platform with planar sections at *c.* 0.5m, 1.0m and 2.0m O.D. This variation is related to the elevation of the basalt flow that is now being actively eroded. These platforms illustrate the salient characteristics of those elsewhere on the north coast, i.e. general surface irregularity, flow top control at various elevations, sub-horizontal gradients, and cliff base gullies well below the elevation of the platform plane.

PORTBALLINTRAE - PORT GORM (*John McKenna*)

The Port Gorm embayment, Portballintrae (Fig. 1), is largely occupied by a contemporary shore platform. The well abraded inner plane has an elevation of *c.* 0.8m O.D. The higher section on the seaward promontory and the isolated residual masses on the inner platform probably represent the remnants of a higher more resistant basalt flow. The western edge of the promontory is probably fault-controlled. The cliffs flanking the embayment contain a particularly friable vesicular lava flow that dips to within the range of marine attack. The erosion of this flow may explain the development of this extensive embayment platform, and may also have provided the basalt sand found in the swash terrace.

The terrace at Port Gorm fronts a degraded cliff and slopes seaward at 10^{0}. A pit excavated on the terrace at a surface

Table 4. $CaCO_3$ contents and grain size characteristics for sediments at Port Gorm, Portballintrae.

LOCATION	SAMPLE	%$CaCO_3$	%SAND	%SILT & CLAY	TEXTURAL PARAMETERS $M_z\phi$	$\sigma_I\phi$	Sk	K_G'
Terrace	Surface	1.6	100	-	-0.66	0.43	+0.13	0.45
	5cm	0.2	65.64	34.36	-0.19	1.00	+0.41	0.61
	40cm	-	88.25	11.75	-0.40	0.63	+0.23	0.56
	1m	-	88.35	11.65	-0.46	0.69	+0.27	0.55
Beach	1	5.6	100	-	-1.05	0.27	+0.58	0.75
	2	5.4	100	-	-0.29	0.59	-0.09	0.51
	3	2.5	99.89	0.11	-0.18	0.59	0	0.50

SAND: -1 to +4ϕ, SILT & CLAY: >+4ϕ.

TEXTURAL PARAMETERS (calculated for sand fraction only): M_z mean size, σ_I sorting, Sk skewness, K_G' kurtosis.

elevation of 6.3m O.D. revealed crudely laminated, coarse, marine sands at least 1m in thickness. Occasional, rounded, discoidal clasts occurred within the sands. The sands were sampled at depths of 5cm, 40cm and 1m below the surface. In addition, a sample was taken from a terrace surface deposit that is known to date from a recent storm. Samples were also taken of the finer sediments on the present storm beach. The grain size distributions and $CaCO_3$ contents for these samples are given in Table 4. Landward of the pit, at an elevation of 7.3m O.D., an abrupt transition occurs between the laminated sands and a surface deposit of vertically orientated, closely packed, flattened cobbles that extends landward for 3m and reaches an elevation of 7.6m O.D. The cobbles are underlain by a sticky clay and give way to a typical clay soil at 8.1m O.D.

Three hypotheses can be suggested to account for the terrace morphology:

1. The terrace is similar in appearance to the apron formed by slump deposits at the base of degraded cliffs and could have been formed by a series of such slumps that were later modified and smoothed by the addition of finer material resulting from the operation of slower slope processes. However, the laminated sands of the terrace are most unlike the poorly sorted cobbles in a clay matrix that typify coastal slumps. In addition, the terrace demonstrates a lateral uniformity quite unlike that created by slump lobes, which characteristically produce an uneven under-cliff consisting of linear rupture ridges marking the lateral margins of each localised slump apron. Nevertheless, it is

accepted that the landward parts of the terrace may be composed of slope debris.

2. The terrace may be a raised beach related to a higher Holocene sea level. While it is not unlikely that a raised beach may underlie several of the coastal terraces, this explanation has an inherent bias in that it searches for a Holocene origin before eliminating contemporary processes. The maximum elevation of the terrace sands is 7.3m O.D.; this is well within the depositional range of contemporary storms which are known to deposit a veneer of sand on the terrace. This evidence greatly weakens the case for a raised beach origin, but even if this point is conceded it would appear that any higher relative sea level (RSL) can only have been slightly higher than that of today.

3. The terrace may represent the accumulation over many years of sediments deposited by storm events at present sea level. The laminations in the moderately well sorted, coarse sands suggest repeated additions of thin layers of fresh water-borne sediment. The presence of rounded clasts, along with observations that contemporary storms throw a discrete layer of sand and gravel, and occasional larger clasts, up onto the terrace are powerful additional arguments for a contemporary marine origin.

Material thrown up onto the terrace by storm-waves consists partly of reworked terrace scarp deposits, partly of material from the clast attrition zone at the base of the storm beach, and also material brought in by waves from the shore platform or bay. During severe storms the terrace scarp is cut back severely, as the base of the storm beach moves landward. The storm of January 1986 moved the base of the beach several metres landward, exposing a rugged bedrock surface covered with fresh striations. Direct erosion of the friable vesicular basalts may be considerable, so the exceptionally well-developed terrace may reflect the presence of a plentiful source of fine sediment.

Interpretation of the grain size characteristics and $CaCO_3$ contents of the terrace sands and beach sands (Table 4) lends some support to the storm sedimentation hypothesis. The silt and clay fractions of the terrace sands are not of marine origin since the contemporary storm beach contains virtually no material finer than +4ø. These fractions probably result from post-depositional weathering of the sands. The surface sample lacks silt and clay because it was collected soon after it had been deposited and had not undergone weathering. The absence of $CaCO_3$ in the terrace sands also suggests that post-depositional weathering has occurred. Sand fraction textural parameters reveal a pattern of broad similarity between the terrace and the beach sands. The stone pavement at the landward margin of the terrace probably results from a single exceptional storm in which large flat stones were thrown onto the terrace surface. There is substantial evidence for this process at Port Gallen, east of Portstewart, and at Seaport, where the backshore terraces are often littered with clasts after major storms.

It is proposed that the supra-tidal terrace at Port Gorm is substantially the result of storm-wave sedimentation at present sea level, and the term 'swash terrace' is considered appropriate. While such terraces are essentially marine features, the role of slope processes cannot be entirely dismissed. In some locations slope processes make a minor contribution to terrace morphology and sediments, but in others slope inputs and marine deposition may combine to produce composite features. Although raised beaches may underlie some terraces, the present terrace morphology is related to contemporary marine activity. Raised beaches may have assisted in terrace development by providing the initial 'step' in the coastal slope. The presence of swash terraces along the north coast greatly increases the difficulty of establishing the elevation and longshore extent of former shorelines related to higher RSL positions.

PORT BALLINTRAE (*George Dardis*)

Exposures of complexly interbedded diamicts, muds and stratified sand intraclasts, overlain by shoreface sediments (sands, gravels and muds) and beach gravels, occur on the west side of Port Ballintrae (Fig. 20) (Creighton, 1974; Eyles & McCabe, 1989).

The lower diamicton comprises a sand-mud matrix, and contains well dispersed clasts. Macrofabrics within the diamicton unit are random (Eyles & McCabe, 1989). Irregular lenses of gravel and laminated sand intraclasts occur within the diamicton unit (Fig. 21). Thin (1-10mm), relatively continuous clay laminae are interbedded with the diamicton unit; these are often heavily contorted (Fig. 22). A distinct hiatus occurs between the lower diamicton unit and overlying sand and gravel units (Fig. 20). The sand unit consists largely of swaley cross-stratification, with subordinate mud laminae, flaser bedding and occasional diamicton inclusions (Fig. 23). The top of the sand unit is wave-cut and capped by post-glacial beach gravels containing shells (Eyles & McCabe, 1989).

The sequence at Port Ballintrae has been interpreted as an emergent facies sequence, associated with increased glaciomarine shallowing (Eyles & McCabe, 1989); the lower diamicton unit formed as deep-water glaciomarine muds and ice-rafted debris, followed by deposition of wave-influenced

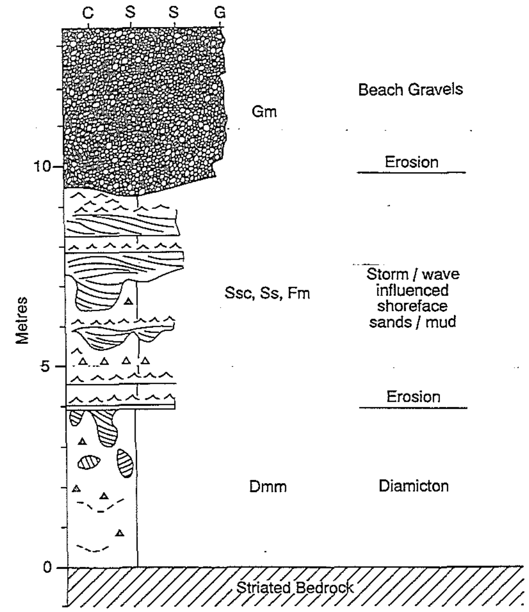

Figure 20. Coarsening-up sequence at Port Ballintrae (modified after Eyles & McCabe, 1989).

shoreface sands and muds in a shallow marine environment.

Critical lines of evidence and interpretations have, however, not been fully considered by these workers:

1. They ignore the possibility that the diamicton unit may be a depositional facies associated with onshore movement of ice of Scottish origin during the Armoy Stage readvance (cf. Dwerryhouse, 1923; Charlesworth, 1939; Creighton, 1974; Stephens *et al.*, 1975). Depositional structures within the diamicton unit may well reflect post-depositional glacitectonic deformation and overturning of the diamicton (which is most likely a composite deposit of glaciomarine muds and resedimented hydrodynamic facies), rather than debris flow activity. This alternative interpretation is consistent with widespread evidence of glacitectonic deformation associated with subglacial and ice-marginal sedimentary sequences formed during the Armoy Stage (cf. Shaw & Carter, 1980). Given that it can prove difficult to distinguish between (subaerial) debris flows and subglacial

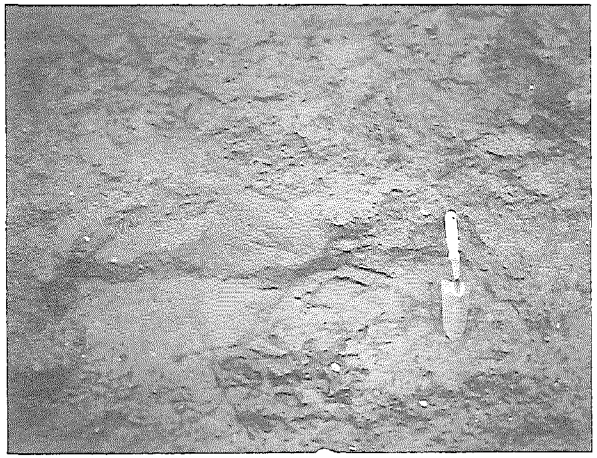

Figure 21. Laminated sand inclusion (left of trowel), lower Diamicton Unit, Port Ballintrae.

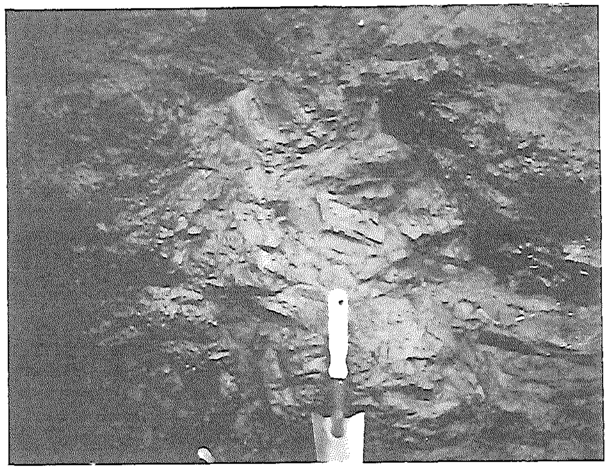

Figure 22. Deformed sand inclusions (right of and above trowel), lower Diamicton Unit, Port Ballintrae.

