AN BOIREANN

THE BURREN

IQUA

Teoir Allamuigh Uimhir 15

Field Guide No. 15

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arna chur in eagar ag/edited by

William P. Warren

agus/and

Michael O'Connell

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Cumann Staidéar Rí Cheatharta na hÉirann

Irish Association for Quaternary Studies

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This fieldguide has been compiled on behalf of IQUA by W.P. Warren based on a fieldtrip to the Burren (2nd to 4th October 1992) which was organised and run by M. O'Connell and W.P. Warren.

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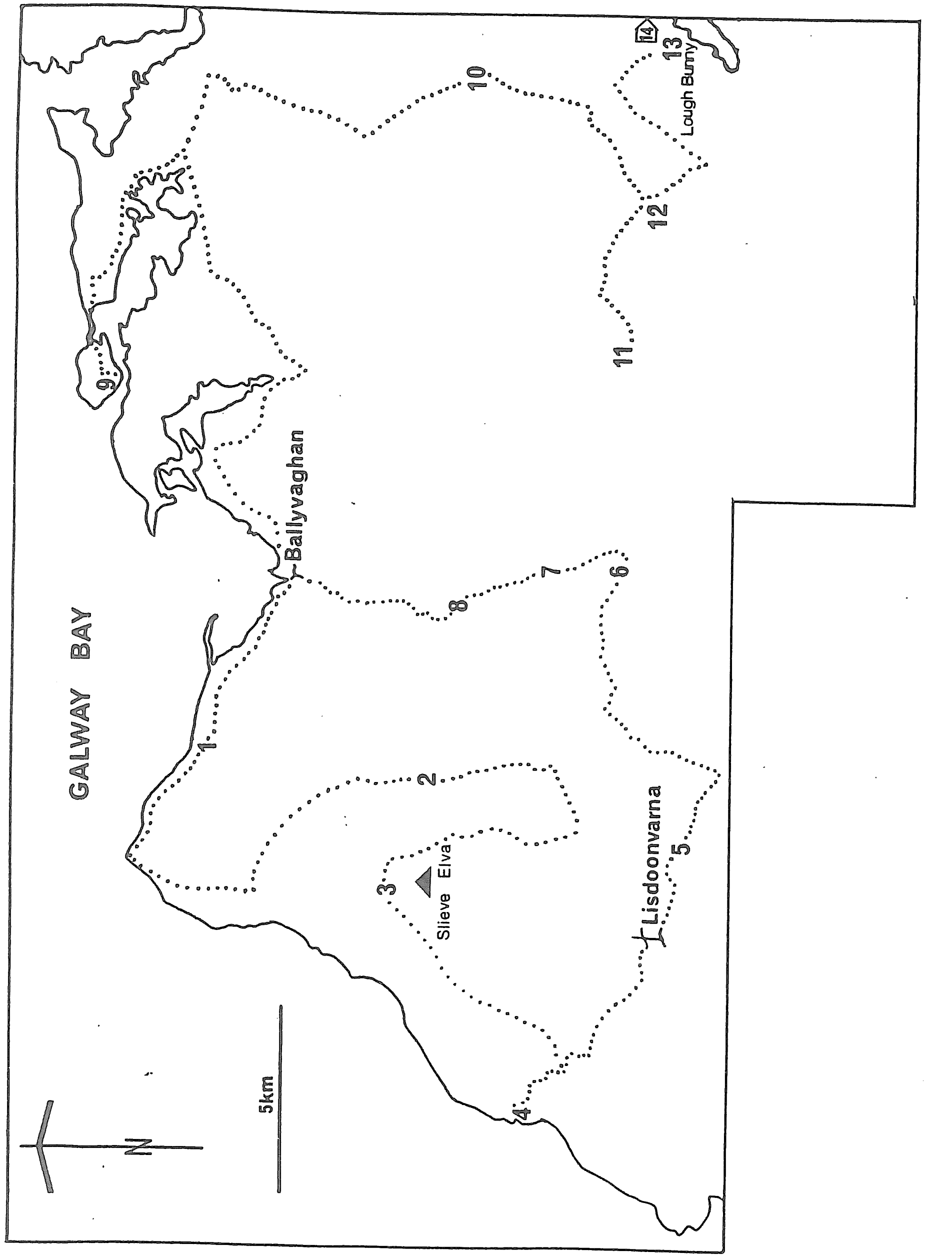


Figure 1. Map showing excursion route and study sites.

INTRODUCTION

GENERAL (W.P.W.)

The Burren (from the Gaelic boireann - a rocky district) is primarily a geological phenomenon. It owes its specific character to the extensive outcrops of karstified limestone, the scatter of glacial erratics, patches of often drumlinised glacial sediment and remnant tracts of shale overlying the limestone. From these follow the topographical expression, the archaeological remains and the characteristic flora.

This guide provides a simple introduction to the Quaternary geology and geomorphology, the archaeology and the palaeocolocy of the Burren. Because the Burren does not define an administrative area its boundaries are somewhat indefinite. For the purposes of this guide it is taken as an area about 450km^2 in extent covering the northern part of County Clare on a small part of County Galway. Its western margin is defined by the coast from Black Head to Doolin, the northern boundary is the southern coast of Galway Bay and the southern and eastern margins of Figure 1 approximate the remaining borders of the area. This definition of the area of the Burren has no validity beyond the convenience of a field excursion. Other definitions may be more or less extensive, and the more restrictive definitions (e.g. Drew, 1990) are probably closer to traditional understanding.

GEOLOGY

Bedrock (W.P.W. and D.D.)

No detailed treatment of the bedrock geology of the Burren has been published since the middle of the last century (Foot, 1863). Modern reference to the geology of the area usually refers to the unpublished work of Conor V. MacDermot of the Geological Survey of Ireland (e.g. Drew, 1990).

The Burren is underlain primarily by Carboniferous limestone but also by Carboniferous (Namurian) shales and sandstones which overlie the limestone on the southern margins of the area. One salient of Namurian strata extends northwest to include Slieve Elva and a large outlier of Namurian shale occurs around Poulacapple (Figure 2).

Two lithologies of Brigantian and Asbian age dominate the Visaian limestone of the remainder of the area. In general these limestones are well bedded and jointed although there are thick sequences of poorly bedded and jointed limestone below the upper Asbian. The Brigantian limestones contain extensive chert layers and the upper Asbian limestones are characterised by shale interbeds which give rise to a characteristic terraced and cliffed topography over a large part of the Burren.

In general the rocks of the Burren dip gently southwards but in the southeastern part of the district a series of alternating northeast-southwest striking anticlines and synclines is seen. Mullaghmore provides an excellent section through one of the synclines.

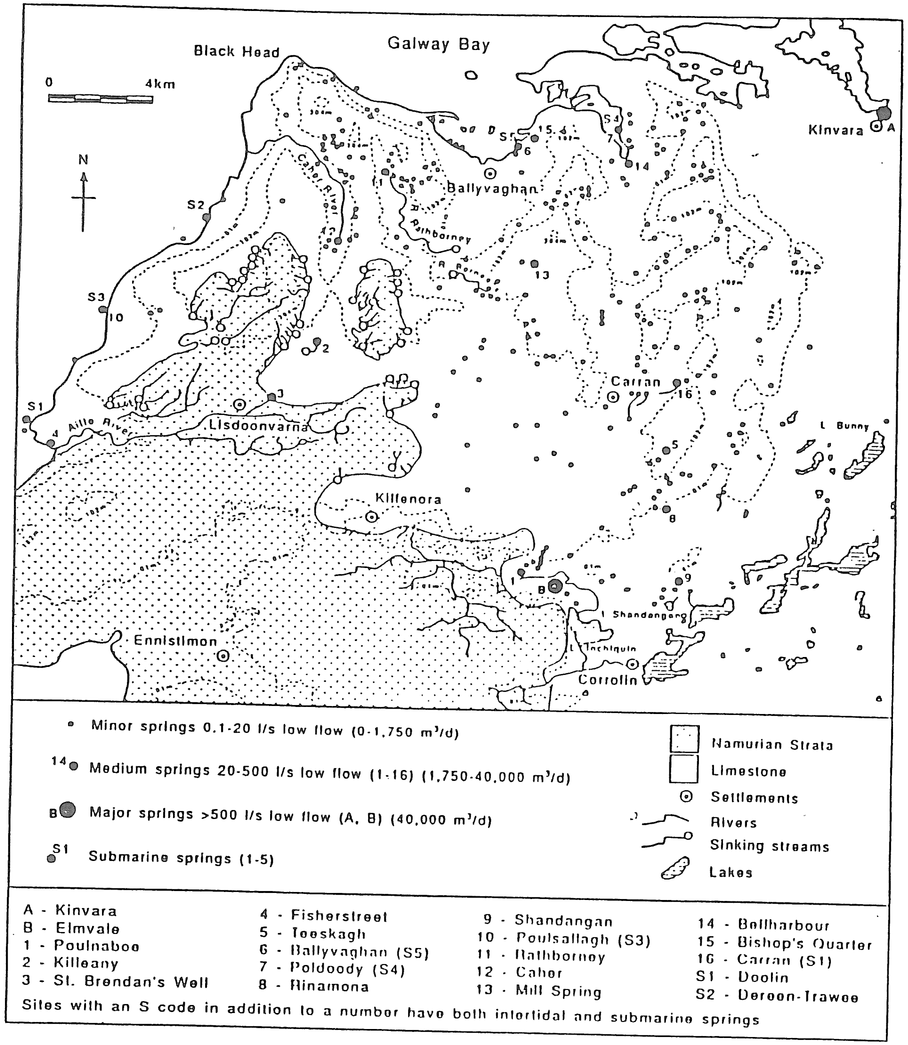


Figure 2. Bedrock geology and hydrology of the Burren.

Glaciation (W.P.W.)

All of the specific indicators of direction of ice movement in north Clare (drumlins and striae) indicate that the most recent ice to move over the area came from the northeast (Figure 3). This indeed is consistent with the regional pattern in general and with the overall pattern of ice movement in Ireland during the most recent (Fenitian) glaciation (Warren, 1993). This direction is consistent with the very high Carboniferous Limestone content in the glacial deposits of the Burren, where far-travelled erratics of other lithologies are rare. Galway granite erratics are rare but nevertheless are widespread. As a distinctive lithology they are easily picked out in till and other exposures but do not generally show in counts of 200-400 clasts.

The widespread, albeit sparse, distribution of these erratics indicates that earlier ice extended from or across Connemara and crossed the Burren. Farrington (1959; 1965) suggested that this occurred during an earlier glaciation but there is no clear evidence that this was the case.

The Burren is characterised by its extensive bare rock surfaces. Glacial sediments are patchy (Figure 4) and, where they occur, they are frequently drumlinised. Farrington (1965) suggested that there had been extensive postglacial erosion of the patchy till of the Burren, but that extensive areas had never been covered by glacial sediments. It is probably that Farrington overestimated the amount of postglacial erosion of glacial sediments given that the process he envisaged was essentially insitu weathering and the mechanical removal of only a small noncalcareous residue.

When viewed in a broader context we can see the Burren as a southern extension of the bare rock surfaces of Connemara where there is no indication whatever of a former sediment cover and where postglacial erosion is even more unlikely.

The general northeast to southwest ice movement has left a very firm imprint on the land surface. Not only do the drumlins and striae generally conform to this orientation, the limestone bedrock (particularly in the eastern Burren) has been moulded to form rock drumlins and larger streamlined hills. Lake basins and whatever surface drainage there is in the eastern part of the area also trend in this direction.

Overall, the Burren owes its present character, a largely bare limestone rock surface peppered with limestone boulders, to glacial erosion. Ice extending from a source east of Galway city extended southwestward as a substantial ice sheet scoured any surface cover there was, moulded the bedrock and deposited patches of mainly drumlinised till chiefly on lower ground and in pockets. The deposits around Poll Salach are an exception an probably represent basal dragging under a zone of extensional ice where ice moved off the Slieve Elva escarpment.

During deglaciation very little sediment seems to have been deposited in the area and this is not surprising. The contrasting situation in the central midlands reflects deposition into a very poorly drained area which was largely lake covered during deglaciation. Thus there was an ideal trap for the huge volumes of sediment that was washed out of the retreating ice sheets. Ice retreating from the Burren area on the other hand had a very different hydrological regime. Firstly, Galway Bay provided a ready escape route for any meltwater that emerged from the ice and secondly an open karstic substrate coupled with low relative sea level would

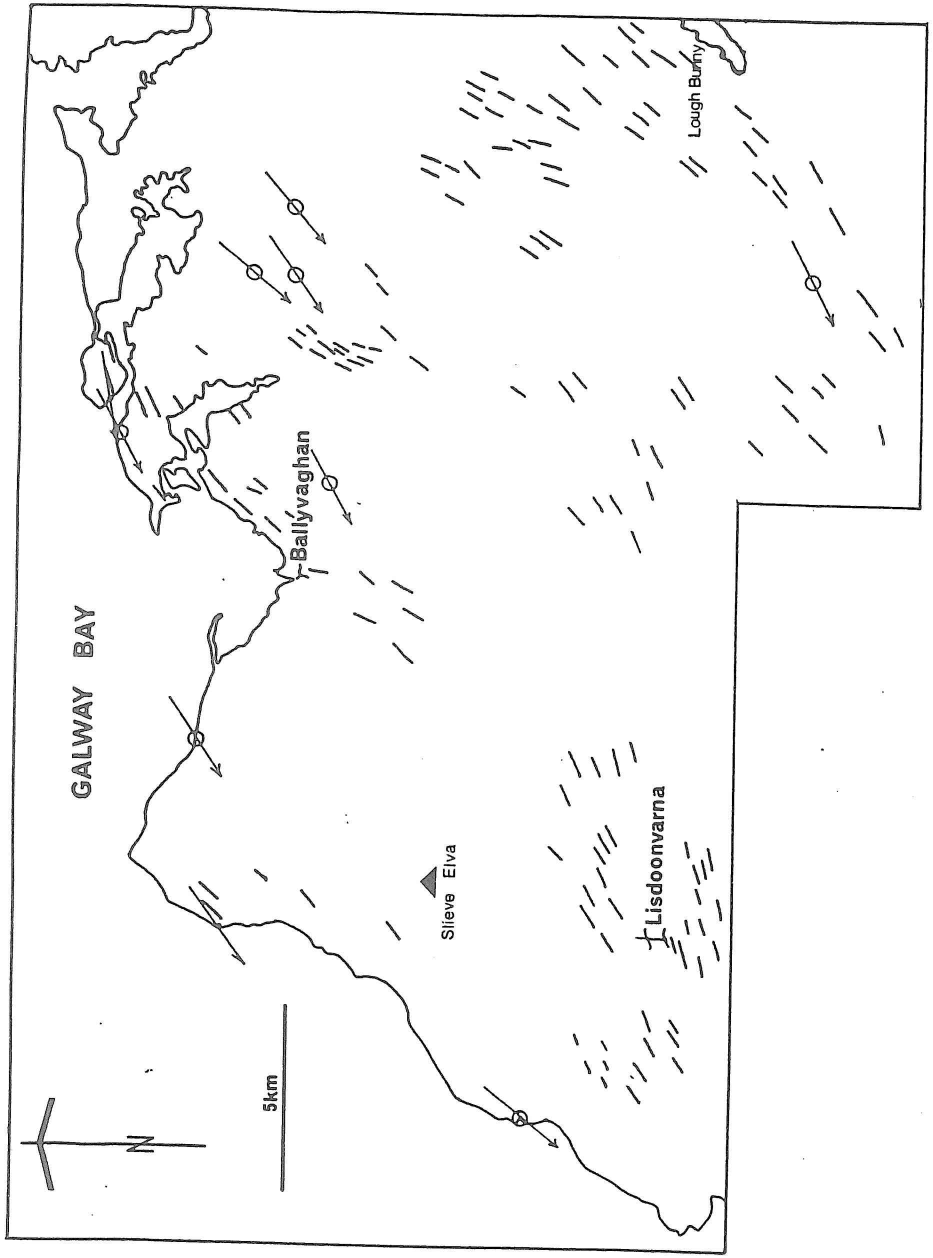


Figure 3. Distribution pattern and orientation of drumlins and striae in the Burren.

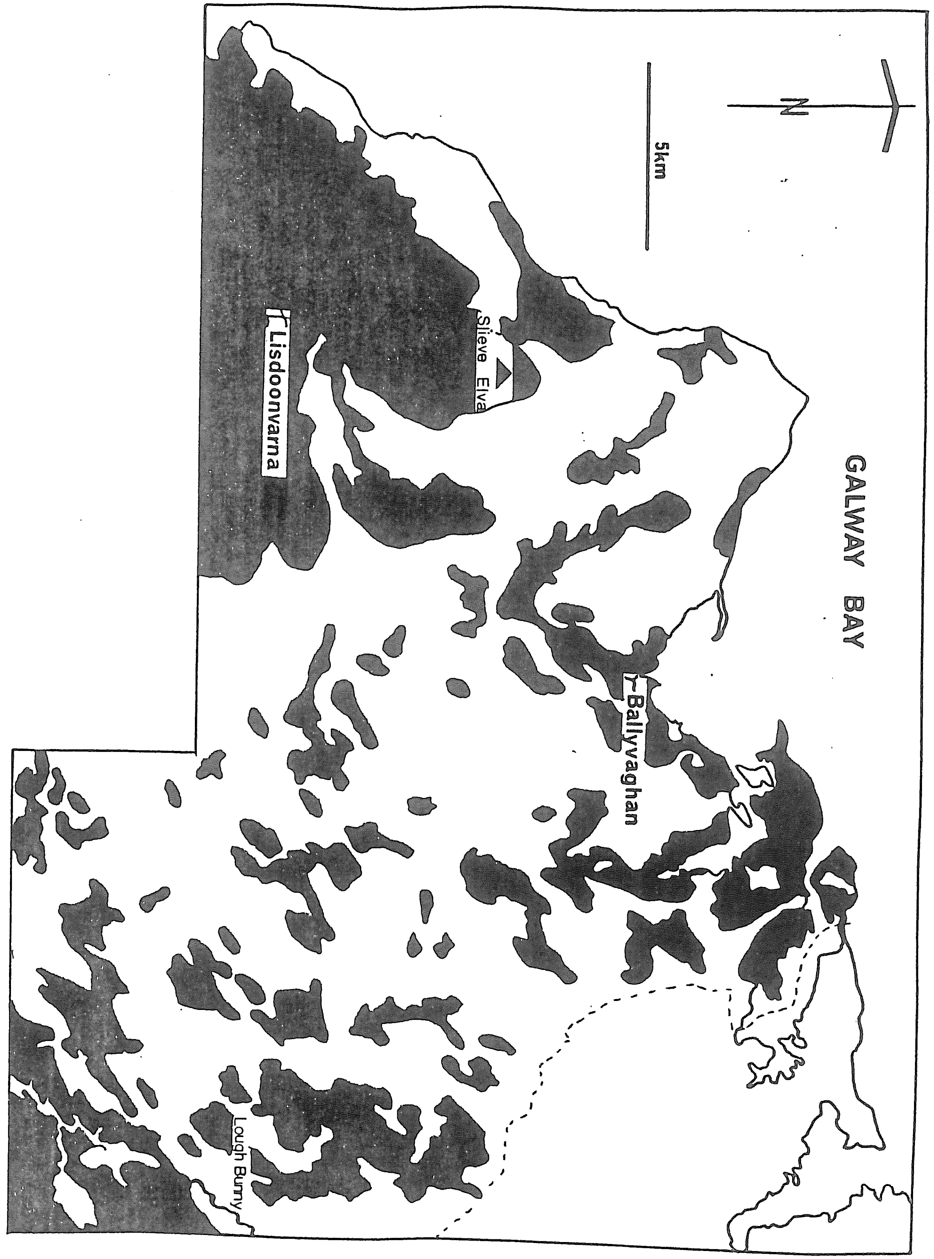


Figure 4. Distribution of glacial deposits in the Burren.

have ensured that much of the glacial meltwater escaped through conduits in the underlying limestone. This would have had implications not only for the disposal of sediment from the ice, but indeed for the movement of the ice over the substrate and the entrainment and carriage of debris. Grinding of bedrock and movement of sediment at the rock/ice interface would have been greatly curtailed by the general absence of water and it is likely that the ice was relatively clean. Thus as it backwasted the ice deposited only a scattering of cobbles and boulders to add to sparse subglacially deposited sediment.

The nearest site providing any stratigraphic information of importance is at Boleyneendorrish near Gort, where disturbed interglacial muds underly glacial sediments. Close by, Farrington (1959) recognised two distinct till facies, a lower one of probable northwestern provenance and an upper one of probable northeastern provenance. The position of the interglacial deposit in relation to these sediments in unknown. There is, for example, no reason to favour an interpretation involving two glaciations over one that involves a change in direction of ice movement during one glaciation.

It is reasonable to infer that the upper till facies, at Bolyneendorrish is a rough correlative of the glacial sediments of the Burren area. There is no direct evidence in the Burren of an ice movement from the north or northwest but the general scatter of sparse Galway granite erratics suggests that earlier deposits relating to such an ice movement may have been reworked during the final ice movement that left its unambiguous mark on the landscape.

Soils (W.P.W.)

The characteristic soils of the Burren (cf, Finch, 1971) are the rendzinas which have generally formed directly on the limestone rock surface. Gley soils and peat are commonest on the Namurian rocks and the tills overlying them while brown earths and grey brown podozolies characterise the glacial sediments which overlie the limestone. Some gleys have also developed on the less well drained limestone till.

The Caves of the Burren (D.D.)

The caves of the Burren, in themselves a reflection of past and present hydrogeological conditions, have been controlled in their origin and evolution by three main factors:

1. Geological controls: in particular the dip of the strata, the joint systems and the presence of relatively impermeable layers such as chert or shales within the limestone sequence.

2. The degree to which runoff is concentrated prior to sinking underground - such concentration into streams occurs on impermeable terrain such as the Namurian strata in the west of the Burren and to a lesser extent on some glacial deposits.

3. Modification of karstic processes by other factors, for example, the effects of changes in base level, or the effects of glacial erosion and deposition.

The present day base level for much of the Burren plateau is the upper part of the valley of the Fergus River between Corrofin and Kilfenona. Some 60% of the runoff from the plateau is discharged from springs in this area. Much of the remainder of the Burren water discharges via coastal or submarine springs.

Figure 2 above shows the sinking streams and springs of the Burren. The concentration of sinking streams around the margins of the Namurian strata (particularly the hills of Slieve Elva and Poulacapple) is very apparent. Associated with these sinking streams is a series of river caves mainly developed in the north-south jointing systems and oriented north-south down-dip. Such caves are commonly developed within a single bedding plane for long distances, occasionally stepping down one or more bed via a vertical drop. The vertical location of these cave conduits is often determined by the presence of chert-rich zones within the uppermost beds of the Brigantian limestones, which appear to constrain the vertical movement of water.

The passage morphology of these caves typically comprises a wide, low roof section of enlarged bedding plane incised by a narrow trench or canyon which contains the stream. The trench is typically 0.3-3m wide by may be up to 30m deep. Passage cross-sections are therefore typically T - shaped. The roof section of passage is of phreatic origin whilst the trench has been cut under vadose conditions.

Three types of active stream cave may be recognised:

1. Simple, single stream conduits in which the morphology and dimensions of the cave passage are obviously related to the present day stream e.g. Poll Dubh.

2. Stream caves with abandoned (dry) sections of passage, oxbows, offset meander belts at different heights above the active stream route, appreciable deposition of calcite speleothems and fossils allogenic sediments, sometimes undergoing re-excavation. Pollnagollum and to some extent the Cullaun series of caves are examples of this type.
3. Caves of type (1) or (2) which have intersected reaches of apparently much older, now fossil cave systems. Such "older" caves are often characterised by a circular or oval passage cross-section suggesting a wholly phreatic origin and by extensive fill deposits. Faunarooska and Pollballiny caves are examples of polycyclic caves.

The age of the Burren caves has not been thoroughly investigated but limited evidence from Uranium -Thorium dating of calcite specimens suggests that Type (1) caves may be Holocene age, Type (2) caves may be originate from, at least, last Interglacial times (in Pollnagollum cave calcite from the lowest, active, stream canyon has been dated to 10,000-3,200 BP whilst in the upper canyon dates 70,000 BP. The segments of old passage invaded by modern caves streams are of unknown age through calcite from a passage of similar morphology in Aillwee Cave in the central Burren has been dated at 150,000 BP.

Caves of these various types may be found in near proximity; for example, the caves listed above are all located on Slieve Elva.

Those parts of the central and eastern Burren that are distant from the present day outcrop of the Namurian strata are very different in morphology from the active stream caves. Although a shale cover must have existed in various parts of the central and eastern Burren until comparatively recent times, no cave systems associated with such conditions have yet been discovered. The region is characterised by an absence of sinking streams and a plethora of small springs. The majority of these springs are small seepages of water that sink underground once more within a short distance and are the consequence of glacial derangement of the ground water flow system. There is little apparent relationship between the known caves of the area and the present day hydrology. Phreatic passage forms are predominant implying a sub-watertable origin for the caves. Sediment infills are widespread ranging in type from complex bedded sequences of fines (e.g. Pol-an-Ionain cave, Aillwee Cave) to extensive sand deposits of unknown provenance (e.g. Glencurran Cave).

Speleothem dates from caves of the central Burren fall into three groups: 5,000-9,000 BP (6 samples), 40,000-42,000 BP (3 samples) and >350,000 BP (2 samples). In all these instances the dates relate to an episode of calcite deposition rather than providing an indication of age for the cave itself).

PALAEOECOLOGY (M. O'C)

The Burren, has long been noted for its classic glacio-karstic features, its unusual flora and vegetation and dense concentration of archaeological field monuments, especially megaliths, ringforts and medieval castles. Reconstruction of past environments in this highly karstified terrain with its patchy and often non-existent soil cover, scarcity of bogs, and surface waters largely confined to seasonal lakes or turloughs, has presented a particular challenge to the palaeoecologist. Indeed, the scarcity of material suitable for palaeoecological research has acted as a deterrent to such investigations.

The earliest palaeoecological investigations from the Burren are those of Watts (1963) relating to the late-glacial period. In his 1963 publication, Watts presents two pollen profiles: Gortalecka, nr. Mullaghmore and Lough Goller, 2 km south of Lisdoonvarna, which lies in the shale region and hence outside the Burren proper. The latter profile, together with a profile from Poulroe, a site due west of Gort in the eastern Burren lowlands, is also presented in Watts' (1977) review paper on the Irish late-glacial.

With regard to the Holocene, four diagrams are available from the southern part of the Burren: three from the Mullach Mór area (Feighan 1985; Watts 1984) and one profile from the Carron depression (Crabtree 1982). The diagrams from the Mullach Mór area, in particular, contain a valuable record of vegetation development and the impact of past human activity, as well as providing information on the history of certain typically Burren species such as *Potentilla fruticose* (Watts 1984). They show that, at least in the south-east Burren, the present vegetation with its abundance of species such as *Dryas octopetala* and *P. fruticose* and its sparse cover of woody vegetation, is a development of the historical period, i.e. post A.D. 400 (Watts 1984; see also Watts, this volume).

A recently completed study in the north-western Burren has provided a record of vegetation and land-use in the Poulacapple area that extends back over 3000 years (Jeličić 1991; Jeličić and O'Connell 1992; and this volume). The results show that, apart from two short periods, the north-west Burren had a vegetation cover largely comparable to that of today.

Other investigations that have yielded evidence of past tree and shrub cover include macrofossil analyses carried out in the context of archaeological excavations (e.g. Cotter 1993; Hencken 1938). Unfortunately, the Poulnabrone site, recently excavated by A. Lynch (see this volume), failed to yield either pollen or macrofossil evidence of the early prehistoric environment.

THE ARCHAEOLOGICAL RECORD (P.G.)

Despite the number, and degree of preservation, of archaeological monuments of all ages which grace the landscapes of the Burren, archaeological research on this region, though by no means insignificant, has been sporadic, disparate and uneven. This is particularly evident in the general absence, until recently, of any overview of the archaeology of the Burren as a whole.

Thomas J. Westropp published a series of seminal field reports from the Burren between 1894-1917, principally in the pages of the *Journal of the Royal Society of Antiquaries of Ireland*. Though packed with detail on individual monuments, Westropp's work generally eschewed an analytical approach, and his interpretation of monuments is, in many cases, now obsolete. Contemporary work on coastal middens by Brunicardi (1914), though it produced a lean harvest, did draw attention to the maritime aspects of the Burren's archaeology. Following in their footsteps, de Valera and Ó Nualláin (1961) have provided us with a detailed record of the megalithic tombs of the region. Their short commentary on the morphology and distribution of the Burren's wedge tombs is particularly useful in providing background information on the past and present topography of the region.

For later periods, Rynne's work on the Iron Age in Co. Clare (1982) also touched on the Burren, and Sheehan (1982) has compiled a list of early ecclesiastical sites in the region as part of a useful discussion of the distribution of these monuments. Finally, there is Robinson's (1977) excellent map of these uplands which illustrates the potential rewards of a holistic and interdisciplinary approach to the archaeology of this unique landscape.

Apart from some early work by Westropp (1909), it has been the work of palaeo-environmentalists (Crabtree 1982; Drew 1982; Plunkett Dillon 1983 and Watts 1984), that has paved the way in unravelling the human settlement history of the Burren.

However, when coupled with Sheehan's work (1982), the recently published archaeological reviews by Waddell (1990) and the present writer (Gosling 1991a and b), do provide the outline of a modern archaeological overview of the region.

Eight archaeological excavations have so far been conducted in the Burren (Cotter 1989; Gibson 1985, 1986; Hencken 1935 and 1938; Lynch 1988; Ó Drisceoil 1988; Rynne 1968). However, three of these, by Rynne, Lynch and Cotter were rescue excavations, prompted by natural and human agencies which threatened a house site, megalithic tomb and "mound", respectively. Gibson's work is part of an American research programme entitled the "Chiefdoms of County Clare Project", but neither it, nor Lynch's nor Ó Drisceoil's work has as yet been fully published. The two remaining excavations, at Poulawack and *Cathair*

Archaeological Expedition in Ireland (c. 1932-6). This pioneering project consisted of the excavation of a range of monuments in order to elucidate current problems of Ireland's archaeology, then still in its infancy as an academic discipline.

Though concerned solely with presenting excavation results, Hencken's reports on the Harvard Expedition's work at Poulawack (1935) and *Cathair Chomáin* (1938), contain a wealth of information on the settlement history of the region. When taken in conjunction with the preliminary results of Lynch's work on the portal tomb at Poulnabrone (1988), they provide us with a framework on which to base a discussion of the Neolithic and Bronze Ages, as well as the Early Historic Period, in the Burren. Furthermore, the pools of light which these excavations shed on the recesses of the Burren's past indicate the existence of stable prehistoric and historic communities there: communities with sophisticated belief systems, material surpluses, and long traditions of association with this "rocky place".

FIELD EXCURSION

Site 1. RINE POINT, MARINE SPIT, M205 100 (R.W.G.C., V.M. and G.P.)

Rine Point is a 2 km long gravel spit on the west flank of Ballyvaughan bay. Access to the site is by a track leading from the R477 road at M206096 and running down to the proximal (attachment) point of the spit. The spit shows excellent examples of sediment sorting and grading as well as geomorphological features such as coarse washovers and small cell structures (Fig. 5).

It is important to view Rine Point within the context of sea-level rise and the general coastal evolution of Galway Bay and the limestone coast of the Burren in particular.

Galway Bay was progressively submerged by the late-Pleistocene and early-Holocene rise in sea-level (Carter *et al.*,1989). Although very little is known about Galway Bay (and for that matter sea level changes in general on western Irish seaboard) it is clear that Galway Bay occupies an intermediate location between the relatively rapidly rising sea-levels of the south and southwest coasts and the stationary or even falling sea-levels in the northwest of the country.

The exact course of Holocene history in Galway Bay unknown; indeed the carbonate environment does not favour widespread sediment deposition (the basal Holocene sediment unit on the floor of the Bay is only a few tens of centimetres thick) (Keary and Keegan, 1978) so that conventional siliclastic sequences are absent (Bertois *et al.*, 1972). But it is unlikely that mean sea-level ever rose above the present level, at least not by more than a few centimetres. (Two rather enigmatic ^{14}C dates have been obtained from the north side of the bay, both indicating a late-Holocene sea-level 5 to 15 m above present. However these uncalibrated dates of 3210 ± 110 (Gif 2667) from Knockagoneen Cliff (M300245) and 2560 ± 110 (Gif-2668) from Seaweed Point (M257229) (Delibrias and Guillier, 1988, p92) may have been taken from Neolithic or early Bronze Age oyster shell middens, and thus have no direct relationship to sea level *per se*.). [Note that coordinates given by Delibrias and Guillier (1988) for these sites are incorrect.]

As sea-level rose into Galway Bay it is likely it would have been accompanied by increasing levels of wave energy as the "windows" between the Aran Islands and the mainland opened and deepened. At some point in time the wave energy would have been sufficient to initiate erosion and transport of the coastal materials. The sediment source for the Rine Point spit comes from a glacial diamicton which mantles the north side of Gleninagh Mountain. It comprises large amounts of locally-derived Carboniferous limestone blocks and occasional erratics (mainly granites) up to 2 to 3 m across. An additional supply may derive from direct erosion of the limestone bedrock.