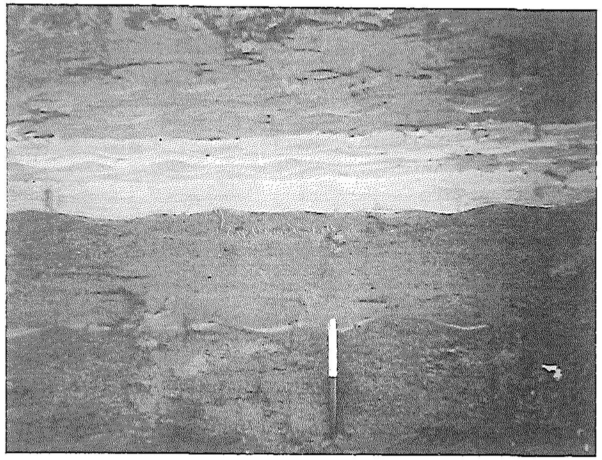

Figure 23. Wave-formed ripples, Port Ballintrae.

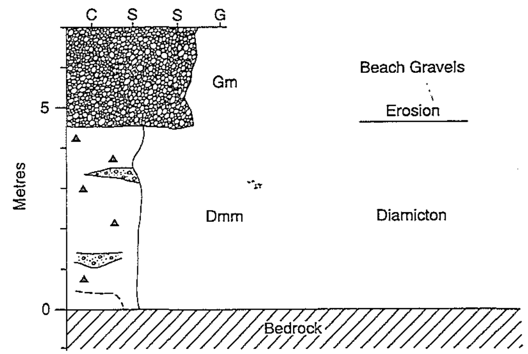

Figure 24. Sedimentary sequence at Runkerry.

diamictons (cf. Mandryk & Rutter, 1990; Eyles *et al.*, 1990), the genesis of this unit needs further consideration.

2. The major hiatus' which separates the diamicton/marine sands and marine sands/beach gravels at Port Ballintrae makes it difficult to discount outright the possibility of major time spans between deposition of these units (Fig. 20), such that it may be unrealistic to group them into a *facies sequence* (see Reading (1978) for a full definition of this term). This view is borne out by the general absence of the marine sands from neighbouring sites (see Runkerry coastal section described below). It seems more likely that a phase of glacitectonic deformation (most probably associated with the Armoy Stage) occurred following deposition of the lower diamicton unit and prior to deposition of the overlying marine sands. It must be stated, however, that it is not yet clear if the diamicton unit is a syndepositional facies associated with the Armoy Stage.

RUNKERRY (*George Dardis*)

A diamicton unit, overlain by post-glacial beach gravels, is exposed at Runkerry (Fig. 24), west of Port Ballintrae. The diamicton unit consists of a sand-mud matrix, containing dispersed pebble- and cobble-sized clasts (Fig. 25). The clasts consist mainly of basalt and chalk. The diamicton unit contains occasional beds of crudely stratified sands and gravels (Fig. 26). The stratified beds show some evidence of immature flaser-type stratification within sand beds and disorganised and poorly stratified facies within gravel beds (Fig. 26). The stratified facies are laterally discontinuous and generally dip northwards at low angles (5-15^{0}). In places, the stratified inclusions are steeply dipping and are partly deformed (Figs 26 & 27). Lensate gravel clusters, 1-2m long and 20-30cm thick, are also found within the diamicton unit (Fig. 28). These are generally disorganised and clast-supported, but may show evidence of internal sorting.

The diamicton unit is broadly similar to the diamicton facies at Port Ballintrae. However, it contains a greater proportion of *in situ* stratified facies. Facies associations of this type are normally considered typical of sedimentation in glaciomarine environments, from turbid high density sediment plumes (Anderson *et al.*, 1980a, 1980b; Domack, 1982, 1983; McCabe & Dardis, 1989a). The gravel clusters (Fig. 28) within the diamicton most likely reflect IRD fall-out (Anderson *et al.*, 1980b). The absence of coarse-grained hydrodynamic facies suggests an ice-distal depositional setting for the diamicton.

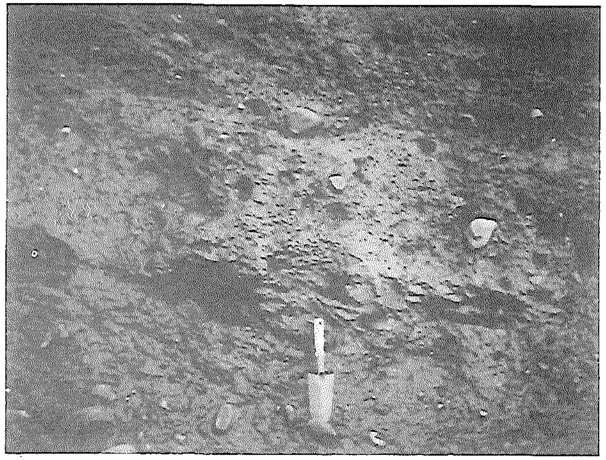

Figure 25. Diamicton Unit, Runkerry.

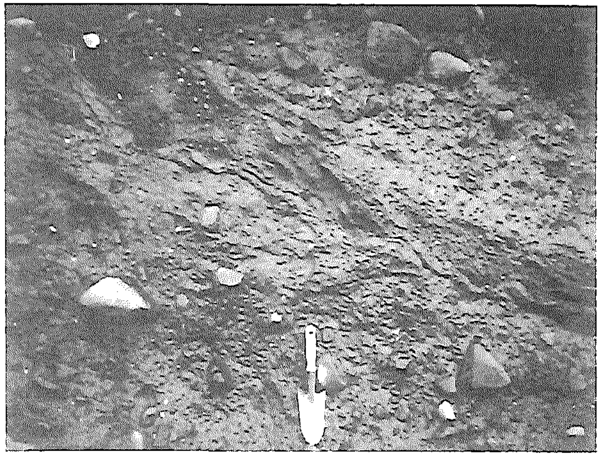

Figure 26. Stratified facies, Diamicton Unit, Runkerry.

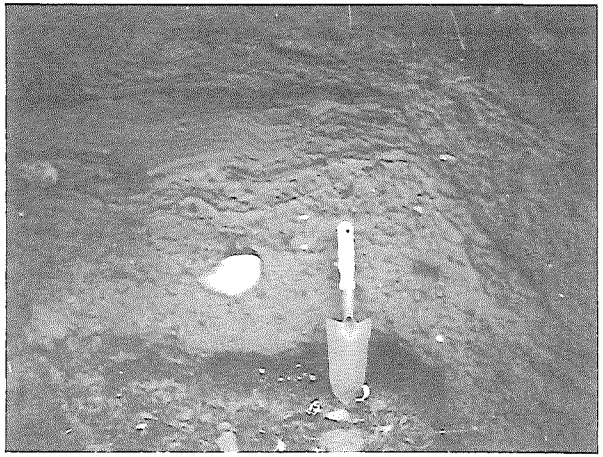

Figure 27. Deformed sand facies, Diamicton Unit, Runkerry.

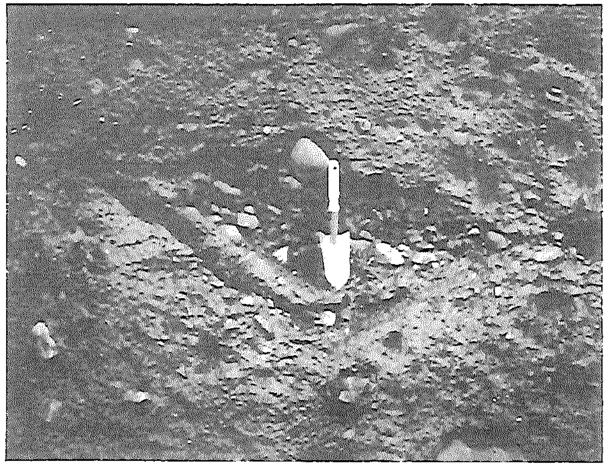

Figure 28. Gravel cluster, Diamicton Unit, Runkerry.

WHITE PARK BAY (*Brian Williams*)

Sand dunes were favourite places for occupation in prehistoric times and material of various periods has been found in dunes around the Irish coast. White Park Bay (Fig. 29) was extensively searched by collectors in the later years of the 19th century and in particular by William Knowles of Ballymena (Knowles, 1889-91a, 1889-91b, 1893-96, 1900-02). He generated a great deal of enthusiasm in Ireland for the study of sandhills and was the leading member of the Sandhills Committee of the Royal Irish Academy.

At White Park Bay, Knowles found an old occupation surface rich in prehistoric remains and over the years collected between 3000 and 4000 manufactured articles among which were flint end scrapers, hollow scrapers, axes, chisels, arrowheads, spearheads, borers, hammer-stones and pottery. These were associated with an occupation layer which had been covered with sand until a few years before he first visited the dunes. A linear group of 20 round houses was located in the centre of the bay, while a separate group of nine round houses was found at the east end (Fig. 29). All the indications point to the majority of the material from White Park Bay belonging to the Late Neolithic, although finds of burial urns and clay casting moulds for swords and spearheads are evidence of activity in the Bronze Age.

Associated with the Neolithic settlement in the bay is a group of megalithic tombs, three set a little distance inland and one in the bay itself, which are part of the well-known north Antrim passage tomb cemetery. Each of the four sites is scheduled under the Historic Monuments Act (NI) 1971.

Ballintoy Demesne and Magheraboy

On a local eminence with an impressive view to the north over White Park Bay to Scotland in the distance. A single-chambered passage tomb known as 'The Druid Stone' is formed by four basalt uprights and one fallen slab, all covered by a single capstone (Fig. 30). The chamber measures 2.0x1.3x1.2m. Two slabs to the north-east of the chamber may be remnants of an access passage. While there are now no remains of a cairn, a retaining kerb survives in an arc of a circle from south-east through west to north-east. A modern stone wall has damaged the perimeter of the site along the east side. The tomb was excavated by Mogey in 1939. A layer of blackened earth under the cairn contained Neolithic finds and it appears not to be significantly earlier than the building of the tomb. The finds included three rim sherds and one shoulder sherd of

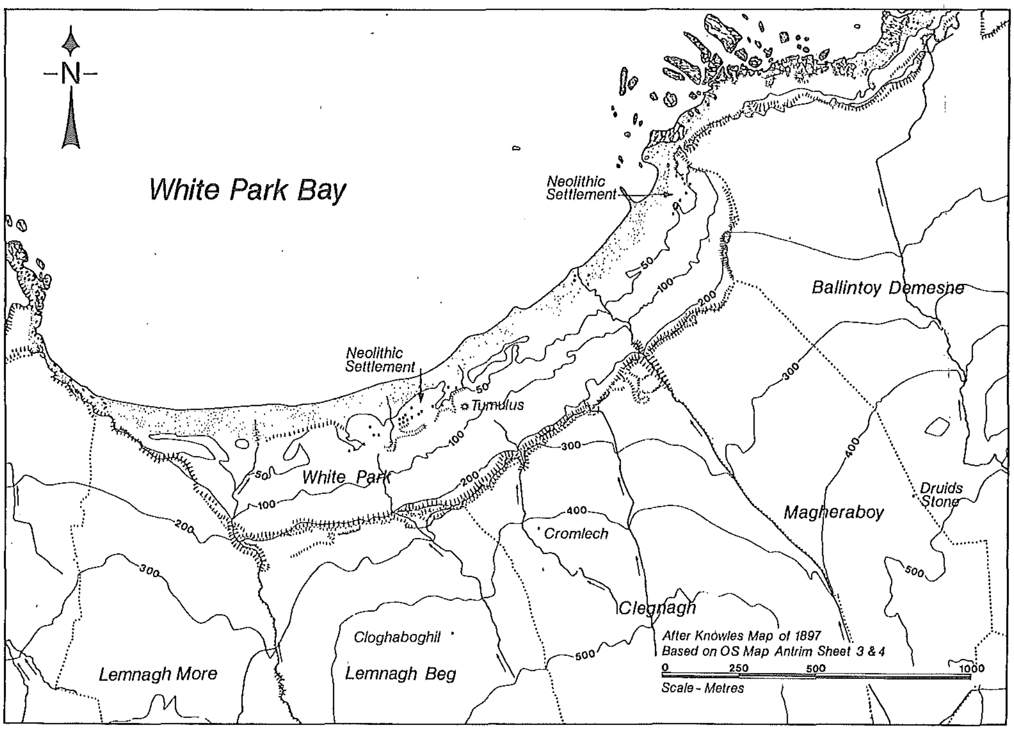

Figure 29. Archaeological sites around White Park Bay.