To the east of Black Head a strong longshore wave gradient exists. As swell waves enter Galway Bay they are partially refracted before breaking obliquely from east to west. Locally this has the effect of moving sediment eastwards into Ballyvaughan Bay, although exactly the

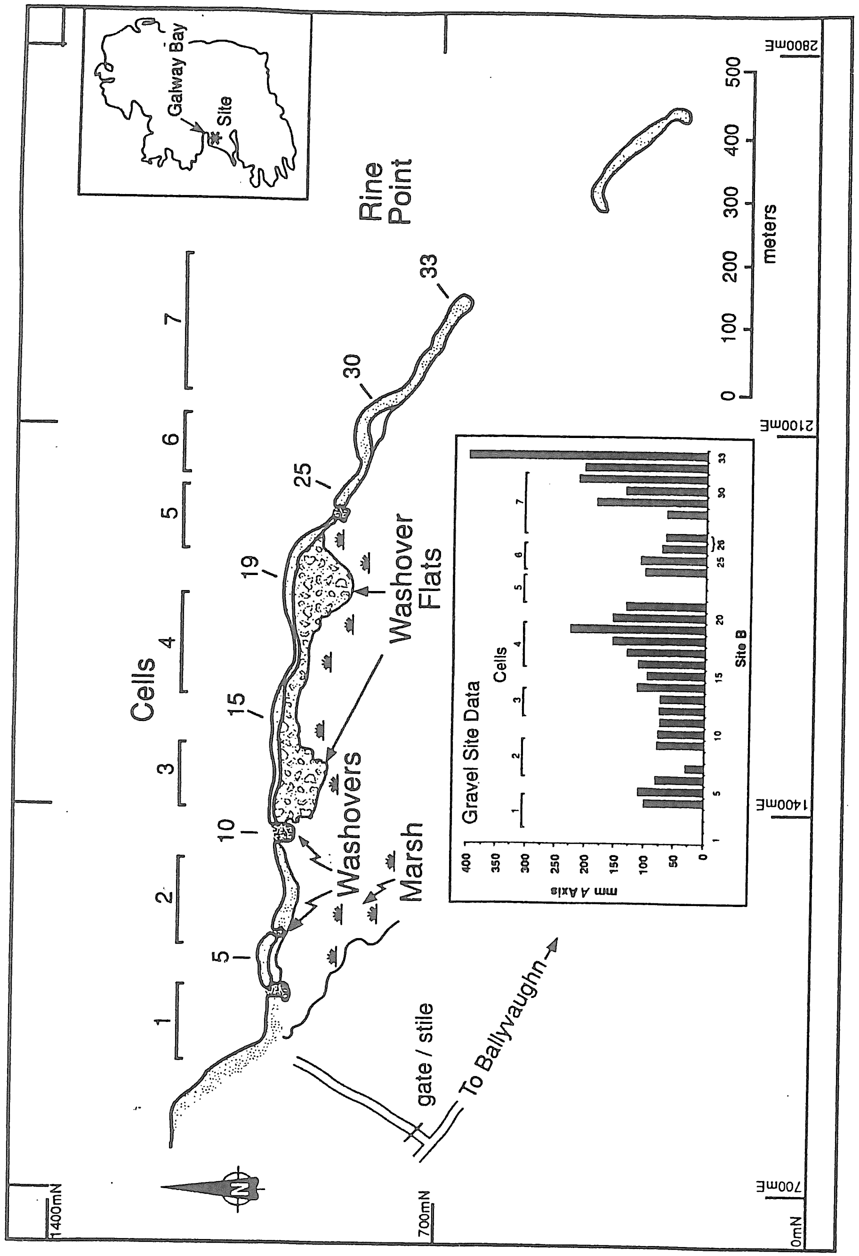


Figure 5. Gravel spit at Rine Point.

same pattern may be observed both along the south shore of Galway Bay around Newtownlynch and further north on Tawin Island and around Carrowmore.

The longshore gradient swept gravel of pebble and cobble sized material east, developing a solitary drift-aligned beach ridge from Gleninagh Castle eastwards to Rine Point. The morphosedimentary structure of Rine Point suggests strongly that since the formation of the spit the sediment supply has failed, leading to local reorganisation in terms of both sediment and landforms. Most characteristic is the segmentation of the spit into a series of seven cells ranging from 200 to 650 metres in length (Fig. 5). Each cell represents a zone in which the oblique waves have attempted to adjust the beach planform to an equilibrium form (Carter *et al.*, 1987). Segmentation processes involve the local remobilisation of barrier sediments, so that updrift material is moved downdrift often accumulating as a prominent headland. Rine Point shows this very clearly especially about 700 m east of the access track. The intracell transfer of sediment results in barrier thinning and breaching, at first via washovers. The landward movement of sediment tends to accentuate the cell structure. Along the length of Rine Point there are several good examples of coarse washover, and towards the distal end (1350 m from the access) the spit has breached leaving a distinctive overwash flat comprising a hard gravel packed surface.

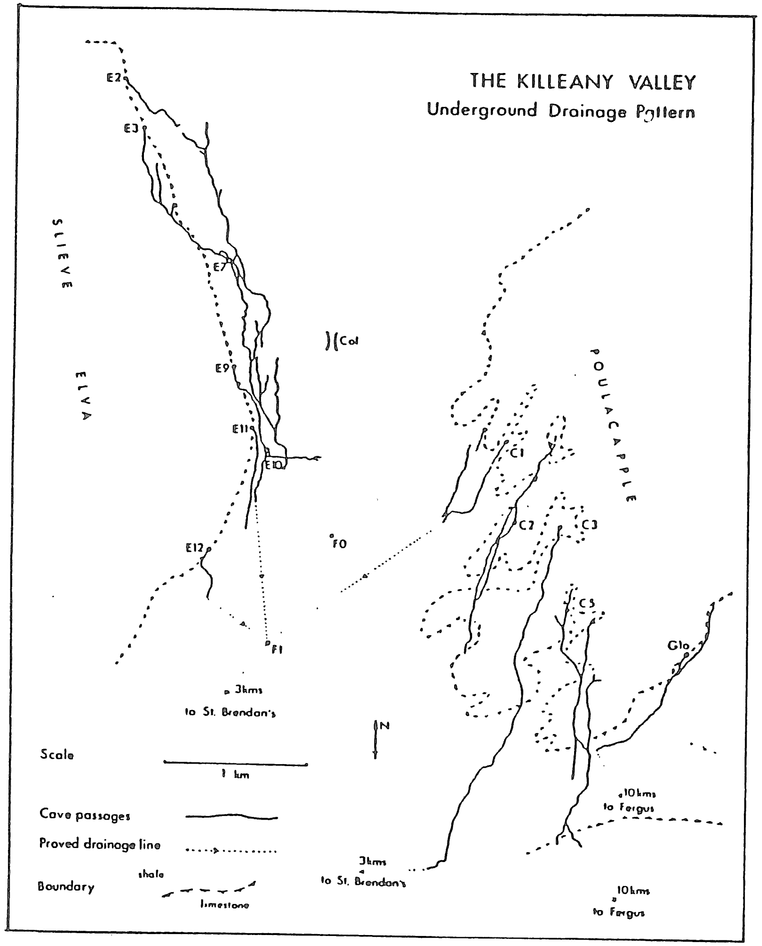
The sedimentary structure of Rine Point is interesting. The proximal barrier comprises well-sorted gravel washovers, topped with a veneer of calcareous sand (which may be, in part, aeolian). This sand has accumulated relatively slowly, and acts as a matrix for individual projective clasts thrown onto the barrier during storms. The sand also contains organic soils and occasional crushed shell layers. Alongshore the clasts increase and decrease in size largely within cells, but interestingly the largest beach face clasts (Fig. 5) occur at the distal end, where they have accumulated. (It is not unusual for large clasts to be preferentially transported alongshore (Carter *et al.*, 1987).)

Site 2. POULACAPPLE

Cullaun 2 Cave, M182 019 (D.D.)

The western flank of the Namurian outlier of Poulacapple is fretted by a series of shallow valleys (containing glacial sediments) incised into which are gorge - like younger valley forms. The valleys are oriented east-west or northeast-southwest. The streams occupying these valleys now sink underground at limestone windows in the shales and a sequence showing headwater retreat of these sinkholes is apparent. The resulting sets of cave passages drain down-dip to the south and are matched by a similar series of caves to the west draining the eastern flank of Slieve Elva (Figure 6). The majority of these caves drain to the Killeany - St. Brendan's Well springs which form a tributary of the Aille River but the most southerly (Callaun 5) drains to the springs of the upper Fergus River. Although consisting of simple networks of parallel or dendritic drainage conduits, the caves of this area are more complex than Poll Dubh (below).

The cave is entered some 500m down valley of the stream sink, though long stretches of the cave between the two points consist of an unroofed canyon passage (the cave is developed



DRAINAGE OF THE KILLEANY VALLEY
E7 Pollnagollum, E9 Pollismorahaun, E10 Pollelva, E11 Bullock Pot, E12 Pollcragreagh, C1 Cullaun One, C2 Cullaun Two, C3 Cullaun Three, C5 Cullaun Five, G1a Pollcahermacnaghten, FO Flood Resurgence, F1 Killeany Rising.

Figure 6. Drainge of Killeany area (adapted from Lloyd and Self, 1982a).

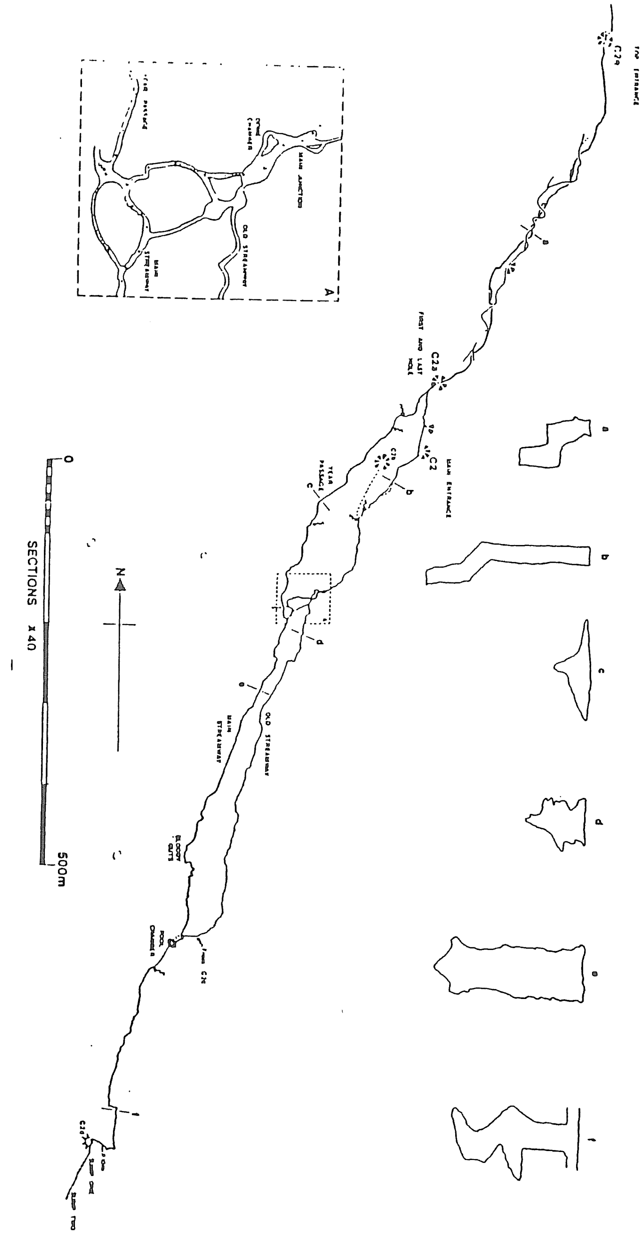


Figure 7. Plan survey of Cullaun 2 Cave (After Self, 1981).

only some 1-3m beneath the ground surface in this section). Figure 7 shows a plan survey of the cave. The initial section of the cave is a dry canyon (the stream occupies a recent, bedding - controlled route). The passage is typically 5m in height and 350-700mm wide with a well developed phreatic roof element. Uranium-Thorium dating of calcite deposits from the walls of the canyon in the vicinity of Cross-Section (b) in Figure 7 gave date of 1,000 BP for a deposit 2.5m above the floor and 3,800 BP for a deposit 5m above the floor (top of canyon). Although these are minimum ages for the passages they do support the possibility of a postglacial age for at least a part of the cave system. If this is the case then downcutting rates for the canyon would be: 0.7 - 3mm/year. These are extremely rapid rates of solutional erosion though remarkably similar to the rates of corrasional fluvial downcutting that appear to have taken place in the river gorges excavated into the Namurian shales by the Aille River and its tributaries in postglacial times (0.5 - 2.5mm/year).

The cave canyon divides into two parts for short distances, an upper 4m high segment developed along a calcite filled north-south joint and a lower (more recent) 1m high segment developed in a different joint set and meandering independently of the older route (Cross-Section (b)).

The gradient of the cave floor below this area steepens (exceeding the dip of the strata) and a 200 x 200mm trench is incised into the floor of the 700mm wide main canyon by a small tributary stream. The steepened section of passage corresponds to back-cutting from a vertical descent by the stream that originally formed the canyon. At the vertical descent the main cave stream joins the passage from a wide bedding cave, some 150-250mm high, developed in the same bedding plane as the roof of the canyon. Evidently the cave waters were inhibited from further vertical downcutting in this zone (in part due to the presence of extensive chert lenses) and prolonged solution under phreatic conditions of slow water movement have allowed slight differences in rock solubility to be picked out. Extensive thin rock shelves and solution hollows (Cross-Section (d)) have resulted. Downstream of this junction (Inset to Figure 7) the entrance canyon continues as a fossil conduit pursuing an independent, though parallel, course to the active stream passage. On the passage wall of the active streamway, above flood level is a line of erratic stalagmites (helicites). Throughout Callaun 2 Cave there is a strong inverse relationship between passage width (stream velocity) and the diameter of the rock scalloping.

Lios Lairthín Mór (LLM II), M180 042 (M.O'C. and Lj.J.)

The peat body that lies to the east of Slieve Elva and west of Corkscrew Hill on the shale outlier at Poulacapple has provided a record of vegetation and land use that extends from recent times to c. 3200 B.P., i.e. the later Bronze Age. The sampling site where core LLM II was taken consists of a small mound of peat at c. 270 m O.D., situated immediately to the north of Lios Lairthín Mór ringfort (9° 13'W 53° 5'N; National grid ref. M 180 042; Figure 8). For a more complete description of the investigations carried out at this site consult Jeličić (1991) and Jeličić and O'Connell (1992).

The extent of different soil types within 0-1 km, 1-2 km and 2-6 km radius bands of the sampling site, based on the soil map of Finch (1971), is presented in Table 1. The radii were chosen bearing in mind the distribution of the natural landscape units and possible pollen

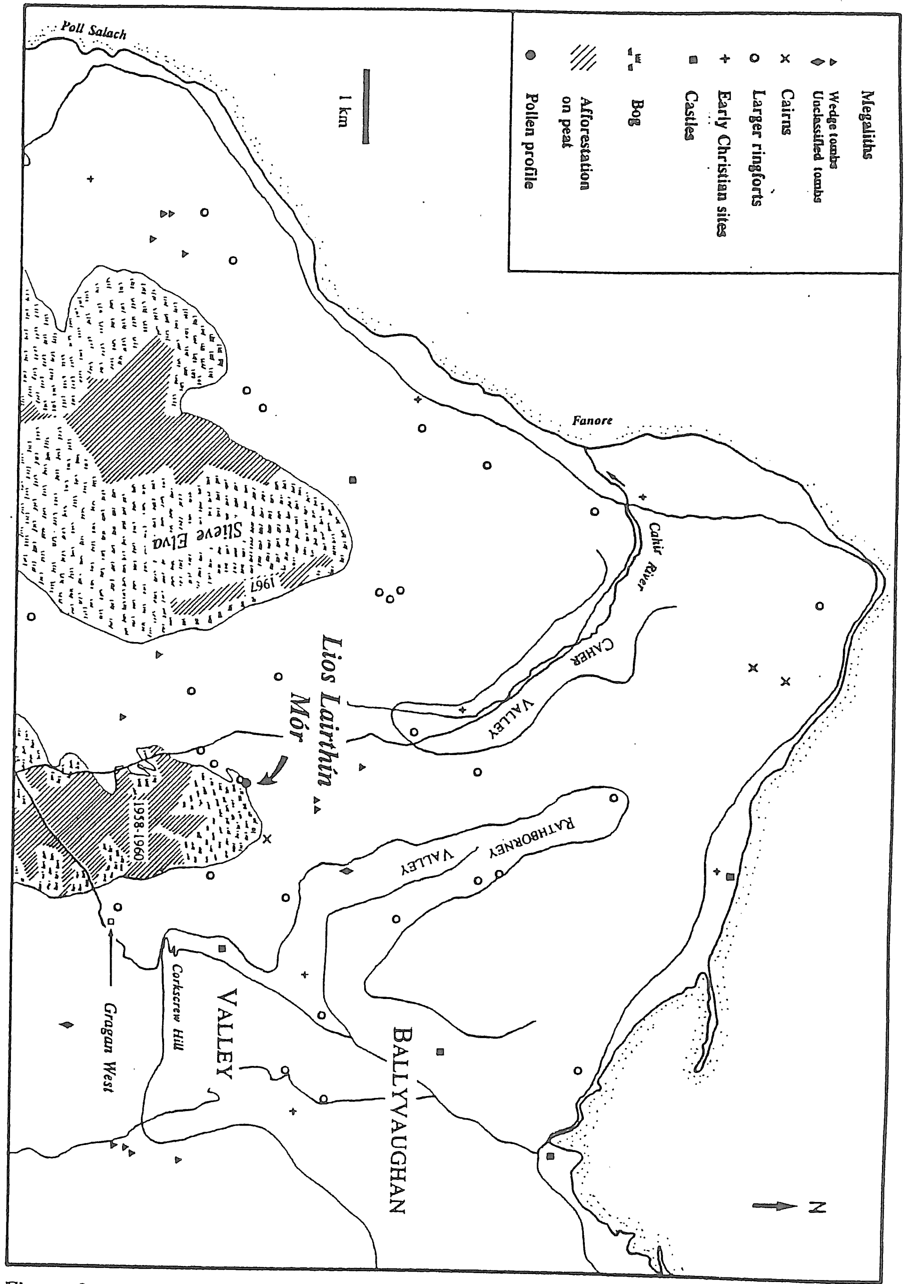


Figure 8. Location of Lios Lairthín Mór site. The lines delineating the three valleys approximates the 150m colour.

dispersal patterns in this wind-exposed landscape. Though soil erosion in a karstic landscape may produce substantial change over a relatively short time interval (cf. Drew 1983), the present soil distribution patterns are considered to provide the best available indication as to former edaphic conditions and hence to the potential natural vegetation and land use in the area represented by the pollen record. Noteworthy is the extent of rendzinas and the more or less complete absence of soils suitable for tillage in the vicinity of the site.