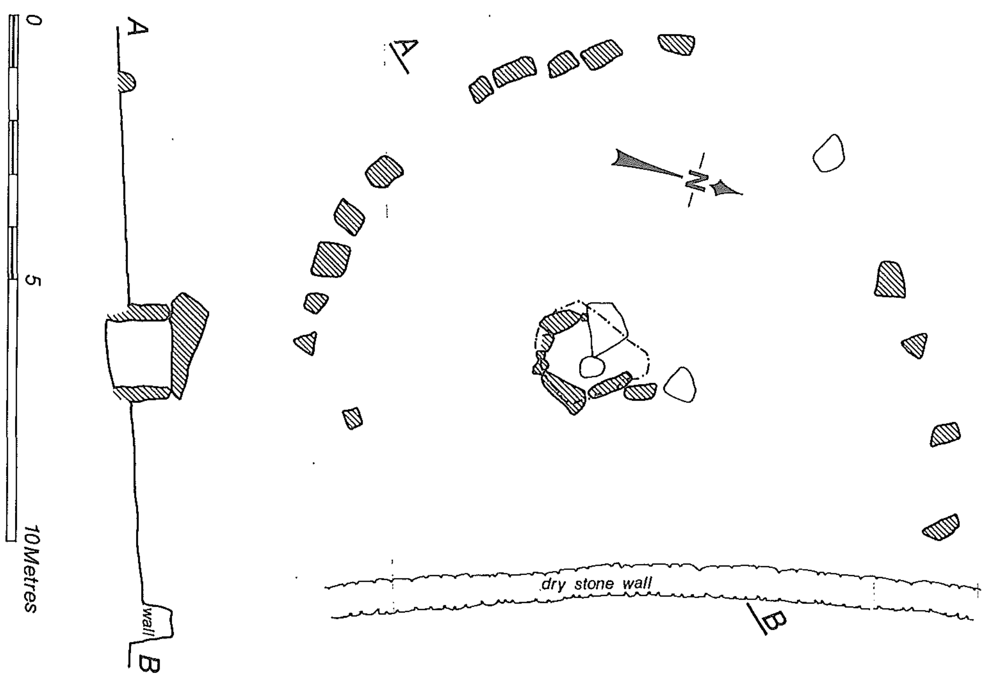

Figure 30. Passage tomb, Ballintoy Demesne and Magherboy. (Crown Copyright)

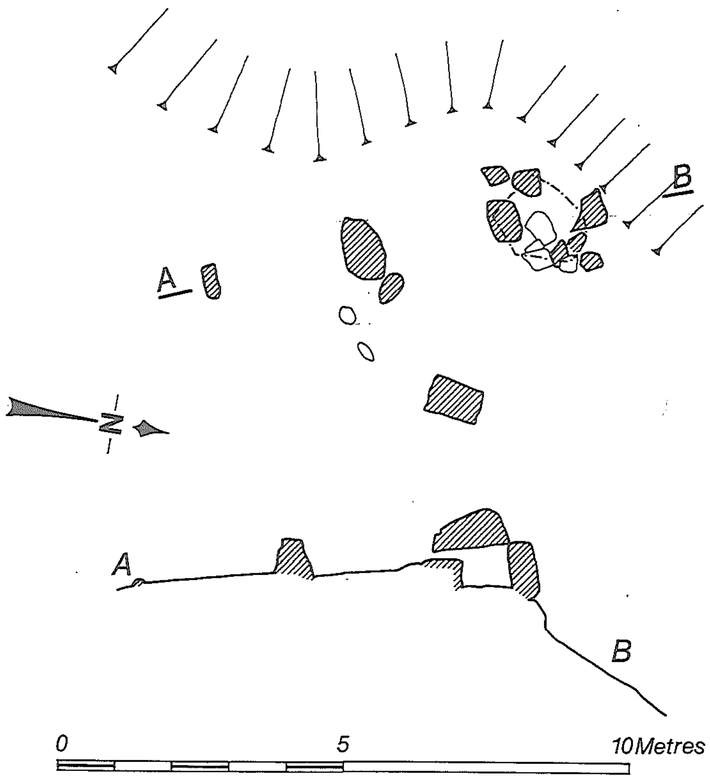

Figure 31. Passage tomb, Clegnagh.
(Crown Copyright)

Neolithic pottery, a broken kite-shaped arrowhead, two rough scrapers and a long blade of flint. Charcoal of oak, hazel and willow was also found, with some cremated adult human bone which may have been the remains of the burials in the chamber (Gray, 1883-84b; O'Laverty, 1887; Borlase, 1897; PSAMNI, 1940; Mogey, 1941; Ó Nualláin, 1968; Herity, 1974).

Clegnagh

On an eminence at the edge of a disused basalt quarry. A single-chambered passage tomb (Fig. 31) with a view over White Park Bay to Scotland. The chamber measuring

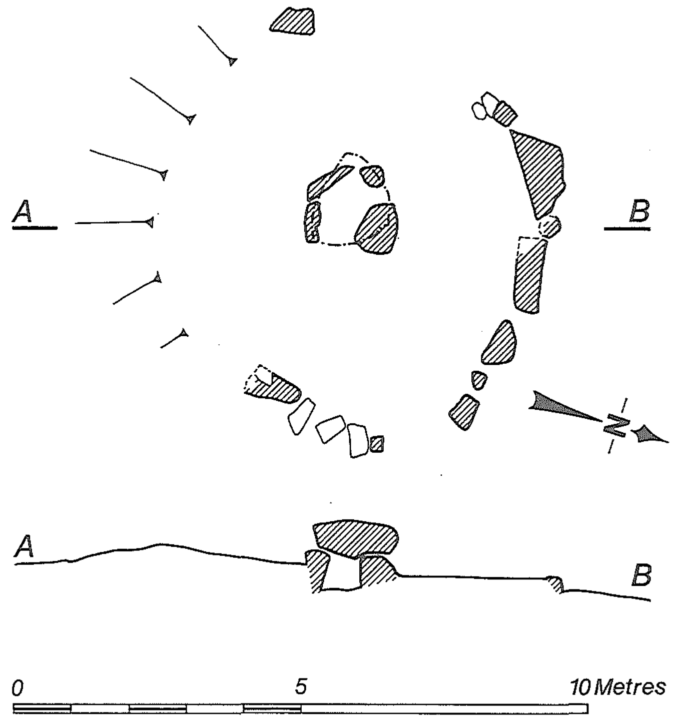

Figure 32. Passage tomb, Lemnagh Beg.
(Crown Copyright)

1.1x0.9x0.7m is formed of basalt boulders of which two support a single capstone. According to O'Laverty (1887) six other supporters formerly stood in the area now quarried away. These may have formed an access passage. Three stones to the south-east of the chamber may be the remnants of a stone kerb which O'Laverty recorded as having 18 stones arranged in an oval measuring 9.7x7.0m. In the exposed quarry section several flint artefacts, including a hollow scraper together with well-fired plain pottery have been found (Gray, 1883-84b; O'Laverty, 1887; Borlase, 1897; PSAMNI, 1940; Ó Nualláin, 1968; Herity, 1974).

Lemnagh Beg

On a prominent height commanding a view over White Park Bay. A single-chambered passage tomb known as 'Cloghaboghil' is formed by four basalt uprights supporting a single capstone

(Fig. 32). The chamber measures 1.3x0.9x0.6m. A gap in the east side of the chamber indicates its orientation but stones from the passage do not survive. The base of the round cairn is evident, revetted with a stone kerb in an arc from west through north to east (Gray, 1883-84a, b; O'Laverty, 1887; Borlase, 1897; Hobson, 1907; PSAMNI, 1940; Ó Nualláin, 1968; Herity, 1974).

White Park

On the top of a small hillock of slipped chalk near the centre of White Park Bay (Fig. 29) are the remains of a small circular cairn, 11m in diameter, surrounded by a stone kerb which has been described in the past as a stone circle. Many of the stones, which are basalt blocks, have fallen down the slope. The tops of two upright stones, 3.3m apart, are visible at the centre. William Gray excavated the site and found the remains of a skeleton laid on a rude platform of flat stones. While it is not possible to determine whether the cairn was chambered it seems likely that it was a passage tomb (Gray, 1879-82; PSAMNI, 1940).

BALLINTOY - BOHEESHANE BAY (*Bill Carter*)

The cliffed shoreline at Boheeshane Bay, Ballintoy, (Fig. 1) is relatively inaccessible, although it may be approached from the National Trust property at Larrybane, by walking up to the old communications tower at the north-west of the site. The cliffs at Boheeshane are cut into the near horizontal strata of the Lower Cretaceous limestones (chalk). From a Quaternary point of view the main interest is the spectacular slope failures, in which blocks of over 5000m³ have toppled into the sea (Carter, 1990). It seems likely that these blocks would have started to collapse in the period around 5000 years B.P. as the sea level fell away from its Holocene maximum, at which time wave activity would have been insufficient to remove the debris. There is no evidence of major instabilities today, although the block faces are scarred by minor rock falls and earth slips.

CAREY VALLEY (*George Dardis*)

Thick sequences of Quaternary drift deposits infill the middle part of the Carey valley (Fig. 33A) (Symes *et al.*, 1888). Dwerryhouse (1923) associated this succession with extramarginal deltaic sedimentation into a lake impounded by Scottish ice, associated with the Ballycastle - Armoy - Ballymoney moraine (Armoy Readvance or Advance). The delta was fed by meltwater overflows emanating from the Clady Burn

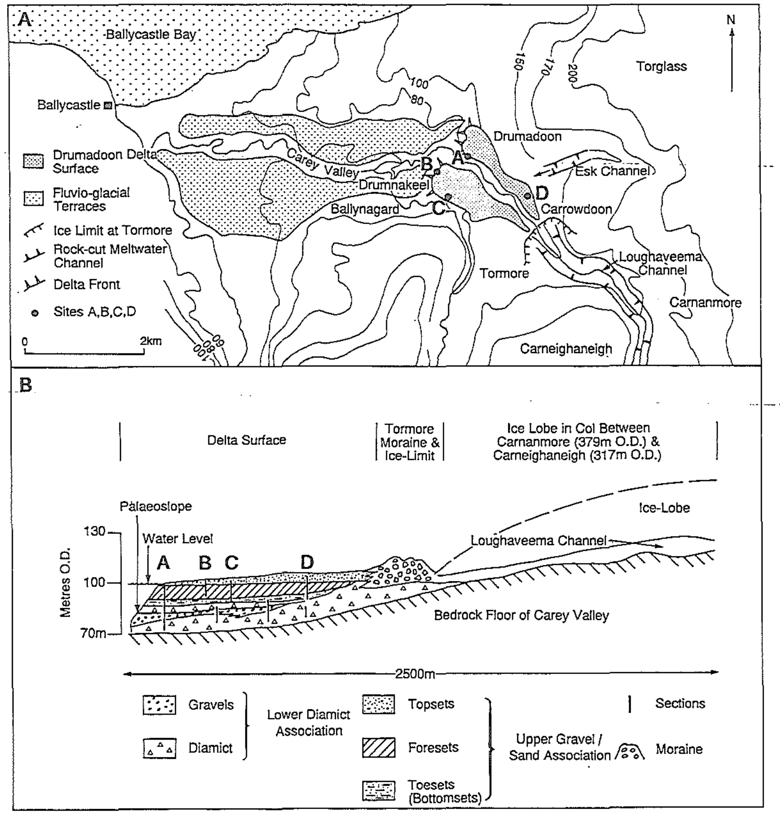

Figure 33. A. Location of the Carey valley and the Drumadoon delta, showing associated delta and fluvioglacial terrace deposits.
B. General stratigraphy, location of exposures and regional extent of the Carey valley succession (modified after McCabe & Eyles, 1988).

valley via the Loughaveema channel (Fig. 33). Lower terraces formed in response to lake level lowering in the course of ice withdrawal.

Later workers (Hill & Prior, 1968; Prior, 1968) suggested a more complex sedimentation history, based on lithological analysis of tills and associated deposits in the Carey valley (Fig. 34). Basal till deposition was associated with northward moving (Irish) ice (S1 stage, Fig. 34). As this Irish ice downwasted and withdrew (S2 and S3 stages, Fig. 34), stronger pressure was exerted by North Channel ice, resulting in deposition of Chalky Till and an associated gravel suite (C1 and C2 stages, Fig. 34). This was followed by forward movement of ice of North Channel and Scottish origin (N1, N2 and N3 stages, Fig. 34), when Irish ice had withdrawn from the northern coastal zone between Ballycastle and Lough Foyle. Northern ice associated with this later stage reached its maximum extent along the Ballycastle - Armoy - Ballymoney moraine (Prior, 1968; Stephens *et al.*, 1975).

McCabe & Eyles (1988) re-interpreted the Carey valley succession as a glaciomarine delta complex, related to a water plane at *c.* 100m above present sea level (Fig. 33B).

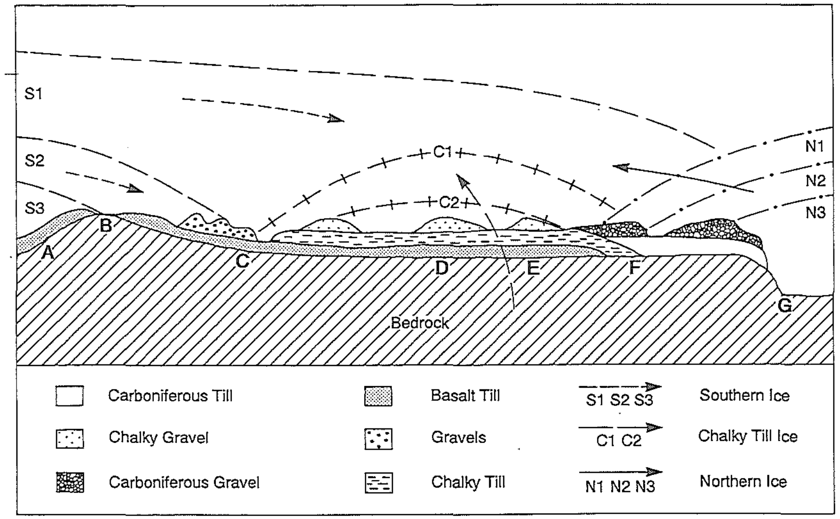

Figure 34. The glacial stratigraphic succession of tills, and associated gravels in the Carey valley (redrawn after Stephens et al., 1975).

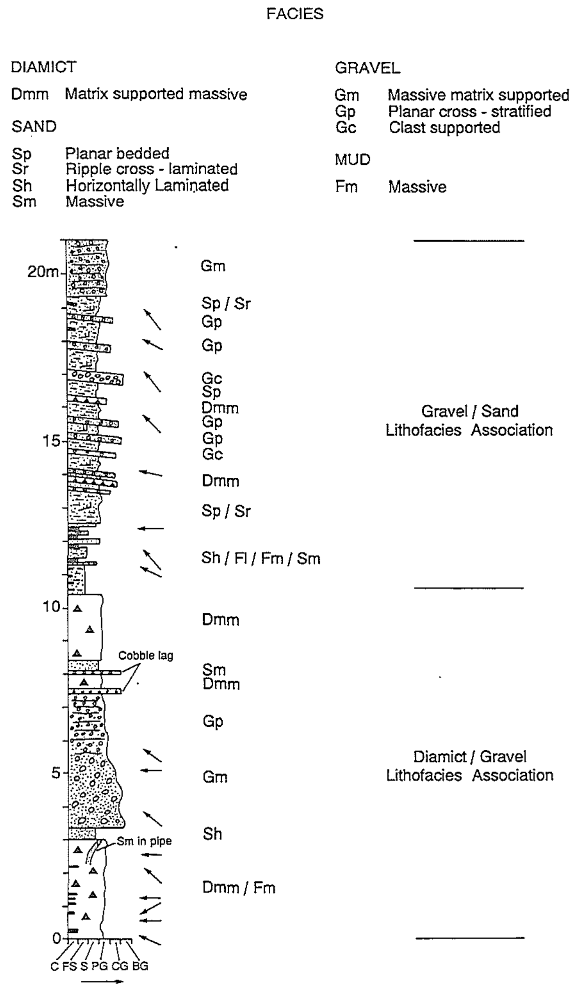

Figure 35. Composite stratigraphic log of the Carey valley succession, based on the Drumadoon and Drumnakeel exposures. Arrows indicate palaeocurrent directions (after McCabe & Eyles, 1988).

A number of small exposures (A-D, Fig. 33) show a lowermost diamict association, composed of massive diamicts and poorly sorted gravels, overlain by a gravelly foreset and topset facies (Fig. 35). The lower diamict facies and associated deposits were interpreted as subaqueous debris flows and resedimented flows respectively. They suggest that the delta records high relative sea levels, widely identified in the Irish Sea basin (Colhoun & McCabe, 1973; McCabe *et al.*, 1984, 1987b; McCabe, 1986) and western Ireland (McCabe *et al.*, 1986; Dardis & McCabe, in preparation), developed in response to isostatic downwarping around the periphery of the last British ice sheet.

Warren (in press), while accepting a deltaic origin for the Carey valley succession, has questioned McCabe & Eyles' (1988) interpretation on the grounds that:

1. A glaciomarine origin for the Carey valley succession could not be demonstrated conclusively by them.

2. They did not address earlier glaciolacustrine models (Dwerryhouse, 1923; Charlesworth, 1939) for the Carey valley succession.

3. They did not elaborate on the regional significance of the Carey valley succession.

The origin of the Carey valley succession will remain enigmatic until the regional significance of the Carey valley water planes is resolved by more detailed field mapping in the north of Ireland. Is it a high marine limit coeval with marine deltas and washing limits found elsewhere on the coastline of Ireland (cf. Stephens, 1963; McCabe, 1986; McCabe *et al.*, 1986), or does it relate to water planes (of presumed glaciolacustrine origin) found at similar levels in the Lough Neagh basin (cf. Dardis, 1986a, 1986b)?

TIEVEBULLIAGH

Archaeology (*Jim Mallory*)

Tievebulliagh is one of the major Neolithic axe-factories of the British Isles and is certainly the most famous in Ireland. It is generally regarded as the primary source of porcellanite (Group IX) axes, the only other certain source being Brockley on Rathlin Island. The site was initially discovered by William Knowles of Ballymena.

Tievebulliagh (Fig. 1) is situated 4.5km west of Cushendall;

the mountain rises to 402m out of a high plateau covered by blanket bog. The eastern side of Tievebulliagh faces the sea and is marked by a series of screes consisting largely of dolerite, the primary material of the mountain. About midway up the east face, the lowest of three porcellanite outcrops is exposed and measures *c.* 5.5x1.7m (Fig. 36). Immediately in front of it, for a distance of *c.* 12m, is a ledge of moderate gradient covered with scree. Above this point, the slope is steeper, scree covered and littered with porcellanite flakes. These flakes are clearly the residue of axe manufacture. At the base of the mountain occur a series of hummocks of various sizes. They tend to be oval in plan-form with their long axes parallel to the base of the screes. They have been regarded as evidence of the axe factory itself, representing quarry spoil heaps associated with a lower porcellanite outcrop. However, both their appearance and the results of recent excavation suggest that they are natural features, perhaps glacial or landslip deposits. Beyond the hummocks lies an extensive bog. Porcellanite flakes can be found scattered over the entire area, including the bog, and during a short excavation in 1984 a 37kg block of porcellanite was recovered from the bog.

The manufacture of polished stone axes such as one made from porcellanite involves several different processes. The first of these is extraction. Broken pieces of porcellanite probably occurred but Neolithic miners also worked the face of the outcrop, perhaps by building fires against the rock and then applying water to cause it to fracture and break off (a technique that was employed at the Great Langdale axe-factory in Cumbria). The porcellanite was then broken into pieces of appropriate size and fashioned by flaking with quartzite hammerstones or antler hammers. These half-finished axes are known as roughouts and William Knowles claimed to have found about 4000 at the turn of the century. Such roughouts are still occasionally found in the area and attest the workings of a sizeable industry. It is essentially roughouts that are found here, not completed axes, which indicates that the final working was done elsewhere.

After the roughouts had been formed, the next stage involved the polishing of the axe. The Neolithic axe-maker would find a suitably abrasive stone, such as sandstone, and rub the roughout against this until the surface was smoothed and polished. At Culbane, Co. Londonderry, six porcellanite axes and a sandstone grinding block were found, indicating a work station for this final part of the axe-making process. The time required to make a polished axe would be of the order of several hours to a day or more. The axes were hafted to wooden handles and although only the working edge need have been polished, they are virtually always found polished over their entire surface which may suggest that

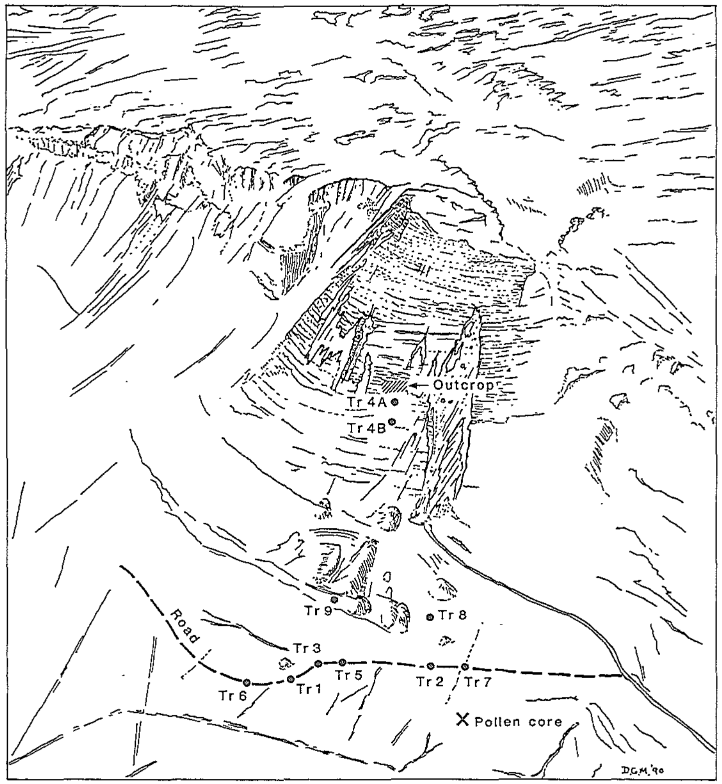

Figure 36. Excavations at Tievebulliagh in 1984.

their role in society was not just a functional one.

The only way to determine the effectiveness of a polished stone axe is to use it to chop down trees. Experiments have been carried out using polished stone axes by a number of archaeologists. For example, three Danish archaeologists, armed with polished stone axes, cleared *c.* 500m^2 of birch forest in four hours while a Russian archaeologist chopped down a pine tree measuring 25cm in diameter in *c.* 20 minutes. Highly effective at clearing the virgin forests of Ireland, these axes were one of the primary tools of the earliest farming colonists and have been found on several Neolithic settlement sites, e.g. Goodland, Lyles Hill and

Donegore Hill and in court tombs such as Ballymacaldrack and Ballymarlagh, all in Co. Antrim. Hence the main floruit for the axe-factory would be *c.* 3800-2500 years Cal. B.C. with some evidence of later use.