Table 1. Main soil types, expressed as percentages of total area, in three radius bands of the sampling site at Lios Lairthín Mór.

Radius band (km)	Peat	Burren rendzina	Kilcolgan rendzina	Brown earths	Podzols
0-1	35	65	-	-	-
1-2	16.4	80	-	-	2.6
2-6	14 + gleys: 10	59	6	7	4

Stratigraphy

Results of stratigraphical investigations are presented in Figure 9. Peat is underlain by silty clay, the total thickness of which was not ascertained because of difficulty of penetration with increasing depth. A well developed ironpan was recorded at most points. An orange to vivid orange silty clay with shale fragments in varying frequency is present beneath the ironpan. This is interpreted as the B_2 horizon.

A diffuse transitional zone of variable thickness separated the peat from the underlying silty clay. Near the centre of the sampling area, the lower peat was amorphous and highly decomposed while, in the upper peat, fibrous remains of *Eriophorum vaginatum* and *Sphagnum* leaves were common. Within the lower amorphous peat, *a silty clay layer, 3 mm thick, was recorded at 140 cm in LLM II,* and a similar layer, 5 mm thick, was noted at 132 cm in 5SW.

Trial corings in the adjoining main area of blanket peat at c. 80 m to the north-east of the sampling site showed peat of over 1 m thickness overlying a silty clay deposit, the upper 15 cm of which was grey in colour and beneath which was a fine dark blue, apparently unweathered, silty clay. The lack of podzolization suggests that peat initiation began here much earlier than at the sampling site.

Chronology

A plot of age (^{14}C years B.P.) *versus* depth is given in Figure 10. The three uppermost ^{14}C dates are too young (two uppermost are indistinguishable in age from the present and are omitted) and are rejected in favour of a chronology based on pollen and historical evidence. On these criteria, the PAZ boundaries 5a/5b and 5b/6 are assigned dates of c. A.D. 1800 and

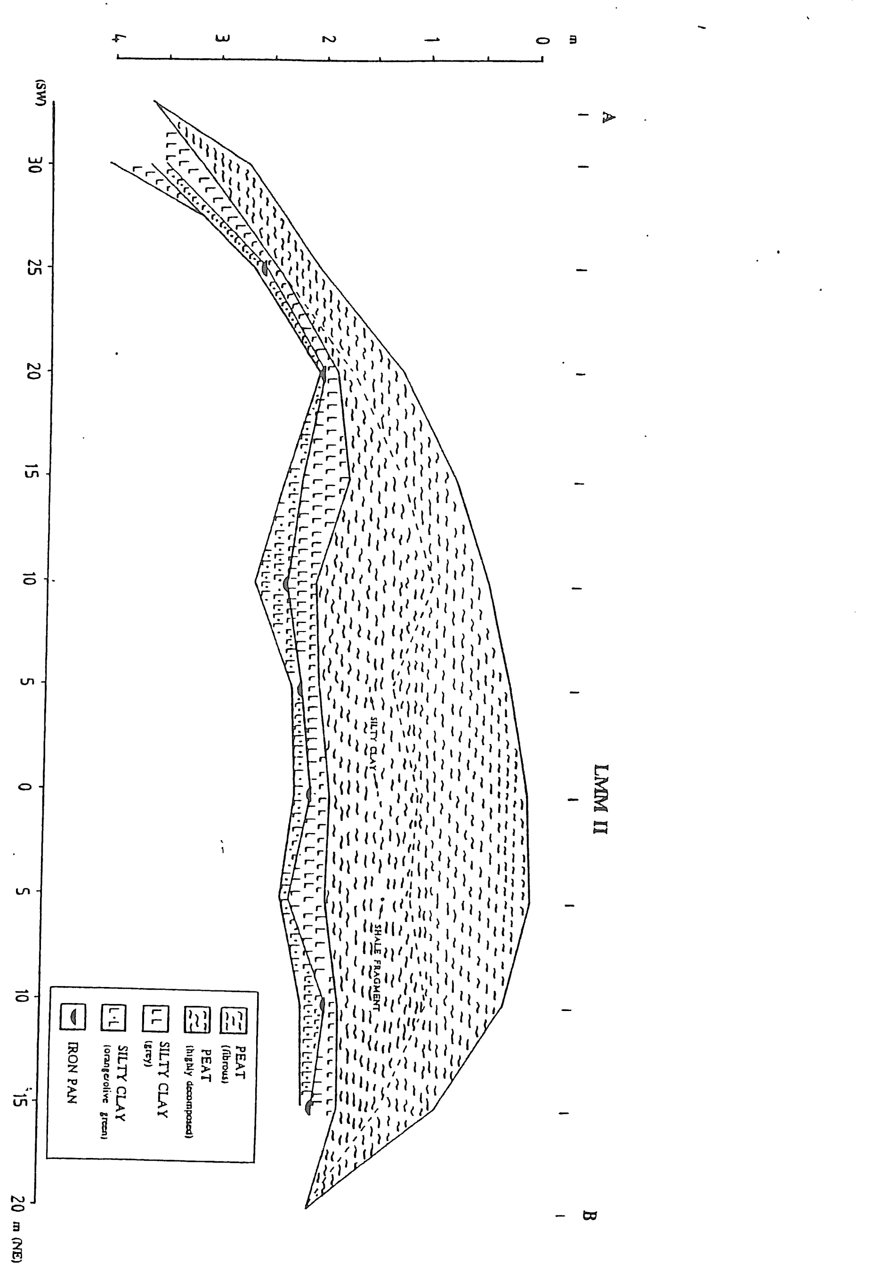


Figure 9. Stratigraphy at LLMII site. The end points are at sink holes which expose limestone bedrock.

1900, respectively, and the boundaries 3/4 and 4/5a are assigned dates of c. A.D. 1650 and 1750, respectively, mainly on the basis of the likely peat accumulation patterns in this part of the profile and also on the pollen and historical evidence.

Macrofossil analysis

Macrofossil remains and sand particles noted in the peat (Figure 11), taken in conjunction with the pollen analytical results, have provided a good guide to local peat and karst development. At 120 cm and below, *Juncus* seeds are recorded in considerable quantity in most samples with the notable exception of 3 of the 4 samples in PAZ 2. Above 116 cm, sand is no longer recorded.

In the upper part of the profile, acidophilous taxa predominate, including *Eriophorum* cf. *vaginatum*, *Sphagnum* sect. *Acutifolia* (leaves and occasional branches with leaves), *Hypnum cupressiforme sensu lato* (*H.* cf. *jutlandicum*), *Pleurozium schreberi* and other pleurocarpous moss leaf fragments.

The significance of these finding are as follows:

1. The transport processes involved in the sand deposition are not known but aeolian processes are unlikely. Transport by water may be involved, which, if true, would suggest that the sink holes around the periphery of the sampling site are karstic features that have developed in the last c. 1000 years (see below).
2. A decline in minerogenic influence appears to have taken place at the base of LLM II-2 (cf. peak in *Calluna* at 144 cm; *Juncus* for first time not recorded). In the upper part of this zone, sand is again recorded and a distinct silty clay layer is present at 140 cm. The sand consists of a mixture of calcite and quartz particles, presumably of local origin, the latter deriving from drift (cf. Farrington 1965). The precise significance of the silty clay layer, which appears to be confined to the central part of the peat body that was sampled (Figure 9), is difficult to ascertain. It is not tephra nor does it appear to be aeolian in origin. In the same level, *P. lanceolata* rises again sharply suggesting an increase in grazing pressure. It may be connected with the construction of the nearby ringfort, Lios Lairthín Mór. The silty clay was probably transported by water from the adjoining higher ground at a time when the present karstic drainage patterns had not yet developed. Unfortunately, there is no independent evidence to date the construction of the ringfort but construction or re-occupation at c. A.D. 440, i.e. the estimated age of the sample at 140 cm, is not unlikely.
3. In subzone LLM II-3c (c. A.D. 1200-1650), acidophilous vegetation becomes firmly established locally (cf. presence of *E. vaginatum* and *Sphagnum*). From 103 cm upwards, there is a decline in peat decomposition and the peat accumulation rate probably doubles. It is assumed that the present-day drainage patterns were now in place.

Pollen results

Surface samples. Pollen spectra from LLM SS1 and LLM SS2 are presented in Figure 12, together with a spectrum from within a *Helianthemum canum* community near Black Head (BH) (data from Proctor and Lambert 1961).

The main features of these results are as follows:

1. Arboreal pollen (AP) representation is low, partly the effect of the high Gramineae values

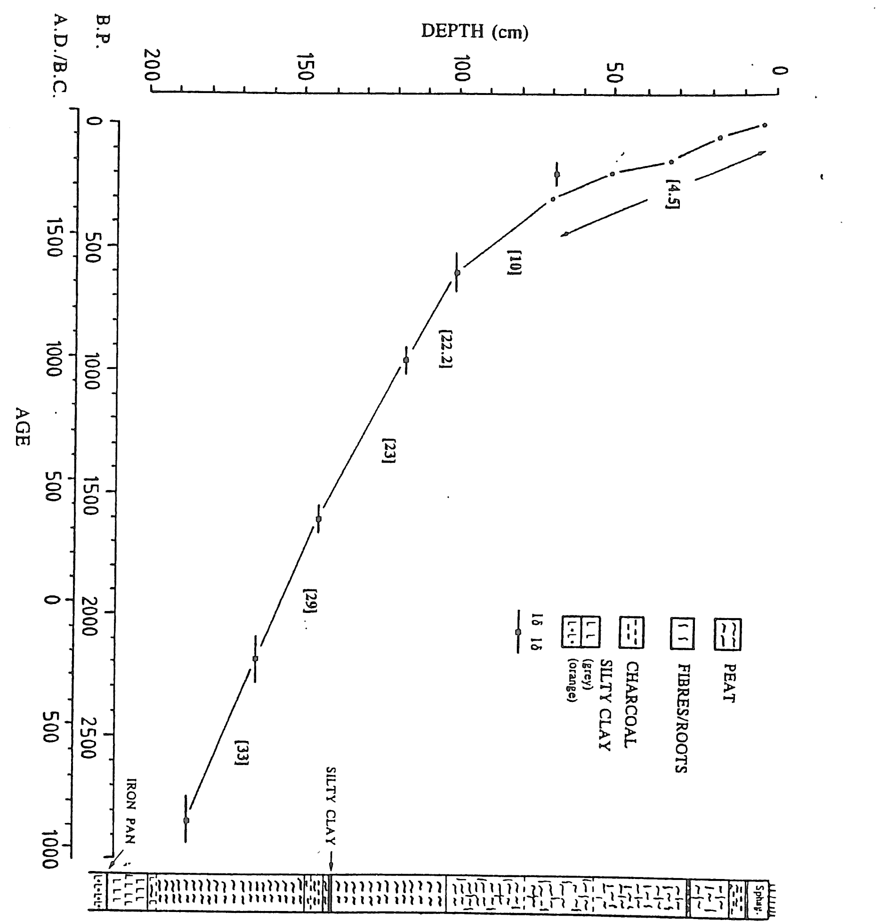


Figure 10. Age-depth curve for profile LLMII (dates not calibrated). Values in brackets estimate peat accumulation rates for corresponding segments in 14C year per cm.

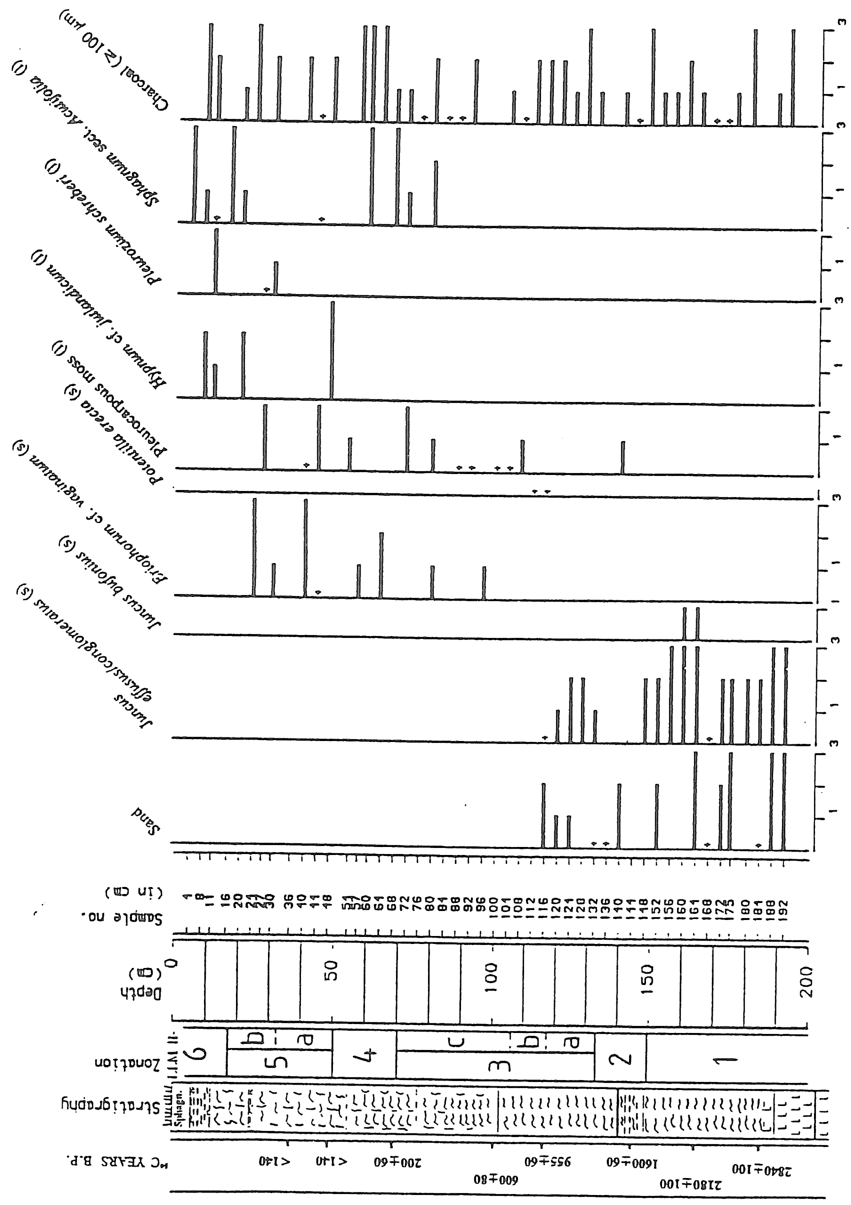


Figure 11. Results of analyses of the coarse fraction (>100 mu) from material prepared for pollen analysis. The horizontal scale is: + rare, 1 occasional, 2 frequent, 3 abundant, (s) seed/fruit, (l) leaves.

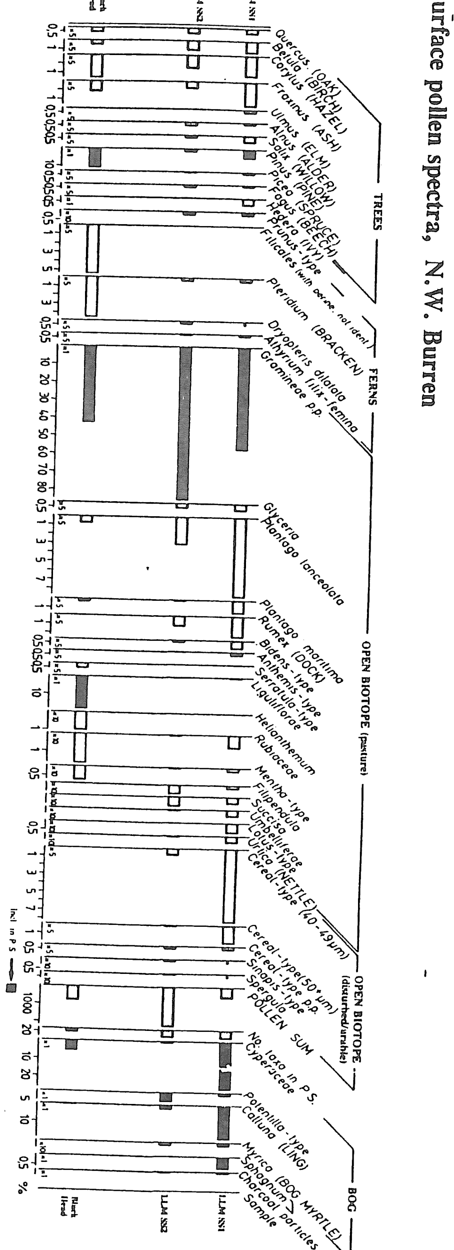


Figure 12. Percentage pollen in surface samples from Lios Lairthín Mór (SS1 and SS2) and Black Head (BH). Where the horizontal scale is magnified, histograms are stippled.

reflecting local bog species such as *Molinia caerulea*. The high *Pinus* values, much in excess of *Corylus*, are noteworthy. The *Pinus* pollen is due largely to long distance transport while *Corylus* pollen production is probably adversely affected by the strong winds.

2. In the herb component, *P. lanceolata* values are relatively high (maximum 8.7%) but fall far short of the values common in profile LLM II. In the surrounding pastures at Lios Lairthín Mór, *P. lanceolata* is not frequent. The species may be over-represented in the pollen record. Though *Dryas octopetala* is abundant in much of the region to the west and north-west of the sampling site (but apparently absent within c. 200 m of the site) its pollen is not recorded in any of the surface samples.

Pollen profile LLM II. The main conclusions that can be drawn from the fossil pollen record (3200 to 0 B.P., i.e. 1230 B.C. (non-cal.) to A.D. 1950) regarding the vegetation history of the NW Burren are as follows (see Figures 13 and 14):

1. *Corylus* was the main woody species in the NW Burren and, apart from the later eighteenth and nineteenth centuries, when woody species were almost totally cleared, it constituted a more important element in the landscape than at present.
2. Small populations of *Quercus*, *Fraxinus*, *Betula*, *Alnus* and possibly *Ulmus* were also present until at least the mid seventeenth century (base of LLM II-4).
3. Exceptionally high values of *Plantago lanceolata* (mostly in excess of 20% total terrestrial pollen) suggest intensive pastoral farming over most of the period.

Other features worthy of note include:

1. *Zone LLM II-2: (A.D. 200-580).* A lull in activity is recorded here during which woody species and, in particular, hazel scrub regenerated. This event may be of regional significance in the Burren (cf. Jeličić and O'Connell 1992) and may be equated to the 'late Iron Age lull' identified by Mitchell (1965) in his Littleton Bog profile. If the regeneration is the result of a decline in human activity, as appears to be the case, it may be concluded that the present open aspect of the NW Burren is largely the result of farming activity rather than factors such as absence of soil cover or severe wind exposure.
2. *(i) Subzone LLM II-3a: (c. A.D. 580-1000).* A substantial decline in occurs in woody vegetation. Hazel scrub and other canopy trees now play a role similar to that at present. The *Taxus* and *Pinus* record more or less ceases, suggesting extinction of both yew and pine, possibly in the Burren generally, at about A.D. 600. The elm population is also greatly reduced. A recent archaeological excavation at Gragan West (Figure 8) has yielded small amounts of charcoal of oak, willow/poplar, hazel, alder and possibly elm from an early Christian context (A.-M. Lennon in Cotter 1993). This supports the pollen evidence for a local presence of these trees and shrubs. Farming appears to be almost exclusively pastoral based. *(ii) Subzone LLM II-3b: (c. A.D. 1000-1200). P. lanceolata* achieves the quite exceptional average value of 50%, *P. maritima* is in the range 1.5-3.5% and the *Artemisia* curve is initiated and continues more or less uninterrupted to the top of subzone 5a. A substantial increase in farming activity has taken place at probably both local and regional levels and, for the first time in this profile, arable farming has now assumed some importance, though probably in the region as a whole rather than locally (Corcomroe Abbey established 1194/5). *(iii) Subzone LLM II-3c: (c. A.D. 1200-1650).* In the lower part of the subzone, arable farming is probably more important than at any

Lios Lairthín Mór, N.W. Burren

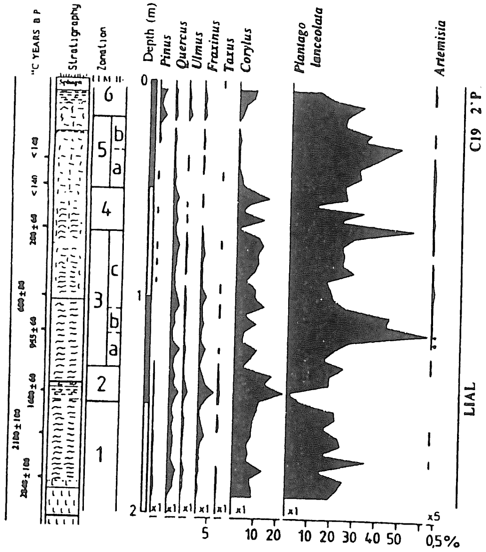


Figure 13. Selected percentage pollen curves from Lios Lairthín Mór (LLMII).

Lios Lairthín Mór, N.W. Burren (LLM II)

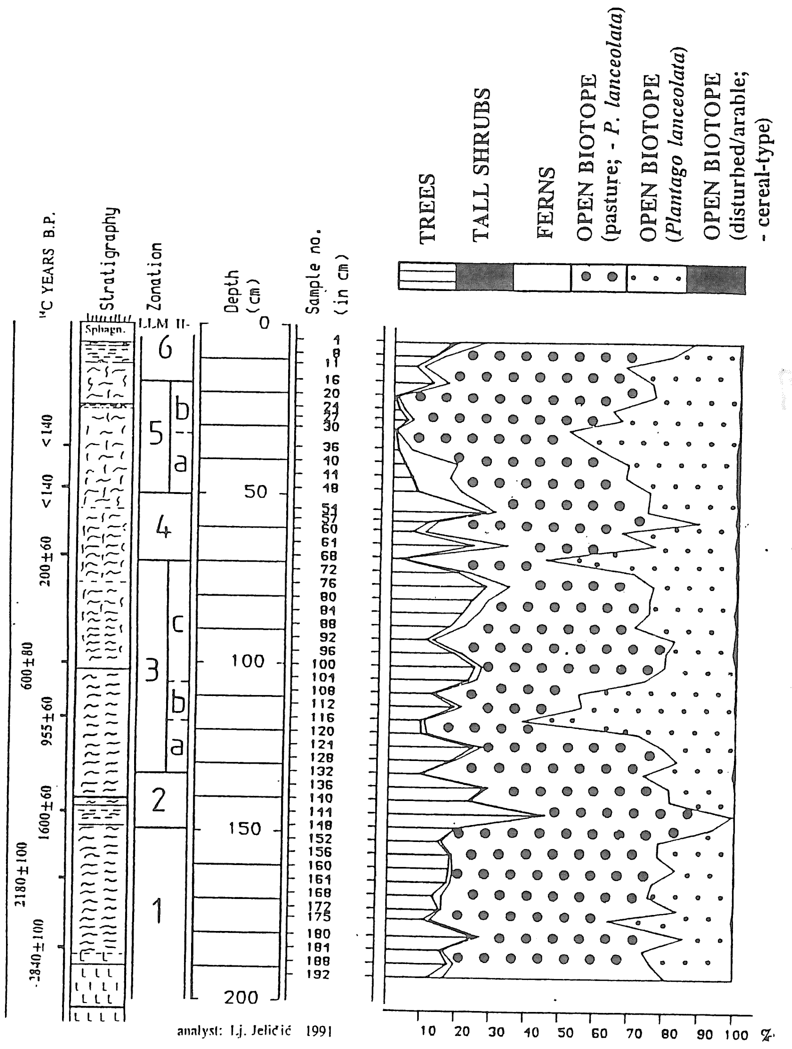


Figure 14. Composite percentage curves from Lios Lairthín Mór (LLMII).

time in this 3200 year record (cf. *Artemisia* and cereal-type curves). The scrub regeneration phase, admittedly minor, recorded at 100 (A.D. 1350) and 96 cm may be the result of adverse political developments such as the Bruce Invasion (1315-1318), and population declines caused by the Great European Famine of 1315-1317, the Black Death (1348-1350) and the succeeding epidemics (Barry 1988). A shift towards wetter conditions (cf. substantially higher Cyperaceae and increase in *Filipendula*), may also be involved. In the mid/upper part of subzone LLM II-3c there is some evidence for a recovery in economic well-being. This may coincide with the construction of tower houses in the fifteenth or more probably in the sixteenth century (three in the Ballyvaughan valley alone, Fig. 8).

3. *LLM II-4: (c. A.D. 1650-1750).* The curves of *Fraxinus* and *Ulmus* cease and high peaks are recorded in *P. lanceolata* (55%) and Gramineae (68%). Tall canopy trees, such as ash and elm, have probably become extinct in the region and perhaps in the Burren generally. Changes in the upper part of the profile (cf. increased representation/ in Gramineae, *Filipendula* and Rubiaceae and *Rhinanthus*-type pollen) suggest increased importance of meadows as against permanent pasture.
4. *LLM II-5: (c. A.D. 1750-1900).* This zone is characterised by extremely low AP values (0 to 7% in subzone LLM II-5b). This reflects the more or less total clearance of hazel scrub and most woody species over large parts of the Burren and certainly within the north-west region. This is also attested to by cartographic, photographic and written evidence.
5. *LLM II-6: (post A.D. 1900).* Arboreal pollen curves and especially *Corylus* recover gradually in this PAZ. This reflects the regeneration of scrub, involving mainly hazel, and the planting of pine, beech and horse chestnut. There is a decline in *P. lanceolata* and a rise in *Filipendula* that may be in response to declining grazing pressure and perhaps also to the use of artificial fertilizer.
6. The record of the typical Burren species is abysmally poor. There are no records, for instance, for *Dryas octopetala* nor *Geranium* (*G. robertianum* and *G. sanguineum* present locally). Only a single pollen of *Gentiana verna* has been recorded (132 cm). Analysis of surface samples (see above) suggests that virtually all the more unusual elements of the Burren flora may be more or less completely silent in the pollen record. In view, however, of the strong palynological evidence for an open landscape, it is assumed that, like today, many of the typical Burren species formed a conspicuous element of the flora in the study region over most of the period represented in the profile.
7. The available archaeological record supports the pollen analytical evidence for intensive human activity in the north-west Burren during the period in question. It appears to be human activity, rather than wind exposure or edaphic factors, that was the main factor controlling scrub/woodland development and hence the extent of the Burren flora.

Site 3. BALLYELLY - COOLMEEN; ANCIENT FIELD BOUNDARIES, M154 061 (D.D.)

The Burren plateau contains a remarkably high density of field monuments including a great variety of enclosures. Such enclosures and their boundary walls, of apparent antiquity, are particularly well preserved on the high plateau areas (winterage) of the Burren either because

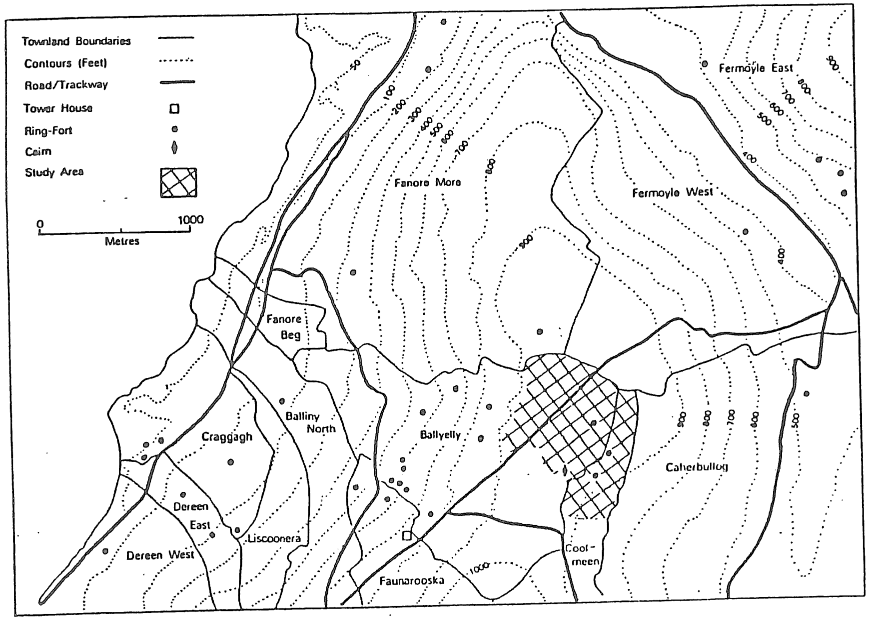


Figure 15. Location Map: Ballyelly-Coolmeen area (after Plunkett Dillon, 1985).

these were the preferred areas for settlement or because their relative remoteness has minimised later disturbance. The existence of such evidence for intensive agricultural usage is intriguing in view of the marginal status of the area for present - day agriculture (Drew 1982).

The Townlands of Ballyelly and Coolmeen occupy a relatively flat area on the dip slope near the northern extremity of Slieve Elva. To the north the land falls steeply to the Caher valley, to the west is a scarp falling 280m down to the coast and to the south-east is the Namurian capped summit of Slieve Elva. The study area is underlain by the uppermost beds of the Brigantian limestone which form areas of limestone pavement where the more competent beds outcrop. Chert lenses are abundant in this area. The nearest reliable water source is from the numerous small streams which sink underground at the shale - limestone contact some 500-1000m to the south-east. Rendzina soils 20-150mm deep provide a patchy (c.70%) cover. Close to the Namurian outcrop grikes are considerably enlarged by solution and soil and vegetation is largely confined to the grikes. Vegetation consists of the normal Burren herb-grass association with *Calluna vulgaris* locally abundant especially in areas of cherty limestone. Cattle are grazed throughout the year over all but the eastern (winterage) part of the area.

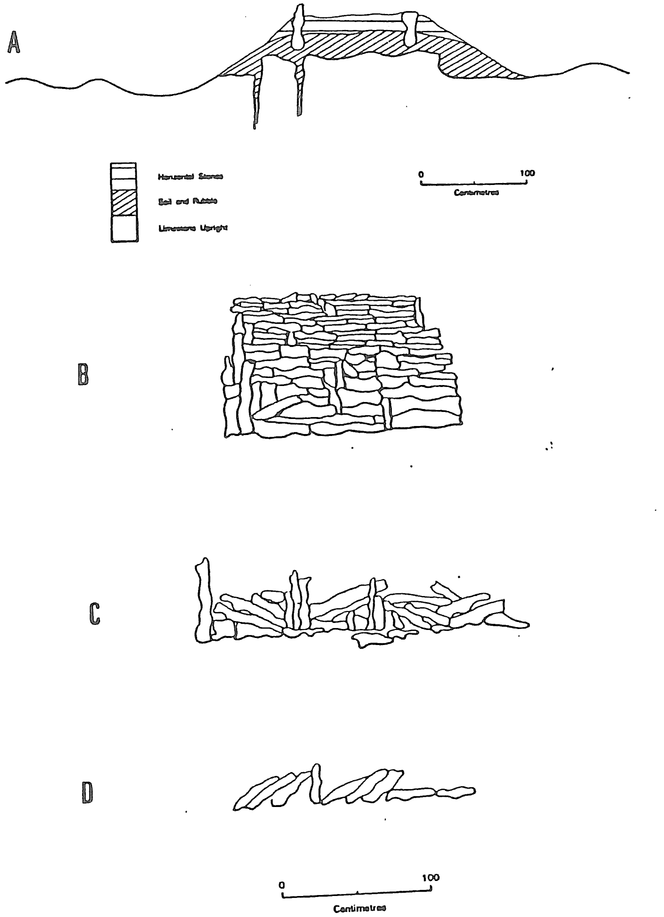
Although part of this, Slieve Elva is amongst the most exposed regions of the Burren, open to Atlantic gales and at an altitude of 250-300m it contains within a small compass a great variety of field monuments including examples of all of the major field boundary types. the location of the area is shown in Figure 15.

The description and analysis of the field sites given below is based largely on the work of Plunkett Dillon (1983, 1985) together with more recent supplementary work by this author.

Plunkett Dillon classifies walls into four groups (Figure 16).

1. Single Walls - one stone in width, 1-1.5m high, sometimes with orthostals, commonly enclosing block shaped or irregular fields 0.1-170ha. in extent. They are considered to be relatively recent in age (past 300 years?).
2. Slab Walls - 1 slab wide, 1-2 slabs high, often in parallel lines, enclosing strip or block fields 0.2-6ha in extent.
3. Tumble Walls - with a core of 1-2 courses of stone then rubble, they often appear as linear heaps of stones but were originally single walls. They enclose fields both rectangular and irregular with areas of less than 1.6ha. Plunkett Dillon suggests a possible association with ring forts.
4. Mound Walls - some 300-800mm in height and 0.8-1.8m wide, built predominantly of large slabs laid horizontally. Field systems are often incomplete or difficult to recognise but range from 0.01-2ha in extent and may be regular or irregular in shape. Unlike other wall types which often parallel the joint systems, mound walls may meander across the grain of the terrain.

In terms of relative age, there are examples of tumble, slab and single walls climbing over mound walls and this and other evidence suggests that they may be among the oldest field boundaries in the Burren. Plunkett Dillon suggests that the mound walls of this area may be linked to the large cairn and that the enclosures may have supported cultivation. She



A - Mound Wall B = Single Wall

C - Tumble Wall D - Slab Wall

Figure 16. Types of wall in the Burren (after Plunkett Dillon, 1985).