Porcellanite axes, originally manufactured at Tievebulliagh or on ~~Rathlin Island~~, were exported all over Ireland and Alison Sheridan of the National Museum in Edinburgh has catalogued *c.* 1400 such axes (Fig. 37; Sheridan, 1986). Moreover, 160 porcellanite axes are known from Scotland, Wales and England. Conversely, axes that were made in one of the British axe-factories are occasionally found in Ulster. In Co. Antrim, for example, axes manufactured in Great Langdale have been found at Cushendall, Portglenone and elsewhere, an axe from Craig Lwyd in North Wales was recovered from Lyles Hill, while Loughaveema also produced an axe apparently derived from Cumbria.

We are uncertain what form of exchange these axes took. If we examine the density of finds, we note that while Antrim seems almost saturated with porcellanite axes, once one moves away from the main source, the number of axes falls off dramatically (Fig. 38). Archaeologists speak of 'supply zones' to describe the area where anyone could go directly to the source of raw material and exploit it and this would seem to fit the situation in Antrim. Beyond this we move into the 'contact zone' where axes were probably obtained through some form of exchange. Alison Sheridan has proposed a fairly simple form of trade which is popularly known as 'down the line' exchange, where one community obtains a certain proportion of the axes and then passes them down the line to increasingly distant communities.

In addition to exchange of the typical porcellanite axes, there was also the movement of some axes that were probably never intended for use. These would include the axes of the Malone hoard in the Ulster Museum which are far too large to have been used by Neolithic man. These measure 20-38cm in length and they are generally interpreted as cult objects and/or symbols of wealth.

Recent archaeological work was initiated on the site in 1984 following a proposal by the landowner to put a road through the area between the foot of Tievebulliagh and the bog (Fig. 36 - broken line). The Historic Monuments and Buildings Branch funded a short excavation which was limited to assessing whether anything of importance might be destroyed by the proposed road. Although *c.* 20 crude roughouts (or roughout blanks) were discovered, no substantial evidence of *in situ* occupation was found. Charcoal removed from several trial trenches produced dates consistent with the Middle Ages and the remains of a hut that may have been associated with Mediaeval booleying activities were also found. Three areas may be of more general environmental/archaeological

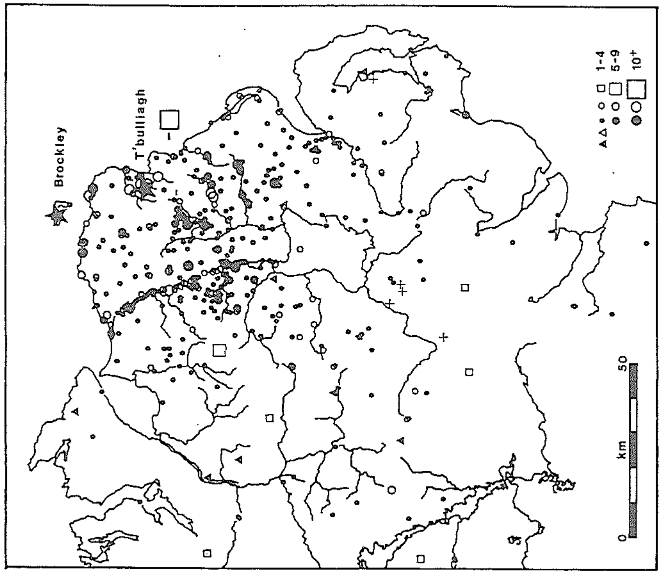

Fig. 38. Distribution of porcellanite artifacts within north-east Ireland.
Key: as Fig. 37.

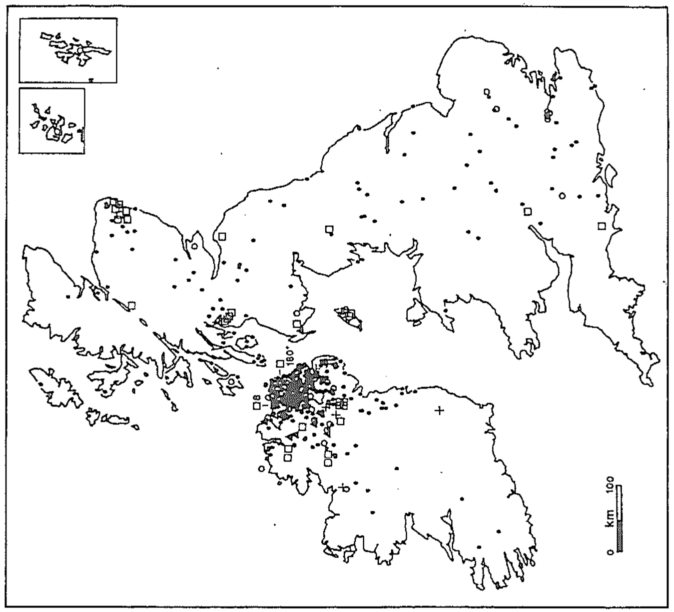

Fig. 37. The overall distribution of porcellanite artifacts.
Key: solid dot = definite identification and findspot (up to Td. or equivalent level); open circle = definite identification, findspot locality uncertain; open square = definite or possible identification, provenanced to county only; solid triangle = possible identification; open triangle = possible identification, findspot locality uncertain; cross = definite or possible identification, findspot obviously not original (e.g. loft).

interest:

Hummock (Fig. 36 - Tr.1)

The proposed roadway passed directly through one of the smallest of the hummocks at the foot of Tievebulliagh. The hummock was aligned east - west and measured *c.* 10-12x6-8m. Its western side terminated at the edge of the extensive bog that fronts the mountain. A trench 12x4m, comprising half the area of the hummock, was opened at 1m excavation intervals.

The stratigraphy of Tr. 1 is exceedingly simple. Below the sods there was a thin soil layer (Layer 1) 15-30cm thick. The soil was brown, friable and contained considerable amounts of dolerite and a number of porcellanite flakes, especially in the vicinity of a small axe-working area. Below the brown soil was a layer of orange clay (Layer 2) in which dolerite clasts continued. Porcellanite flakes were found at the junction of the brown and orange layers but disappeared after 1-2cm into the orange clay. Such hummocks have been described as evidence for quarrying of porcellanite but the opinions of geomorphologists on these features would be welcome.

Outcrop (Fig. 36 - Tr. 4A & 4B)

The porcellanite outrop visible today measures *c.* 5.5x1.7m. During the excavations a small test exploration of the outcrop was made to determine its dimensions and to discover any evidence for exploitation during the Neolithic. A trench 1m in width was opened perpendicular to the outcrop and revealed a more irregular face, than that currently exposed, with considerable evidence for flake scars and overhangs, presumably created when quarrying took place. This part of the outcrop is still visible.

The excavation revealed that the outcrop is a minimum of 4.5m in thickness and that most of this has been covered by dolerite scree. No porcellanite flakes or charcoal (which might indicate that the face was worked by first applying heat and then water) were observed and the floor of the working face is probably still deeper. In an attempt to discover the actual working floor, a small test trench was opened at the lip of the ledge *c.* 12m downslope of the outcrop. The trench was *c.* 2m deep but failed to yield any evidence of porcellanite and terminated against solid dolerite.

Depression (Fig. 36 - Tr. 8)

Upslope of the proposed road and between a series of hummocks, a peat filled depression was investigated by means of a small test trench. Ultimately, an area of $8m^2$ was opened with the following stratigraphy:

Layer 1 (0-8cm) Sods.

Layer 2 (8-15cm) Black soil and roots.

Layer 3 (15-30cm) Brown peat containing many wood fragments, with birch prominent.

Layer 4 (30-40/45cm) Dark brown silt with roots and a few flakes of both porcellanite and flint.

Layer 5 (40/45-50/55cm) Brown clay.

Layer 6 (50/55-60cm) Dolerite clasts forming a stone 'floor'. Associated with this was a thick scatter of charcoal especially in the north-east corner of the trench. This appeared to be the remains of a hearth which measured *c.* 60x40cm and was up to 8cm thick. Charcoal samples recovered from the feature were dated to 575± 70 years B.P. (1280-1450 Cal. A.D., UB-2710). Another sample from the top of the stone 'floor' yielded a date of 830±70 years B.P. (1030-1290 Cal. A.D., UB-2709).

Layer 7 (60-90cm) Orange clay.

The results of the excavation produced little new concerning the Neolithic occupation of the site but it did indicate settlement in the vicinity from the Iron Age through the Mediaeval period.

Palaeoecology (*Dave Weir*)

In conjunction with the 1984 excavations a small peat filled depression was located below the excavated areas (Fig. 36). This had a maximum diameter of 25m and a maximum depth of 90cm. The amorphous nature of the peat and the location of the basin on a slope suggests that much of the accumulation was of material being flushed downslope. Accumulation was therefore slow and the deposit covers *c.* 5000-6000 years. Whilst the deposit has an obviously low temporal resolution, its very small diameter should result in a particularly high spatial resolution.

The main pollen diagram is not reproduced here, but the early phases show a woodland dominated by hazel (*Corylus*), with levels of elm (*Ulmus*) and willow (*Salix*) at 10-12% suggesting local presence. All other trees are generally at

levels below 5% at this stage and were presumably unimportant locally. Grass (Gramineae) is present at all levels, as is a herbaceous spectra, including Ericaceae, Devil's Bit (*Succisa*), buttercups (Ranunculaceae) and Rosaceae, typical of a heathy grassland. A completely closed tree cover is thus not represented. A ^{14}C date of 3970-3700 years Cal. B.C. (UB-3079) was obtained for a sample of peat at 82-84cm. This apparently dates either the late phase of an early clearance episode, or a second episode. Elm values also drop slightly at this point, but the combination of the deposit not being deep enough, a very slow accumulation rate and lack of proper charcoal counts makes this portion of the diagram difficult to interpret.

The Neolithic and Early Bronze Age appear to be characterised by phases of activity resulting in a steady reduction of tree cover and a concomitant increase in grass and herbs. The nature of the activity is not completely clear, but certainly no large sustained clearances are evident until the Late Bronze Age. Some large grass pollen is present in each of the clearance phases, but most overlap in size with naturally occurring grasses. The herbaceous spectrum includes buttercups (Ranunculaceae), docks (*Rumex* spp.), clovers and vetches (Leguminosae) and plantains (*Plantago lanceolata*). The available evidence would suggest relatively small clearance phases, predominantly pastoral, during the period of exploitation of the porcellanite outcrop. This is apparently similar to the evidence from the Langdale area of Cumbria and is also in keeping with the archaeological evidence. The predominance of roughouts in the area, rather than finished axes, does not suggest settlement but rather intermittent exploitation.

The first major clearance is particularly interesting. Tree pollen values fall from 50% to 25% over only 1cm. A ^{14}C determination for this phase gave a result of 1130-850 years Cal. B.C. (UB-3080). Given recent speculations about the impact of Icelandic volcanic eruptions, and particularly the possibility of the collapse of Bronze Age society in the uplands due to climatic disruption following the eruption of Hekla 3 at about 1150 years B.C., this date is interesting.

According to the theory, climatic deterioration due to the eruption made habitation of the uplands (both here and throughout Britain) untenable. As a result there was a retraction of the population into the lowlands. Resulting population pressure in these areas increased the value of land, leading to an increase in warfare and hence an expansion of fortified settlements such as hillforts.