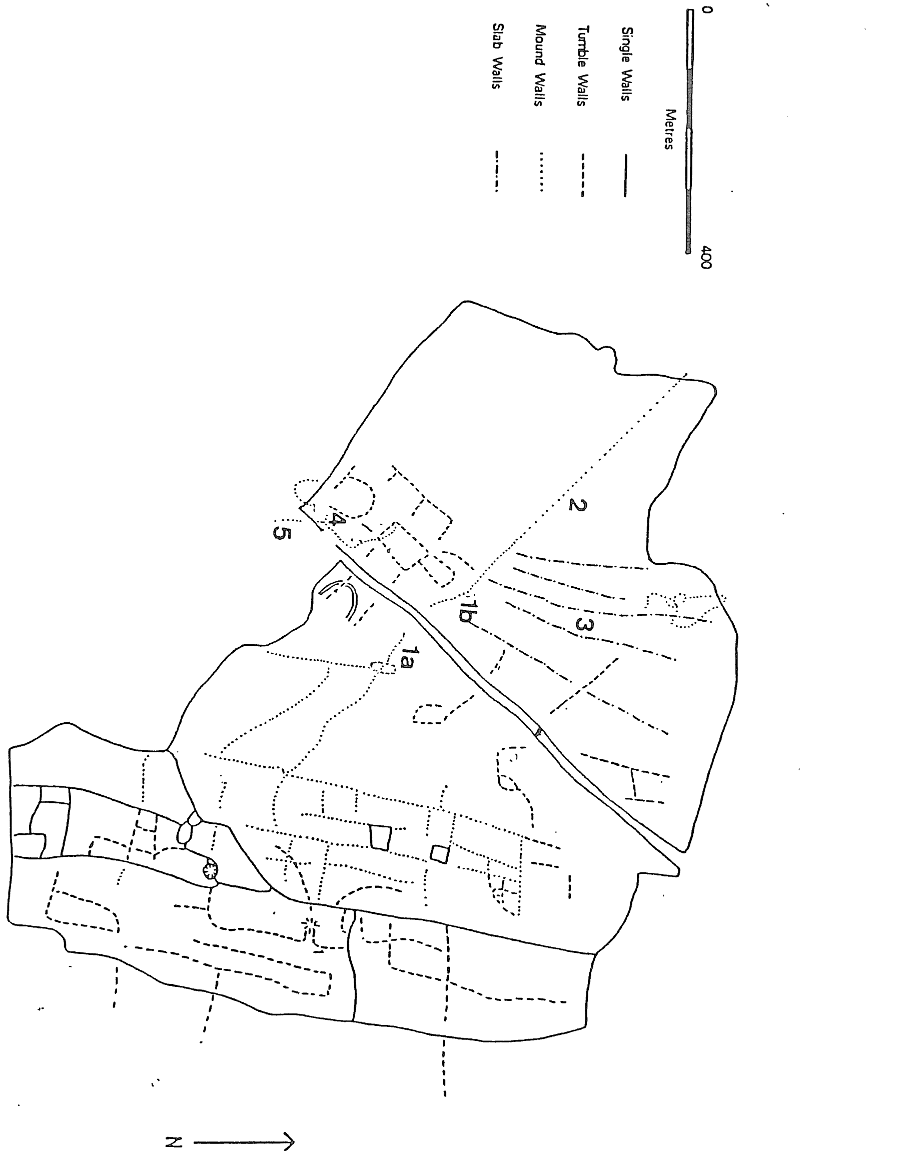


Figure 17. Ruined field boundaries in Ballyelly-Coolmeen. Numbers refer to sites mentioned in the text. Adapted from Plunkett Dillon, 1985).

associates the tumble walls with pastoralism. Field layouts are summarised in Table 2.

In Ballyelly-Coolmeen there is little evidence for settlement other than two circular and two rectangular forts and several smaller circular and rectangular features that were possibly house sites.

Table 2. The Distinguishing Characteristics of Field Layouts

Field Shape of at least 75% of the fields layout	Range of Field sizes in layout (in hectares)	Occurrence of repeating elements within the layout	Predominant Boundary types used in the layout
1.1 Regular-block	0.15 - 8.6	—	single double earth bank
1.2 Regular-block	0.02 - 3	—	single tumble mound
1.3 Regular-block	0.21 - 3	Fields set between parallels	single double earth
1.4 Regular-strip	0.25 - 6.4	Fields set between parallels	single slab
2.1 Irregular	0.05 - 2.9	---	single
2.2 Irregular	0.01 - 1.1	---	single tumble mound
3.1 Mixed	4 - 170	---	single earth bank

The field boundary systems are shown in Figure 17 together with the location of sites 1-5 described below.

1. An example of an extensive mound wall which pursues a sinuous course across the area at an oblique angle to the dominant joint sets. The wall crosses small scarps and to the east of the droveway crosses a small tumble wall enclosure and links with a series of rectangular enclosures. To the west of the droveway the mound wall continues beyond the townland boundary to the steep descent to the sea. Although *Calluna* is abundant in the area it is conspicuously absent from the wall vegetation.

2. The mound wall described above crosses an area of bare limestone on a part of which is characterised by an uneroded rock surface or by smooth karren forms and joints unopened by solutional erosion.

3. A series of parallel slab walls (20-30m apart) originates in this area and extends

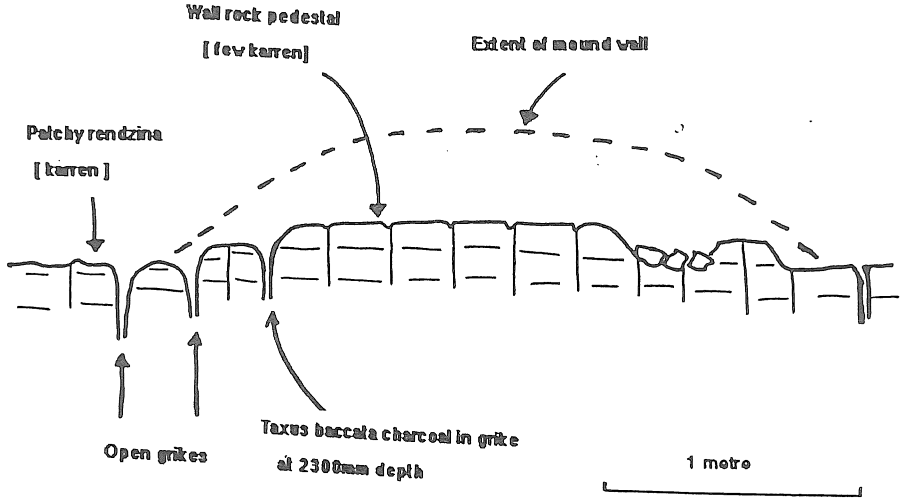


Figure 18. Diagrammatic section through a mound wall, Ballyelly (composite of walls at sites 4 and 5 in Figure 17).

northwards beyond the Townland and towards the Caher valley. The slab walls are crossed by a tumble wall and intersect a small system of mound wall bounded enclosures.

4. A 2m length of mound wall has been removed at this point allowing the structure of the wall to be seen. Unlike the other wall types, mound walls are built primarily of large slabs of limestone placed horizontally on the ground. This affords a degree of protection to the underlying soil from leaching and erosion and to the bedrock surface from solutional erosion. Thus the character of both soil and bedrock surface when the wall is built may be preserved. In the case of several mound walls investigated in the Burren it has been found that they rest upon a pedestal of bedrock in the same manner as do erratic or transported blocks elsewhere in the Burren. The height of the pedestal corresponds to the extent of vertical lowering of the surrounding limestone surface that has taken place since the wall was constructed. The pedestal form for Ballyelly-Coolmeen mound walls is shown in section in Figure 18. The pedestal averages 140mm in height over the exposed section and its location, transverse to the orientation of the long axis of the major clint blocks makes it improbable that it is other than a weathering residual. In the rock surface that lay beneath the slab wall the joints are some 10-20mm wide (due to solutional erosion) compared with 100-200mm on either side of the pedestal. In theory it is possible to estimate the age of mound walls by reference to the amount of lowering of the surrounding limestone surface that has taken place since they were constructed, but in practice such estimates are liable to considerable uncertainty. Williams (1964) measured current solutional loss of limestone within the southern Burren catchments and estimated an average annual lowering of the limestone surface of 0.051mm. This global figure of necessarily included zones of accelerated erosion such as cave conduits and zones of minimal or zero erosion such as limestones overlain by calcareous drift. If, indeed the mean height of rock pedestals beneath transported blocks in the area is used, a direct comparison with the environment of the tumble walls is obtained and the need to extrapolate present day erosion rates for several millennia into the past is obviated. The mean pedestal height beneath some 78 blocks in the north-western Burren is 350mm. If it is assumed that this is the result of c.10,000 years of erosion then an annual rate of 0.035mm/year is obtained. If the range of sub-wall pedestal heights and the range of values that comprise the mean value for natural pedestals is taken into account, an age for the mound walls within the range 2900 - 4000bp results, approximating to Bronze Age times in Co. Clare. Plunkett Dillon adopts a more rapid solutional rate and estimated the age of the pedestal mound wall as being at least 2000 years.

5. A continuation of the tumble wall at site 4 crosses the droveway and extends southwards past small round and rectangular enclosures which may represent house sites. A grike parallel to this part of the wall yielded small quantities of charcoal from *Taxus baccata* at a depth of 300m in a red-brown mineral soil. Palynological work by Rutherford (1982) at Faunarooska and Dereen South some 1-1.5km south of this area demonstrated a mixed oak climax forest with an upper boundary at c.2700bp, followed by open heath and grass with some weed and cereal pollen. This late Bronze Age date is of interest compared to palynological work in other parts of the Burren reported elsewhere in this publication and the evidence presented above for the age of field boundary systems.

Site 4. POLL DUBH CAVE, M135 034 (D.D.)

Poll Dubh cave is located on the south-western flank of Slieve Elva and is a good example of a simple stream cave related to present day landforms and hydrology and very probably of Holocene age. As the plan survey (Figure 19) shows the cave passage is closely associated with the present day shale-limestone boundary, paralleling the boundary and functioning as a drain collecting water from the numerous stream sinks at the shale margin. The cave is developed in the north-south joint system and follows the shallow (0-5^0) dip to the south. The cave system is developed within the uppermost 2-10m of the Brigantian limestone and is therefore always within a few metres of the surface. The water re-appears at the surface a short distance beyond the limit of exploration in the cave and then flows south, sinking again into a very immature cave system. Under high flow conditions in this section the capacity of the cave passage is exceeded and a stream flows on the surface. Thus, all the stages of initiation and early development of karstic drainage are represented in the Poll Dubh system.

The main stream sink Poll Dubh (B3) feeding the Poll Dubh system has created a series of small canyon passages all of which unite into a single conduit some 2.6m high developed in four beds. The passage meanders gently (amplitude c. 15m). The phreatic roof bedding plane is c.150mm high and contains flood-borne deposits. Further downstream the passage enlarges (scalloping on the walls increases in diameter from 1 -20mm to 30-40mm corresponding to a reduction in stream velocity). Evidence for changes in stream discharge is provided by the patches of semi-calcreted gravels that are now being eroded. The level of frequent and occasional floods can be determined by reference to the zones of calcite deposition on the passage walls above the stream (no deposition below 500mm, thick deposits above 1m). 120mm from the entrance the water from Poll Dubh North enters the cave at roof level, the passage being developed in the same bed as Poll Dubh South. The steepening of gradient associated with this junction has allowed the cave stream to cut through the chert layers above which the passage upstream is perched. Poll Dubh North has a uniform cross-sectional area through height and width alter. Several small (250 x 200mm) vadose passages enter the streamway at roof level. Beyond the point at which Poll Dubh North passes out from beneath the shales, calcite deposition, mainly derived from seepages down north-south joints, is extensive. A collapse to the surface at the intersection of solutionally enlarged cross joints forms entrance B3a to the cave.

To the west of Poll Dubh the limestone forms a plateau for 1km, beyond which the land descends steeply to the sea. The plateau includes an area of hummocky drift and an extensive, complex enclosed depression (uvala) oriented north-south but with extensions east towards the shale margin and westwards towards the scarp (Figure 20). This enclosed depression is though to relate to an earlier phase of karstification in the area (Lloyd and Self, 1982). To the north of Poll Dubh are two caves systems (Pollaballiny and Faunarooska) which also drain a part of the shale/limestone boundary. However, in their further reaches both of these caves invade fragments of much older phreatic cave oriented to the west and northwest and, unlike Poll Dubh, drain westwards to submarine springs.

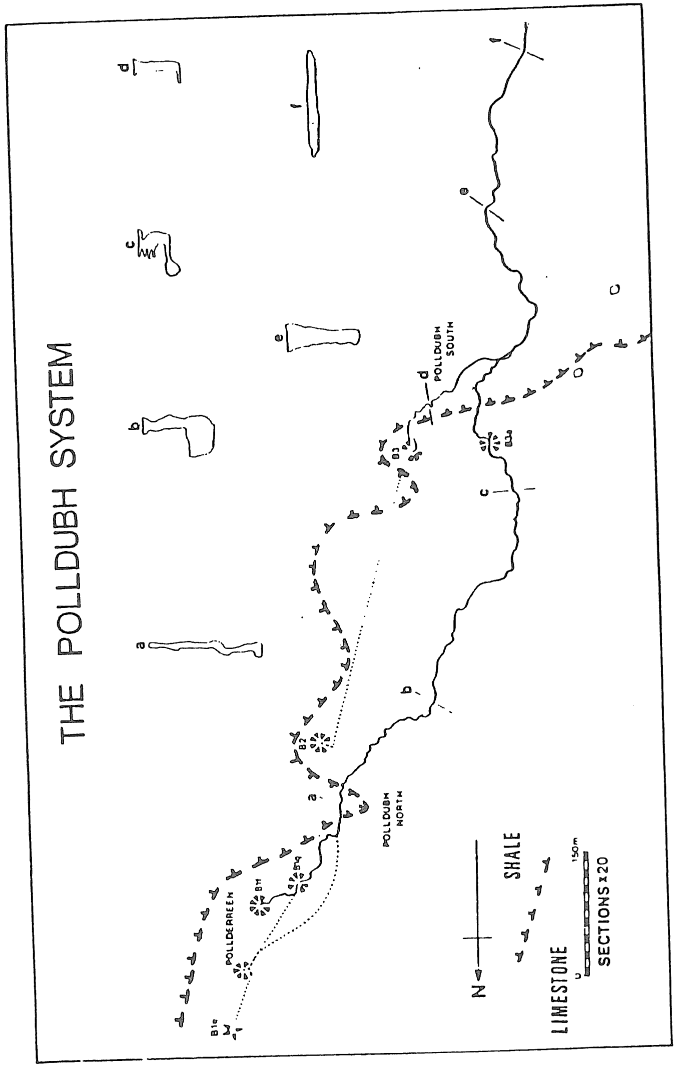


Figure 19. Plan survey of Poll Dubh Cave (adapted from Lloyd and Self, 1982b).

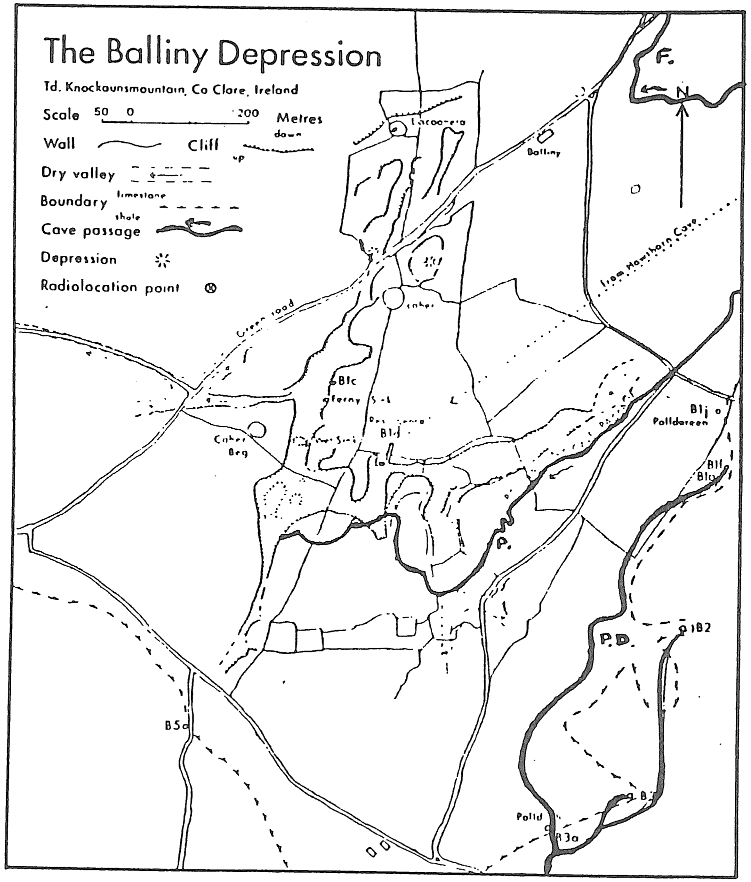


Figure 20. Landforms and caves of the Ballyiny depression: F, Faunarooska Cave; P, Pollballyiny Cave; PD, Poll Dubh Cave (adapted from Lloyd and Self, 1982b)

Site 5. POLL SALACH, M085 015 (W.P.W.)

Glacial Deposits

The glacial deposits on the low ground around Poll Salach are quite different from these occurring in the rest of the Burren. They are composed of a very coarse boulder till, containing angular boulder-sized clasts in a silt-to-pebble matrix. Rock is never far from the surface and some exposures indicate that the sediment is composed of broken limestone not far removed from its source with a matrix probably injected from overriding ice.

The sediments are arranged in a series of elongate mounds with boulders appearing at the surface. Clearly the sediment is a till (deposited directly by ice), but the genesis of the ridges is not clear.

At Poll Salach on the coast, just west of the sharp bend in the road (L54), a section exposes the till lying on a well striated, ice moulded surface, a roche moutonée. The striae are oriented approximately northeast-southwest, and the roche moutonée indicates ice movement from the northeast.

The mounds here do not parallel the direction of ice flow. They have the form of ridges seen elsewhere in drumlin areas in Ireland (N. Mayo and east of Clew Bay) which are associated with glaciotectonised bedrock. They are probably associated with extensional ice flow, as ice passed over the Slieve Elva escarpment and dragged loose bedrock slabs and till to form rough heaps which in places are streamlined subparallel with the direction of ice movement but may also be aligned at right angles to this. The ice in this area under the shadow of Slieve Elva may for a time have moved almost east-west as it did in the low ground around Kilfenora, between the Burren and the shaley high ground to the south. However, association between the shape/orientation of the mounds and former ice movement, must await further study.

Storm Beach

A blocky storm beach traverses the low ground parallel with the coast at Poll Salach. It is one of a number of similar features found on this part of the coast of the Burren. The beach is clearly active yet it is striking that the boulders of which it is formed are not rounded. At best they are sub-angular to sub-rounded. They appear here to be derived from the till. It is possible that the lack of roundness is due to a more rapid solutional process associated with sea spray than can be accommodated by the corrasional process of the beach system.

Site 6. BALLYCASTELL DRUMLIN, R157 972 (W.P.W.)

Around Lisdoonvarna a well developed drumlin swarm sweeps across the Carboniferous limestone on to the overlying shale. Sections through the features are rare, but the occurrence of well developed glaciotectonic features in drumlinised tills elsewhere, prompted a reconnaissance survey of the Lisdoonvarna swarm.

A section in an old pit in a drumlin at Ballycastell some 3km southeast of Lisdoonvarna reveals well developed glaciotectonic structures. The drumlin as exposed is composed largely of diamicton derived from the subjacent Upper Carboniferous shales.

Large rafts of this friable shale are exposed in the lower part of this section. A number of thrust faults and overfolds are seen where the rafts have been pushed or sheared up over each other and the surrounding diamicton. The orientation of these structures indicates pressure was exerted from the east or northeast.

The drumlin crest line is aligned eastnortheast - westsoutheast as are those in the surrounding area.

Sections, through other drumlins on the Carboniferous shales also indicate significant glaciotectonic displacement. It is clear that these shales were easily dislocated and entrained by overriding ice. And it seems likely that much of the shale cover may have been removed from the underlying limestone of the Burren in this way. Finch and Walsh (1973) have suggested that large rafts of shale may have been shunted across the limestone surface, by the overriding ice close to the margins of the shale. The occurrence of glaciotectonic structures both at Ballycastell and in the area south of Lehinch support Finch's suggestion.

Site 7. POULAWACK RINGFORT, R227 984 (P.G.)

The ringfort was the characteristic enclosed settlement form of the Early Historic Period (AD 400-1200) in Ireland. They generally consist of a circular or oval area, varying in diameter from c. 20-60m, internally, which is delimited by one, or more, earthen or stone enclosing elements. These can take the form of an earthen bank(s) and fosse(s), stone rampart(s), and/or scarp(s), giving rise to the designations, uni-, bi-, and multi-vallate.

The entrance, frequently marked by a stout gateway, was usually situated on the eastern side, and the interior would have contained the buildings of the household. This most probably comprised the members of an extended family who farmed an estate of 40 hectares upwards.

Some ringforts contain souterrains, or artificially-built subterranean chambers, beneath their interiors. Whether built of wood and/or stone (less frequently, tunnelled), these artificial caves appear to have been designed as refuges for people and property in times of danger, eg. during cattle raids.

The Poulawack ringfort is a typical example of this type of monument, of which the Burren probably has c.500 examples. From it, one also gets a good view, northwards, of a number of other ringforts, including the well preserved Cathair Chonaill.

Multiple Cist Cairn

This humble looking cairn (Figure 21) with a diameter of 21m and a height of 2.5m was one of two monuments in the Burren chosen for archaeological excavation by the Harvard Archaeological Expedition in Ireland (Hencken, 1935). Excavation in 1934 revealed that it contained 10 graves, including the remains of at least 16 people. These comprised 3 adults,

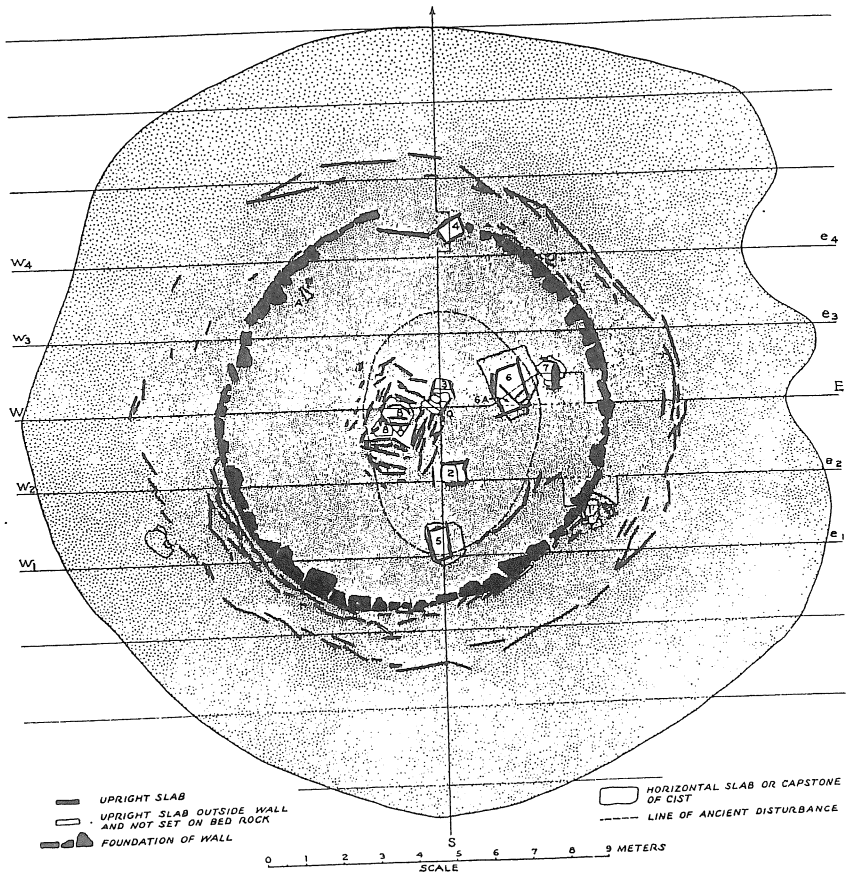


Figure 21. Poulawack Multiple Cist cairn (from Hencken, 1935).

4 young adults, 5 children and 4 unspecified. The central grave (Grave 8) has recently been dated to the Neolithic (Waddell, 1991,67), but most of the others are probably Early Bronze Age in date.

Within the cairn, two concentric stone revetments, probably representing at least two main phases of construction, were identified:

a) an inner cairn (D. 10.5m) delimited by a drystone revetment wall (H 1m) within which was a centrally placed double cist (Grave 8 and 8a) defined by a wall of multiple, inclined slabs and roofed by a number of capstones. Grave 8 contained some human bone, a hollow scraper of flint, two tiny potsherds, and a boar's tusk. Grave 8a contained the disarticulated skeletal remains of four individuals; an infant of about one year, a young adult female, and a middle aged male and female. These were accompanied by a solitary shell of Ostrea edulis L. Grave 5 was also considered as primary, and number 6-7 were evidently placed in the inner cairn as it was being built. The former grave contained a small potsherd of Beaker pottery (Ryan, 1981, 138).

b) a concentric, outer ring of slabs set on edge (D. 13.4m, H 0.9m) which was completely mantled by the cairn material. This contained Graves 1-4, though the possibility that number 1 could have been earlier than all the others, was considered by the excavator. The only finds from these graves were a bone point and a flint scraper from Grave 2.

From a palaeoenvironmental viewpoint, the excavations also indicated that the whole cairn, including the Late Neolithic cental cist, was built directly on the limestone pavement.

Site 8. POULNABRONE PORTAL TOMB, M234 009 (A.L.)

The striking portal tomb at Poulnabrone is one of four such monuments in Co. Clare. It is also one of the few portal tombs excavated in recent times and has contributed significantly to our knowledge of this monument type.

In 1985, a crack was noted in one of the portal (entrance) stones which threatened the stability of the structure and as a consequence, excavation and conservation works were carried out by the National Monuments Section of the Office of Public Works. The entire chamber was excavated and the NW quadrant of the surrounding cairn.

The orthostats of the chamber were found to be sitting directly on the limestone bedrock, held in place by the weight of the capstone. The sill-stone at the entrance to the chamber was sitting in an east-west gryke, and just outside of the sill-stone, three stones had been placed on edge forming a portico or antechamber which had been backfilled with earth and stones shortly after construction. The cairn, which is roughly oval in plan was constructed by piling large slabs of limestone against the chamber of orthostats and then covering these with smaller flat stones to produce a relatively smooth surface sloping down to the cairn matrix; and several large stones had been placed on edge in grykes to help stabilise the structure. It is unlikely that the cairn was ever much higher than it is today and it seems to have served a strictly functional purpose in helping to consolidate the chamber of osthostats.

The burial deposit within the chamber produced the disarticulated remains of at least thirty three individuals, seventeen of these were adults and sixteen were children. Study of the remains has shown that the majority of adults died before reaching the age of thirty, there was an equal distribution of males and females among the adults and the vertebral pathology suggests a lifestyle characterised by hard physical labour. The dental data suggest a coarse diet with a high abrasive content - stoneground cereals would produce the type of attrition seen in the teeth. The tip of a flint or chert arrowhead was found in the superior margins of an ilium that probably belonged to a male. Apart from the remains of a newborn baby which were found in a gryke close to the sill-stone, it is unlikely that the burials are in their primary position since the bones were totally disarticulated and some had been pushed into grykes to depth os of up to 57cm. It is likely that the remains were initially interred somewhere else (or left exposed to decay) and later transferred to the tomb.

Items which may have been of particular significance to these people were placed in the tomb with their remains and included a bone pendant, part of a bone pin, a polished stone axe, stone beads, two large quartz crystals, flint and chert implements and shards of pottery.

Ten radiocarbon dates were obtained from the human bone and these indicate that the tomb was used sporadically over a period of 600 years between 3,800 and 3,200 Cal BC. The neonate was a later Bronze Age insertion. If we assume that the time lapse between death and interment was not very great then we can suggest a date of c. 3,800 Cal BC for construction of the tomb.

The cutting through the cairn revealed a pre-cairn soil cover averaging 10-12 cm in depth. This was a friable brown earth with shell fragments and frequent stones. Pollen analysis undertaken by Dr. Michael O'Connell had negative results - it was assumed that the original pollen content had been more or less completely mineralised in the alkaline environment.

Preliminary results of the animal bone analysis indicates the presence of cattle, pig, sheep/goat, dog, hare, stoat, pinemartin, wood mouse, and bird.

Conservation works at the monument included the replacement of the broken portal stone and the insertion of a new stone into the gap between the two eastern chamber orthostats to provide extra support for the capstone.

Geological Note (D.D.)

The builders of the wedge and portal tombs in north-west Co. Clare appear to have conformed to particular "lithological" rules. Thus, in both types of tomb the roof slab is invariably placed "right way up" i.e. as it was oriented prior to quarrying. The side slabs of the portal dolmens are placed with the "up" side facing outwards whilst the side slabs of the great majority of the wedge tombs are built with the "up" side facing inwards. Thus, the side slabs, particularly of the wedge tombs, preserve to a large extent the solutional weathering forms (karren) that were present when the tombs were built, whilst the top slabs have been subject to subaerial weathering for the entire period since the tomb was built.

It is noticeable that on Poulnabrone the undisturbed, east facing side slab shows subdued, rounded karren forms characteristic of development under a soil cover. However, the top slab

had developed a series of sub-circular, angular hollows (kamenitza) of subaerial origin superimposed upon the original smooth karren and similar to those found on the surrounding exposed limestones. The mean depth of these hollows is 43mm compared with 27mm for adjacent wedge tombs, thus reinforcing the generally accepted younger age for the wedge tombs. It also provides some evidence for the existence of a soil cover at the time at which the tombs were built.

The kamenitza on Poulnabrone exhibit overflow channels downslope with a mean depth of 23mm. This suggests that originally the top slab was more nearly horizontal than at present and that, for whatever reason, tilting to its present inclination took place at some point in the first 2000-2500 years following construction.

Site 9. BALLYVAUGHAN VALLEY, FROM M223 035 (P.G)

Overview of archaeology: Given the large concentration of megalithic tombs in the Burren, their absence from the Ballyvaughan Valley is notable. While the reasons for this have, as yet, not been studied in detail, it may well have been related to its deep soils which probably supported relatively dense woodland in postglacial times. As de Valera and Ó Nualláin (1961, 108-9) have commented, the distribution of the Burren tombs suggests that their builders preferred the highland plateaus of these uplands (150-300m OD) for settlement, probably because of the presence of open upland pastures (see also Waddell, 1991).

There is, however, a loose group of five wedge tombs (c.3000-2000) at Berneens and Glenisheen, on the upper slopes (150-200m OD) at the south end of the valley. It is perhaps more than coincidental that this area also boasts two undated prehistoric cairns as well as the find-spot of a Late Bronze Age, gold collar known as the Glenisheen Gorget. the only other evidence for settlement activity here in the Bronze Age, is a number of fulachta fia near Mám Chatha, on the eastern side of the valley.

The most common archaeological monuments in this valley are medium sized circular enclosures (20-60m in diameter), of which about two dozen have been identified to date. The majority of these are probably ringforts. When compared to the dearth of evidence for prehistoric settlement, the presence of these enclosures suggests that the valley floor may not have been opened up for dense settlement until the Early Historic Period (AD 400-1200, see Gosling, 1991a). This is further underlined by the presence of two probable early ecclesiastical sites, at Rathborney and Ballyallaban.

In view of the Burren's reputation as a stony place, it is interesting to find that some of the largest and most impressive enclosures in the Ballyvaughan Valley are constructed of earth i.e. Dún Torpa, near Rathborney, and An Ráth , at Ballyallaban. The former monument is a multi-vallate enclosure, suggesting that it may have been the residence of a chieftain, while the latter, with its water-filled moat, displays certain affinities with Anglo-Norman earthworks of the 13th century.

In medieval times (AD 1300-1600), the Ballyvaughan Valley formed the heartland of the O'Lochlainn clan who controlled the Burren uplands, and appear to have maintained a degree of independence from their overlords, the O'Brien dynasty of Thomond. The valley contains five of their late medieval castles (fortified tower houses), four of which are strategically located to control routeways. At least some of the valley's ringforts also continued to be occupied at this period, as the medieval gateway to Cathair Mhór testifies (see Gosling, 1991b).

Site 10. AUGHINISH DRUMLIN, M227 126 (W.P.W.)

The drumlins of the Burren are generally very poorly exposed so that both their composition and structure remain speculative (cf Finch and Walsh, 1973). A well exposed section, cut through a drumlin on the southwest coast of Aughinish in Galway Bay is an exception. The exposure, cut transverse to the drumlin crestline, is about 500m long and exposes an 8-10m vertical sequence of glacial sediments. The crestline is aligned 260°.

The glacial sediments take the form almost exclusively of horizontally bedded diamicton. The beds are conformable and grade one into the next. They are defined by the density of clasts contained within a silt-sand matrix. The particle-size distribution appears to be strongly bi-modal with the clasts suspended in the matrix. Extensive lenses of almost clast-free silt-sand also occur. Bed thickness is of the order 1-2m. Clasts are generally subangular to subround. They are commonly prolate and often well striated. Clasts are generally well dispersed and clusters are uncommon. Boulder pavements occur often at or close to the upper surface of a bed. Commonly the upper surface of a clast is polished bevelled and striated while the lower surface is rough and more angular. Clasts with rough upper surface and polished/striated lower surface have not been observed. The a-axis dip of clasts is generally low and vertical to near vertical clasts are very rare.

Preliminary fabric analysis indicates a strong preferred a-axis orientation of 256°. The drumlin crest line is aligned 2,600. Thus there is a very strong accord between ice direction indicators within the sediment and the morphological orientation of the drumlin.

All of the measured and observed characteristics of the diamicton point to deposition subglacially by active ice (cf Dreimanis, 1989). It contains the chief characteristics generally ascribed to a lodgement process (overconsolidated, strong fabric, boulder pavements), but the extensive nature of the "beds" would question a simple grain by grain plastering on process. The distinctive "bedding" and the concomitant sorting of the larger particle mode suggests a periodic depositional process in which each bed relates to a specific depositional period or event. The well mixed "pudding stone" appearance of each bed suggests a fluid bed but both over consolidation and strong fabric suggest direct glacial deposition. A deforming bed process is possible but there is no indication of pervasive deformation through the sediment pile (e.g. Boulton, 1987).