In an attempt to locate a layer of ash to act as a marker horizon, a second monolith was taken and a diagram constructed to cover this part of the deposit (Fig. 39). There are some discrepancies with the original diagram but

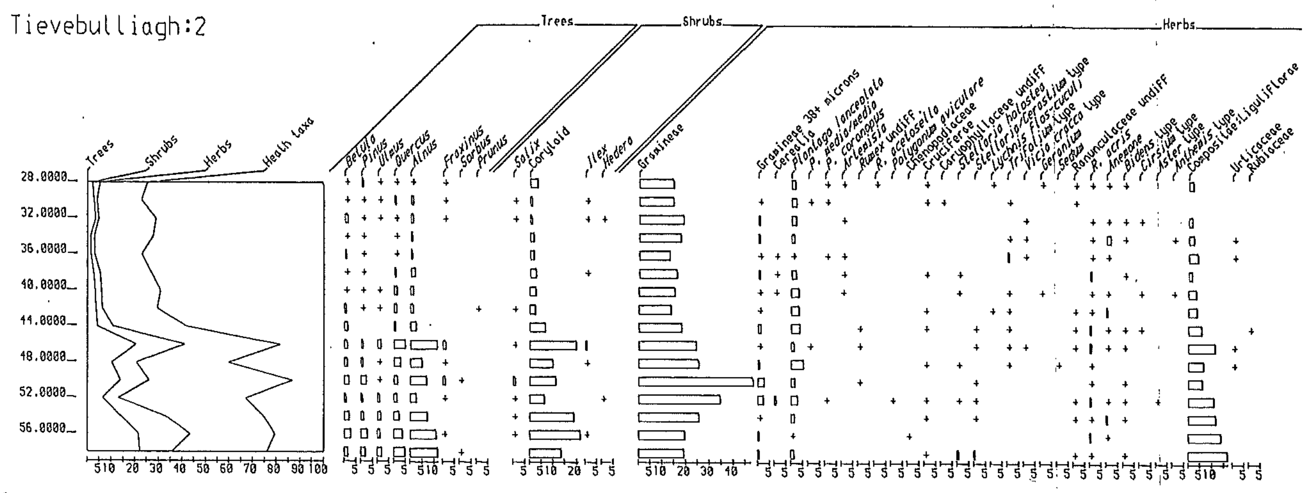

Figure 39. Pollen diagram, Tievebulliagh 2.

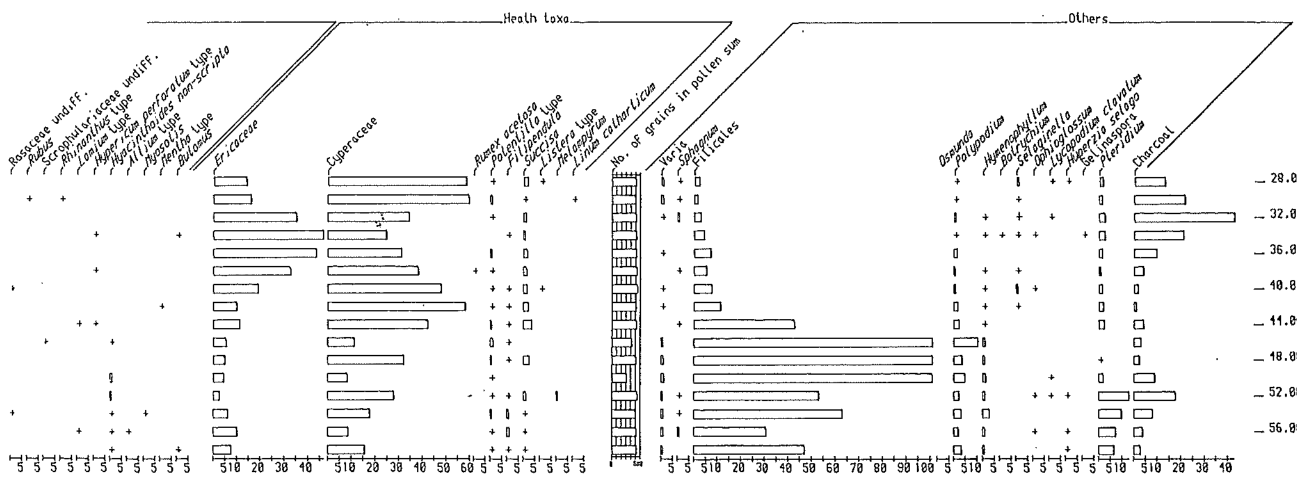

Figure 39. Continuation.

the overall pattern is similar. Tree pollen drops from 45% at 56cm to 15% at 52cm, before recovering slightly as the episode ends, and then finally dropping to 10% by 42cm as a damp heath vegetation develops. Charcoal has been counted and expressed as a percentage of the pollen sum (the charcoal values have been divided by 10 to make them fit). The presence of rather high levels of large grass pollen, but also more 'definite' cereal pollen, and of species such as Cruciferae, *Polygonum aviculare*, and *Plantago media* may suggest some arable activity, but the grassland element is still predominant. The presence of a highly ruined fieldwall system nearby may be associated with this period, and Francis (1987) obtained an almost identical date from beneath a fieldwall further to the south at Galboly Lower.

Thus, the evidence from the Antrim Plateau to-date does not appear to support a catastrophic event as causing a lasting reduction in Late Bronze Age upland population. Rather, it suggests that a major phase of activity, possibly including cereal production, is occurring in the uplands at about this time. Indeed the evidence from Haughey's Fort, Co. Armagh, beginning after *c.* 1170 years B.C., includes faunal remains of above average size and the largest carbonised grain assemblage to-date from an Irish prehistoric site. Again this is not initially suggestive of environmental constriction. The probable royal status of the site, its lowland situation, and a possible function as a redistribution centre could, however, produce such rich evidence even during a period of climatic deterioration.

The fragmentary nature of the archaeological record, magnified by the inherent errors present in ^{14}C dating, does not easily lend itself to resolution of complex scenarios like this. The location of an ash band, identified to Hekla 3, in the peat profile would provide a more reliable marker around which higher resolution pollen analysis could be based. At present Neil Rose (U.C.L.) is attempting to locate traces of volcanic ash and hopefully a result will be communicated by the time of the field meeting. It is only by this route that questions about the sequence of events at Tievebulliagh can be addressed. If located, it might indeed show that there was a sufficient lapse of time for a collapse and subsequent recovery to have occurred between the period of the eruption and the event(s) as seen in the present diagram. This level of resolution would also depend on the suitability of the deposit for higher temporal resolution pollen analysis. A deposition rate of only 1cm per 60-70 years imposes a limit of perhaps 6-7+ years per 1mm slice, but the integrity of the deposit may not support even this. Given the high spatial resolution of the site, the importance of delineating events at this time and also the floristic richness evident in the pollen diagram, this may be worth attempting.

SLIEVE-AN-ORRA (*Roy Tomlinson*)

Within the northern part of Co. Antrim, the Antrim Plateau, whose extensive surface has a general elevation of 350m, is cut in the east by deep, steep-sided glens aligned south-west to north-east. On the western side the rounded, but steeply sloping upland mass with Slieve-an-Orra as its summit (508m), has a radial drainage pattern of small, headwater streams, and is aligned north - south. The underlying rocks of the upper slopes are Lower Basalts whereas the lower slopes are of Glendun Schists of the Upper Dalradian; between these and running parallel with the road lies a narrow band of chalk (Fig. 40). Drift covers the chalk, schists and basalts. Changes in the underlying rocks bring about major variations in slope angles, as may be seen from the contour pattern (Fig. 40). North-east of the road slopes are gentle, whereas to the south-west the edge of the basalt has given a steep slope. Peat covers both solid rock and drift and has been planted extensively with Sitka spruce.

The site may be used to illustrate two forms of peat erosion:

1. Anastomosing channels - the form varies from those that are shallow, only 0.5m in depth and up to 1m in width, to deeper channels extending to bedrock. Shallow channels have little visible bare peat, the sides being overhung with living vegetation. In plan there is a network with seemingly no direction to the drainage; peat islands between the channels are quite small (1-4m^2). Deeper channels extending sometimes to bedrock, may be over 2m deep and 2-5m wide; channel sides have three clear elements: (a) overhang of living vegetation, (b) vertical free face, and (c) a constant slope. Peat islands or haggs are very small (0.5m^2 or less).

The Slieve-an-Orra National Nature Reserve was chosen to demonstrate one proposed sequence of development of anastomosing channels. These develop in a particular peat type with low, drier mounds separated by shallow, wet depressions. An outlet created in one of these depressions would lead to water movement (most evidence on hydraulic conductivity of peat suggests that water movement is restricted to only the top few cm) between depressions, linking round the low mounds. Erosion would eventually result in leaving the mounds as haggs.

The Slieve-an-Orra National Nature Reserve is in three parts: (a) a pool and hummock complex below the road, (b) a hagged/anastomosing channel area on Orra Beg, and (c) an almost completely eroded area on the summit, with only isolated haggs amongst bare rock and rubble (Fig. 41).

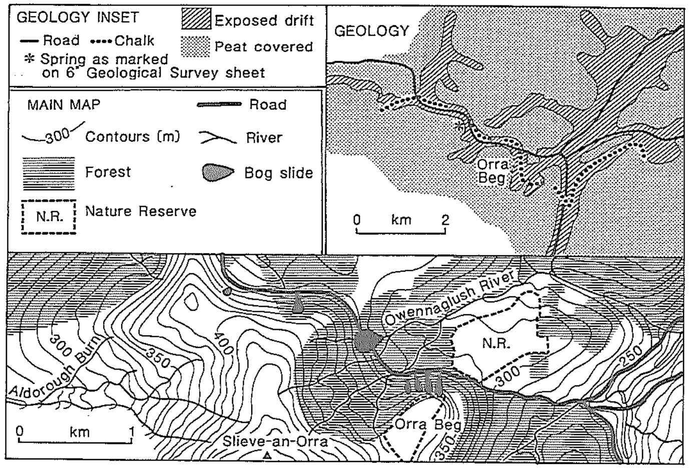

Figure 40. Geology, topography and location of bog-slides on Slieve-an-Orra.

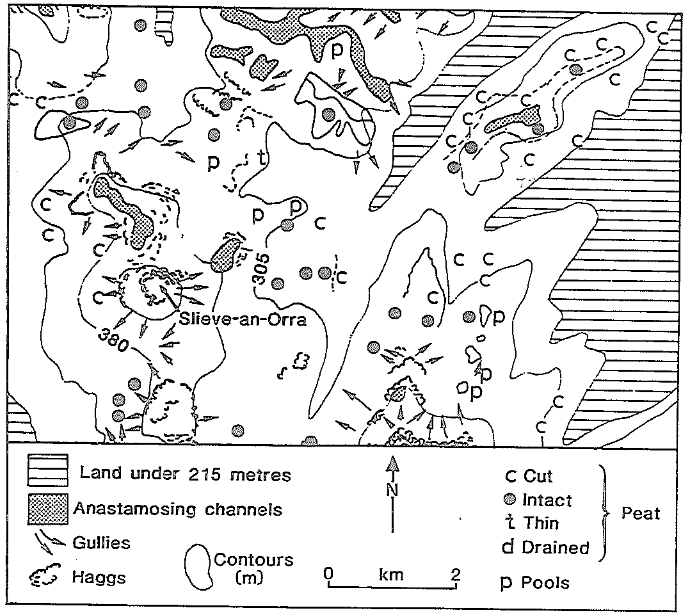

Figure 41. Features of peat erosion on Slieve-an-Orra.

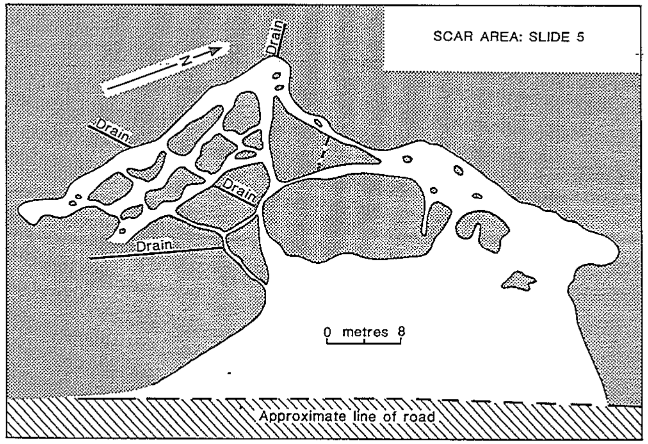

Figure 42. Detail of bog-slide scar, Slieve-an-Orra, showing positions of drainage channels.

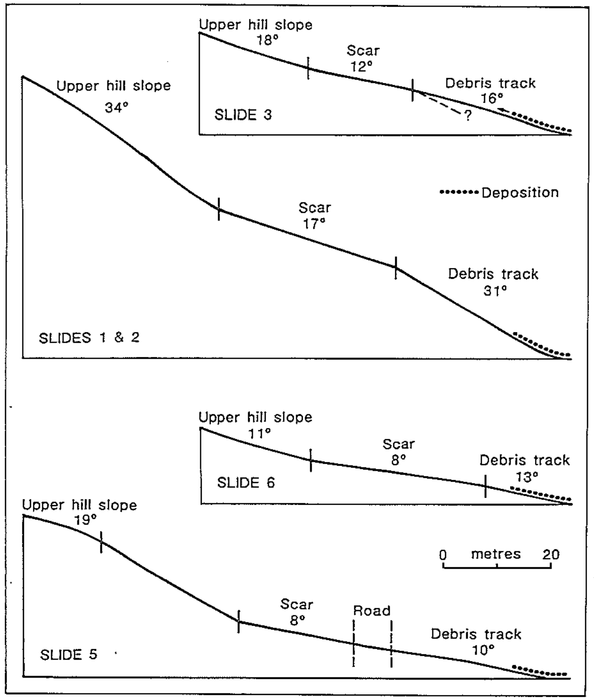

Figure 43. Profiles across bog-slides on Slieve-an-Orra.

These three parts may be thought of as sequential.

However, too little attention may have been paid in the past to the underlying topography and drainage beneath the peat. Most areas of deep peat, and with some surface patterning (low mounds, pools and hummocks), are found over pre-peat basins. These basins often have a pre-peat outlet. Is it possible, therefore, that many of the deeper channels develop from the base of the peat rather than from above? Collapse of pipes leading to the erosion of softer, less resistant *Sphagnum* peat and leaving the more fibrous hagg peat?

2. Bog-slides - on Friday 1st August 1980 an intense thunderstorm affected a tract of Co. Antrim from Ballymena in the west to Cushendun, passing over the Slieve-an-Orra hills. The trend of these hills may, through uplift, have caused even greater rainfall since that recorded on Orra Beg (97mm) was the highest 45-minute intensity rainfall ever recorded in the British Isles. One result of this event was a series of bog-slides (Fig. 40) so that this site may be used to illustrate consistent features in the occurrence of bog-slides/flows/bursts:

(a) all are products of extreme climatic events, though the rainfall history of preceding months needs to be considered.

(b) they move along a junction between materials, in this case between an impervious 'greasy' till and an overlying sandier, organic-rich till.

(c) man is also involved, here forest drains and culverts may have acted as weak points (Fig. 42).

(d) changes of slope also seem to be a pre-requisite (Fig. 43).

GARRY BOG (*Jon Pilcher & Mike Baillie*)

Garry Bog, situated just north of the town of Ballymoney (Fig. 1), is the largest raised bog in the north of Ireland. It is one of the most northerly raised bog systems in Ireland, and this position, together with its exposed character, suggest that it may form a useful record of past environmental change.

A 9m core was taken from the north of the bog during the 1970s and a relative pollen diagram was produced by Robert Larmour in the Palaeoecology Laboratory (now Centre) at Queen's University. A series of ten ^{14}C determinations, providing a timescale for the diagram, were produced in the same laboratory by Gordon Pearson (Fig. 44).

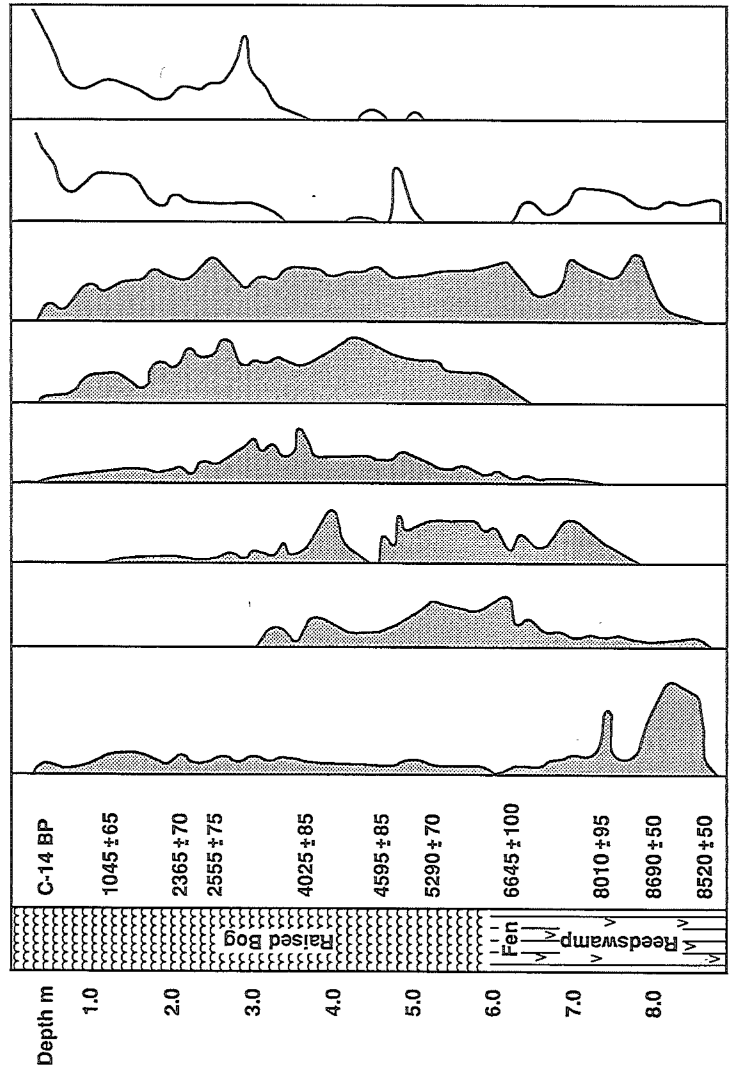

Figure 44. Garry Bog: summary pollen diagram.

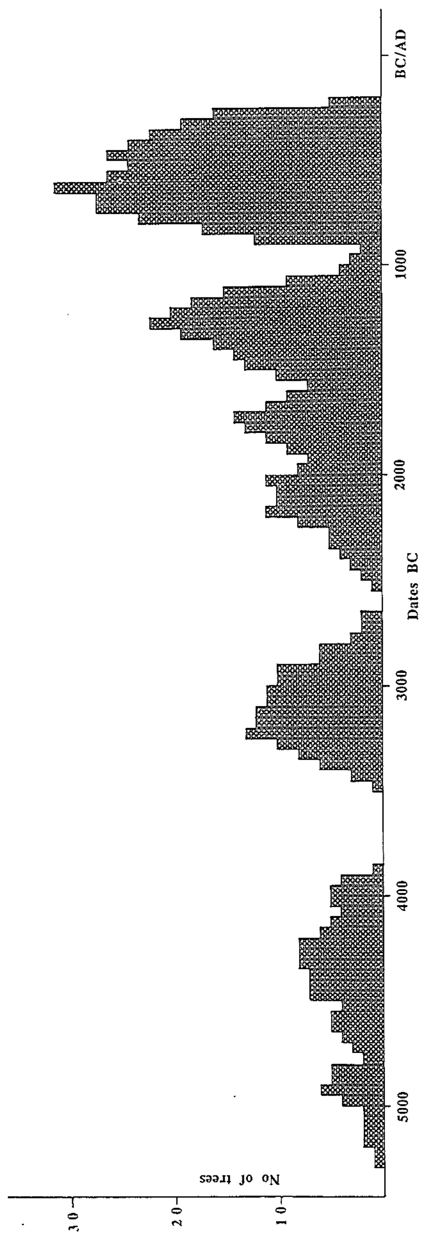

Figure 45. Garry Bog: distribution of bog oaks through time.

At the point of sampling, the diagram spans the last 8500 ^{14}C years and snows a classic succession from clay and lake mud to reed-swamp peat. Around 6650 years B.P. the reed-swamp gives way to a woody phase coincident with the arrival of alder. At 6m, around 6000 years B.P., we see the beginning of the raised bog. The profile offers a typical northern Irish pollen story. Pine is present from around 9000 years B.P. while oak and elm arrive around 8000 years B.P. The elm decline can be detected just before 5000 years B.P. and at the same point we see the first appearance of *Plantago lanceolata*. The latter, which is normally considered as an agricultural weed, is present in significant quantities (*c.* 5%) from 4000 years B.P. onwards. Another marker is the decline of pine which is normally found around 4000 years B.P. on northern diagrams. In this case pine declines at almost exactly 4000 years B.P. but, rather than disappearing at this point, it trickles on until around 3300 years B.P.

One of the most interesting aspects of the pollen story on this site lies in comparison with the parallel story offered by tree remains from the bog. Bog oaks from Garry Bog were extremely important in the construction of the long Belfast dendrochronological sequence. During the 1970s large numbers of pine boles and oak trunks were removed from the bog during agricultural reclamation. The ring patterns from these oaks were measured and cross-matched into a series of site chronologies. The exact ages of these chronologies, and their constituent trees, are now known. It is clear that Garry Bog supported growing oaks for most of the period from 5300 years B.C. to 200 years B.C. Extensive searching produced no evidence for oaks older or younger than this range. Interestingly, 5300 years B.C. equates very well with a ^{14}C age of around 6400 years B.P. So it appears that the oaks began to colonise the bog surface, as might be expected, after the reed-swamp period and with the initiation of the raised bog. It may also be significant, given the 200 years B.C. ending of the oak chronology, that there is a dramatic blip in oak pollen at around 2.3m to 2.4m which gave ^{14}C dates of 2365 ± 70 years B.P. and 2555 ± 75 years B.P.

Figure 45 represents the frequency of oak occurrence based on 163 tree-ring dated trunks from the bog. It is clear from the diagram that the frequency of oak survival, and probably therefore of original population on the bog, varies with time. One particular episode, which was noted very early in the chronology building, was the break in the 10^{th} century B.C. (there is in fact a complete break of several decades - the diagram is compiled in 50 year blocks). While there are plenty of oaks pre-1000 years B.C. and post-900 years B.C. from the bog, none could be found which span the 10^{th} century. Various hypotheses have been offered for this

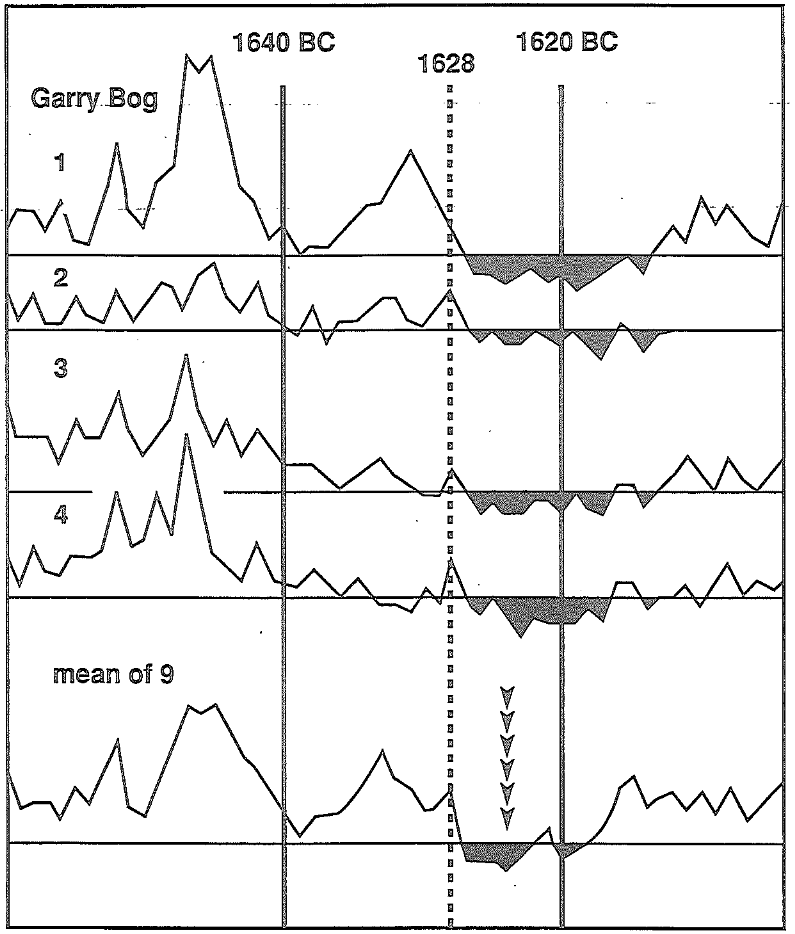

Figure 46. Bands of extremely narrow growth rings in Garry Bog oaks record the effects of a large volcanic dust veil in the 1620s B.C.

phenomenon. The two most likely are either: (a) a major storm and (b) a significant short-term rise in the water table. The arguments for (a) have been considerably strengthened recently with the 1988 hurricane in the south of England. However, other work on the climatic effects of volcanic dust veils serve to reinforce (b) - the idea of trees being affected by increased wetness. In other words we still don't know the actual cause. It is worth pointing out that chronologies from other sites both north and south of Lough Neagh also break in the 10^{th} century B.C. This problem was so severe that the tree-ring chronology was actually completed using an English oak chronology which spanned 381 years B.C. to 1155 years B.C.

The possible link between reduced growth in Irish oaks and climatic deterioration due to volcanic dust veils was first recognised in trees from Garry Bog. In 1984 an American tree-ring worker specified 1627 years B.C. as the possible date of a large volcanic eruption - possibly Santorini in the Aegean. It was noted that several Garry Bog oaks showed a narrow band of rings starting in 1628 years B.C. (Fig. 46). Further investigations showed a consistent agreement between severe reduced growth episodes in bog oaks and several other suggested prehistoric volcanoes. The Garry Bog trees also grew across, and record the effects of, the 1159 years B.C. Hekla 3 eruption in Iceland.

Figure 44 shows the Bronze Age demise of pine in the north of Ireland. This makes it impossible to construct a continuous pine tree-ring chronology anchored to the present. However, the recent upsurge in interest in past climate and environmental change has led to renewed interest in the construction of floating pine chronologies. This is further enhanced by the opportunities to produce very refined dates using high-precision ^{14}C dating. It is now possible to date consecutive samples from a tree-ring series and in effect reproduce a short section of the high-precision calibration curve as shown in Figure 47. This allows the section of chronology to be placed within about ten years in real time. So a floating pine chronology could now be 'dated' with a high degree of refinement. Unlike the oaks which were mostly unstratified, the south-west edge of the bog boasts a continuous 'forest floor' of pine stumps which should offer an interesting insight into the colonisation, succession and demise of a bog-pine population. Currently, David Brown is developing a study of pines from the bog at the Palaeoecology Centre.

N.B. A.D./B.C. are calendar dates derived from dendrochronology, B.P. dates are based on raw ^{14}C determinations, calibrated ^{14}C dates are designated Cal A.D. or Cal B.C.

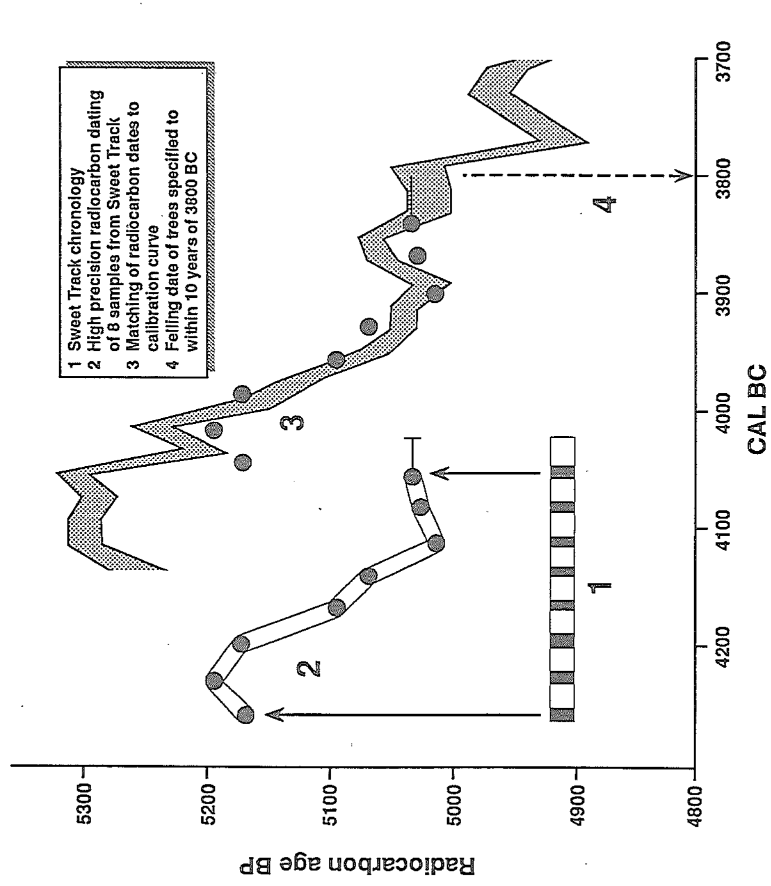

Figure 47. High-precision wiggle match dating of the Sweet Track (Somerset) chronology. A short section of calibration is reproduced and fitted to the original curve.

VOW (George Dardis)

A hummocky moraine complex, orientated parallel to drumlins, occupies the central portion of the Bann valley (Creighton, 1974). Ridges within the complex are not well exposed. A gravel pit at Vow (Fig. 4), at the northern end of the moraine complex, shows a glaciolacustrine delta, with planar bedded sands overlain by a gravel foreset-toeset sequence, interbedded with thick sequences of glaciolacustrine rhythmites.

The gravel units within the foreset-toeset sequence (Fig. 48) are generally orientated northward, are steeply dipping (5-25°), and are sedimentologically complex. The basal portions of the foresets consist of multiple sets of avalanche-front cross-stratification, with occasional interbedded mud units (Fig. 49). These grade up into foresets consisting of nested sediment gravity flows interbedded with thin (5cm) mud laminae (Fig. 50). Thick beds of rhythmites with multiple sand-clay couplets occur at major reactivation surfaces (cf. McCabe & Jones, 1977; Cohen, 1979) within the foresets (Fig. 51). Sand layers are highly variable in thickness (up to 5cm), while mud layers are generally uniform in thickness (1cm). These thick rhythmite sequences were deposited on the pro-delta palaeoslope; consequently bedding style (Fig. 51) conforms to the overall dip of the gravel foresets, and the rhythmites do not appear to have undergone post-depositional remobilisation. The upper part of the foreset-toeset sequence consists of low-angle gravels and planar cross-stratification (Fig. 48), showing an increase up-sequence of interbedded mud units (Fig. 52).

The general sequence, characterised by juxtaposed gravel foresets and distal mud drapes, represents deposition in rapidly alternating high and low energy environments. Facies associations of this type are not unusual and may reflect fluctuating or floating meltwater efflux, caused by a number of factors (e.g. seasonality, proglacial channel avulsion, closure of subglacial conduits, etc.). The extremely high concentrations of rhythmites in these sediments and in neighbouring areas (e.g. Aghadowey; Creighton, 1974), suggests high sediment yield within a relatively small proglacial lake basin, with regression of rhythmites onto proximal pro-delta slope environments, and supports the view that this occurred in an inter-lobate glaciolacustrine environment, between Scottish and Irish ice masses (Creighton, 1974).

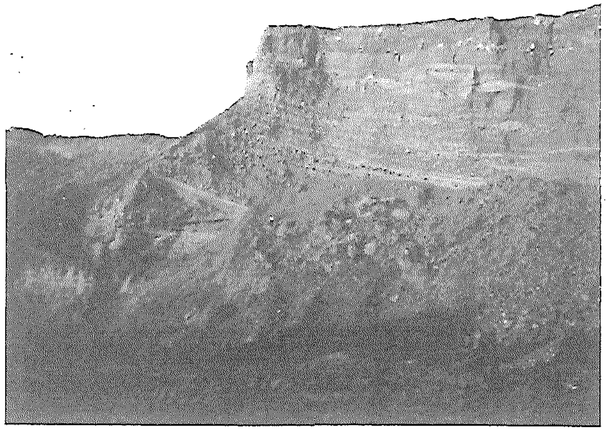

Figure 48. Gravel foresets, Vow.

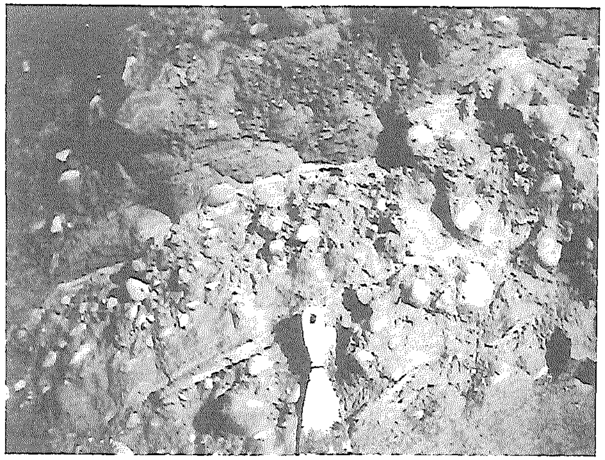

Figure 49. Interbedded cohesionless debris flows, avalanche-front cross-stratification and fine-grained rhythmites, Vow.

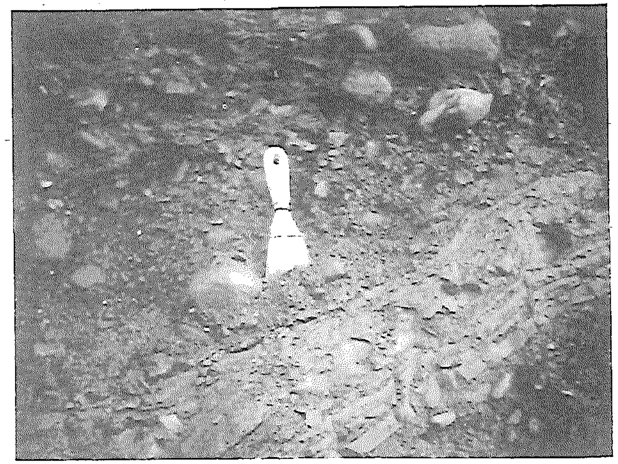

Figure 50. Rhythmite layers within the gravel foresets, Vow.

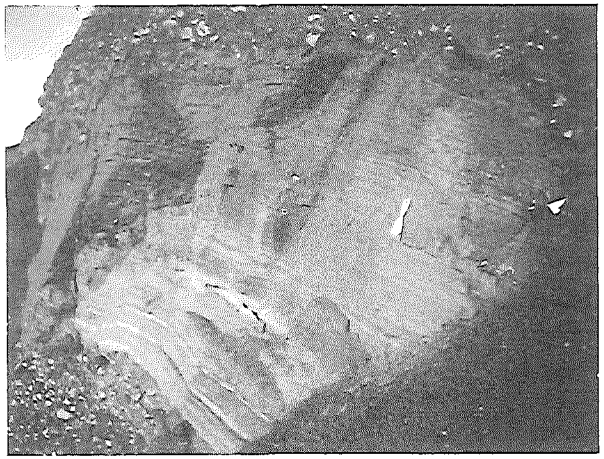

Figure 51. Rhythmite sequence within the foreset-toeset sequence, Vow.

Figure 52. Interbedded gravels and fines, upper part of the foreset-toeset sequence, Vow.

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