A number of conclusions are possible:

1. There were periods of very wet conditions below the ice sheet.
2. The ice sheet was mobile.
3. The sediment was probably water-saturated during at least part of the depositional process.
4. Following dewatering (at intervals) clast surfaces were glacially abraded.
5. Each bed might be regarded as having been a deforming bed.

A tentative overall interpretation is that the sediment pile was deposited sequentially as a series of deforming beds. Each one passed through a cycle in which it was first a water-saturated deforming bed then dewatered and became rigid, was overconsolidated and sheared by the overriding ice. The process envisages each incremental bed acting as a thin deforming bed which gradually dewaters and becomes over consolidated as it is plastered on to the underlying bed. During the latter stages of this process clasts are polished and striated and boulder pavements are formed. The system would be a very closely analogous to the application of quick drying wall plaster in a series of layers.

It is likely that such a process accompanied drumlinization given the close relationship between drumlin alignment and fabric orientation.

Site 11. TULLA (CROSSROADS) DRUMLIN, M365 029 (T.F.F. and W.P.W.)

An old aggregate pit is cut in a northsoutheast - southsoutheast oriented drumlin just north of Tulla Crossroads. This pit, although it now provides poor exposure of the sediment of which the drumlin is composed (but see Finch and Walsh, 1973), clearly illustrates that the drumlin is composed of three distinct diamicton beds each distinguished by the density and size of contained clasts (Finch and Walsh, 1973). Although lenses of sand and gravel occur, probably as interbeds, there is sufficient similarity between the sediments exposed here and those at Aughinish to suggest tha the depositional process described for the Aughinish Drumlin probably obtained here also.

The till matrix here appears to be more sandy than that at Aughinish. This, while it would facilitate dewatering, would probably render the saturated sediment less mobile. Nevertheless, there is sufficient evidence here to suggest a depositional process which may have been widespread in this area and probably other karstic areas of Ireland.

Site 12. MULLAGH MORE VEGETATION HISTORY R307 943 (W.A.W.)

The Burren, especially the eastern lowland from Ennis to Galway Bay is relatively rich in late-glacial and earlier Holocene sediments. Difficulties arise in the study of the later Holocene where fen peats or cutover bog do not provide satisfactory sediments for study. The difficulty was overcome at Gortlecka and at Rinn na Móna, both near Mullagh More (Figure 24 below) where small permanent lakes were cored from a raft to obtain younger records. The pollen diagrams (Figures 22,23) are rich in information, Gortlecka has sufficient radiocarbon dates to provide a satisfactory time scale. The main points to notice are the early abundance and disappearance of pine, the abundance of yew (Taxus) as pine declined at about 5,000 BP when the elm (Ulmus) fall can be seen. Yew subsequently became rare. In the last thousand years grass, (Gramineae) heather (Calluna) and bracken (Pteridium) record clearing of woodland or scrub for agriculture. It seems likely that the Burren has been forested

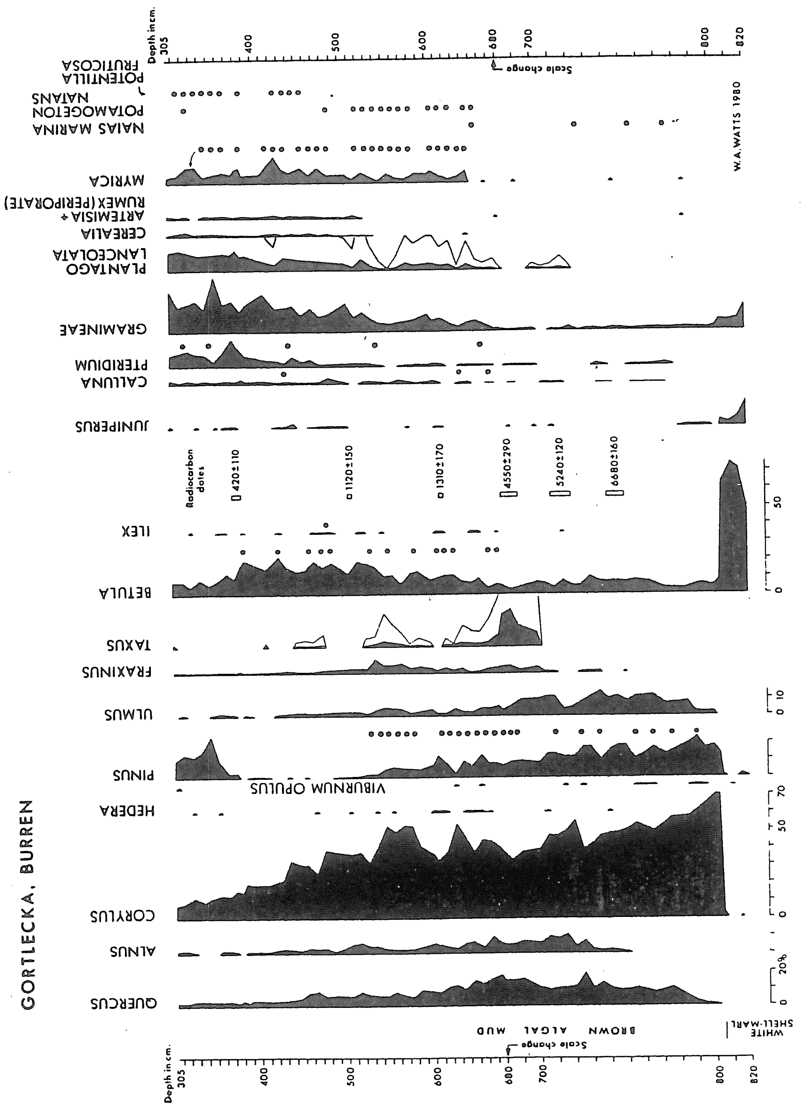


Figure 22. Pollen diagram from Gortlecka.

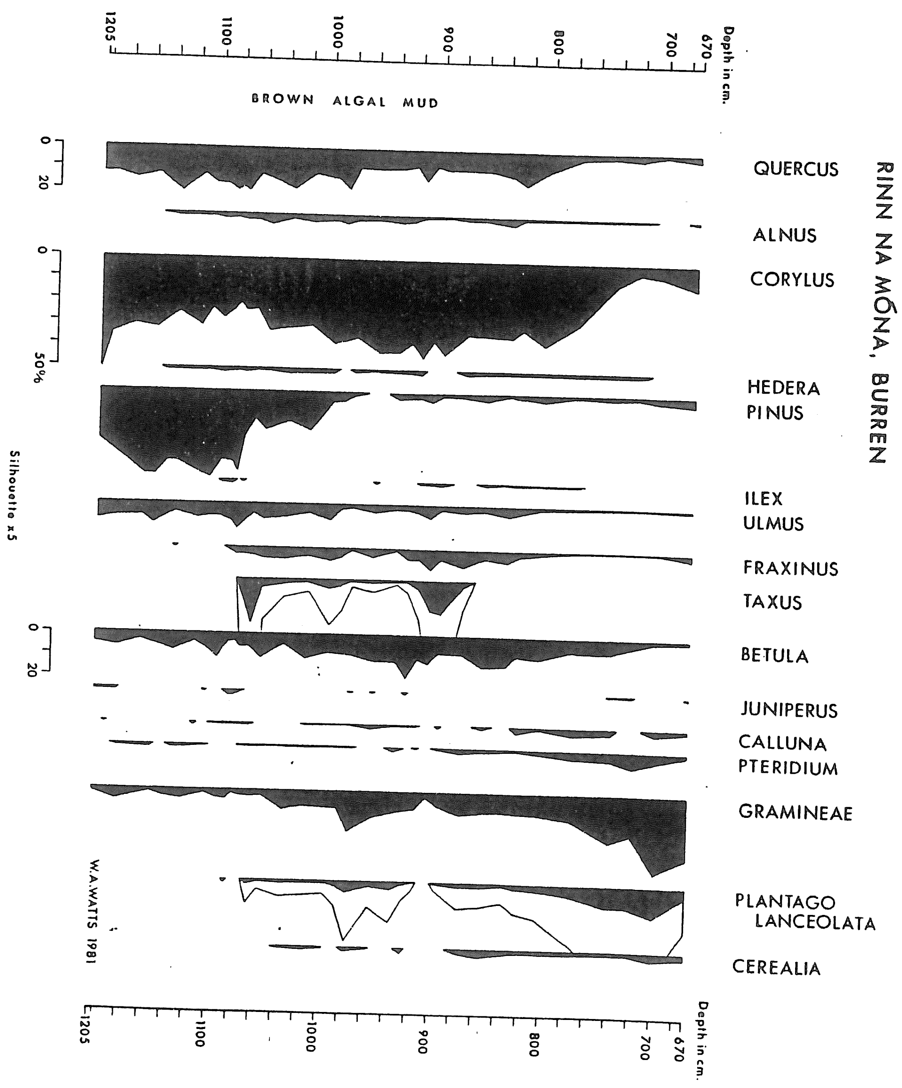


Figure 23. Pollen diagram from Rinn na Móna.

throughout the Holocene, though rock outcrops, cliffs and boulders will always have provided habitat for artic-alpine and other herbs. Macrofossils were collected at Gortlecka. The presence of the submerged aquatic *Naias marina*, now extinct in Ireland and with only one remaining station in Britain, points to an earlier Holocene of warmer summers and cooler winters, relating to well-documented changing patters of solar radiation. For further detail and regional context see Watts (1977, 1984).

Site 13. LURGA, S.E. BURREN. PRECONSTRUCTING THE LATE-GLACIAL ENVIRONMENT, R420 965

Pollen and lithological evidence (A.P., M.O'C. and C.C.H.)

Several late-glacial deposits have been identified, often in shallow basins, in the low-lying karstic landscape north of Tubber, south-eastern Burren. One such deposit is that at Lurga 6.34 km S.W. of Gort; Fig. 24) where, from a cutover bog, a 10 cm diameter core (LGA II), 140-323 cm below the present surface, yielded sediments that span the period from the end of glacial melt to the early Holocene (in the absence of ^{14}C dating, tentatively dated to c. 13 500—9 600 B.P.).

Pollen analysis has been carried out by Aa. Paus and physical measurements by C.C. Huang (Figure 25 and 26).

Six pollen assemblage zones (PAZs) are recognised as follows:

1. LGA II-1: Ericaceae—*Artemisia—Pinus* PAZ
   It is assumed that the Ericaceae curve represents reworked pollen of interglacial age; *Pinus*, on the other hand, is more probably long distance in origin. The *Artemisia* curve may reflect the presence of an *Artemisia*-rich open vegetation during the final stages of the pleni-glacial, or it too may largely reflect long distance transport.
2. LGA II-2: *Rumex—Salix—Empetrum* PAZ
   The rise in *Rumex* and Cyperaceae coincides with a rise in organic content of the sediment. These changes together with the rise in *Pediastrum* and *Botrycoccus*, followed by curves for *Typha/Sparganium*, *Myriophyllum* and *Littorella*, indicate climatic amelioration. Subsequently, *Empetrum* and *Dryas* curves are initiated which suggest the presence of an *Empetrum-Dryas* heath. *Salix* was also important. These vegetational developments suggest soil stabilization and humus formation.
3. LGA II-3: *Juniperus—Empetrum—Betula* PAZ
   Scrubby vegetation in which *Juniperus* has a major role dominates during this PAZ. The highest pollen concentrations are recorded here which suggests high pollen productivity, presumably in response to substantial climatic amelioration. Note the increased silt content and the decline in *Juniperus* and increase in Gramineae, Compositae, *Dryas* and *Gypsophila* mid way in the PAZ (indicated by broken line). These changes suggest a fairly severe climatic reversal that resulted in soil erosion and favoured species of more northern or arctic/alpine distribution today. In the upper part of the zone, *Juniperus* recovers but increased representation of taxa such as *P.*

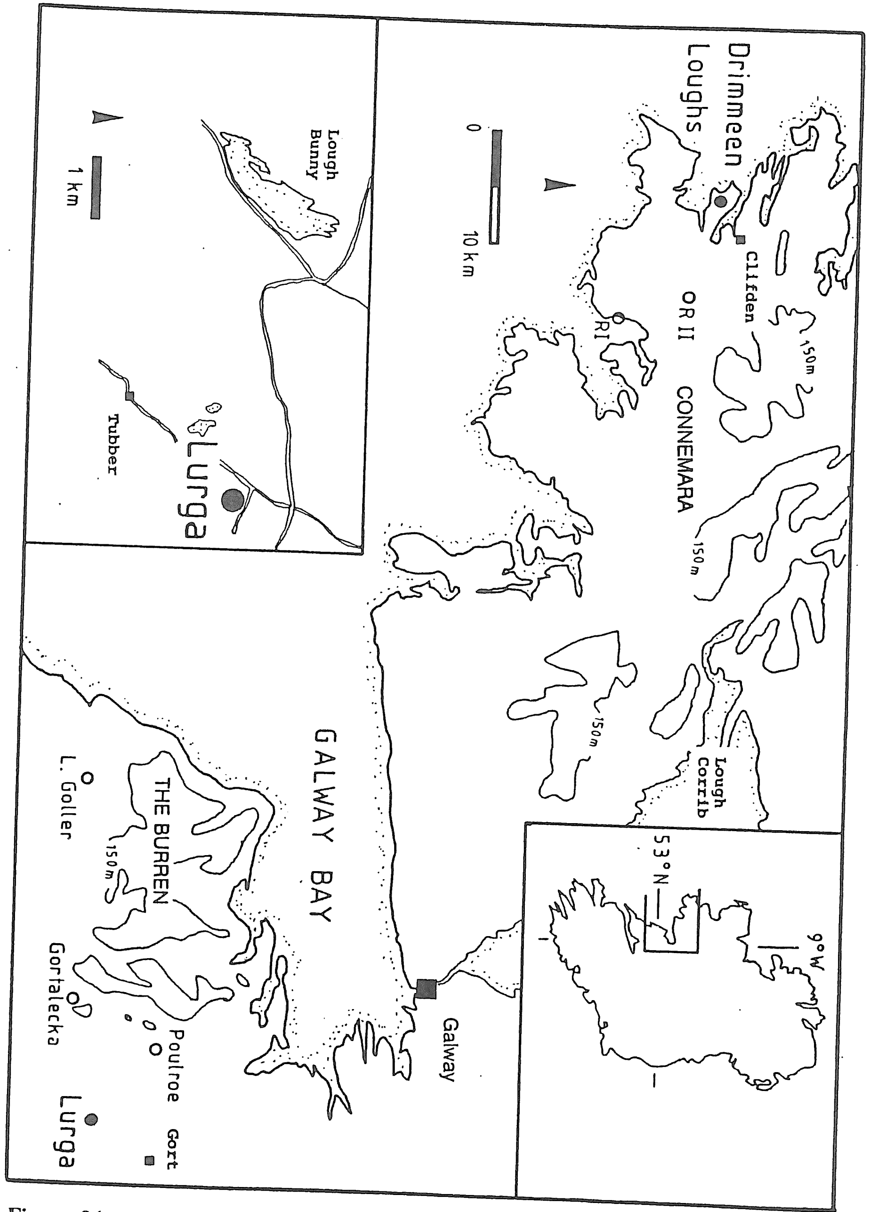


Figure 24. Location of lateglacial sites at Lurga and Gortlecka.

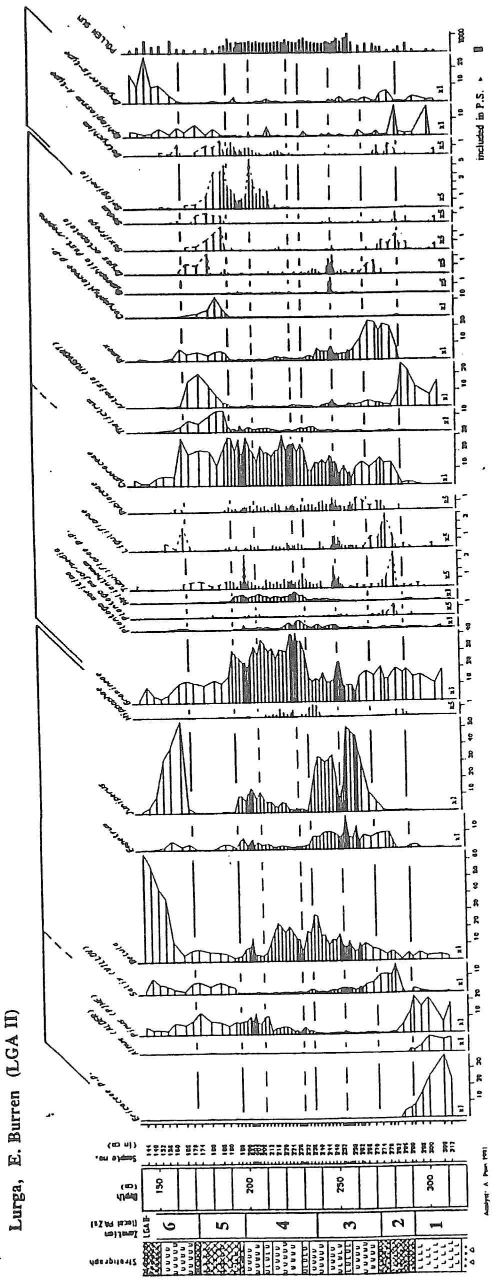


Figure 25. Percentage pollen diagram from Lurga (LGAII).

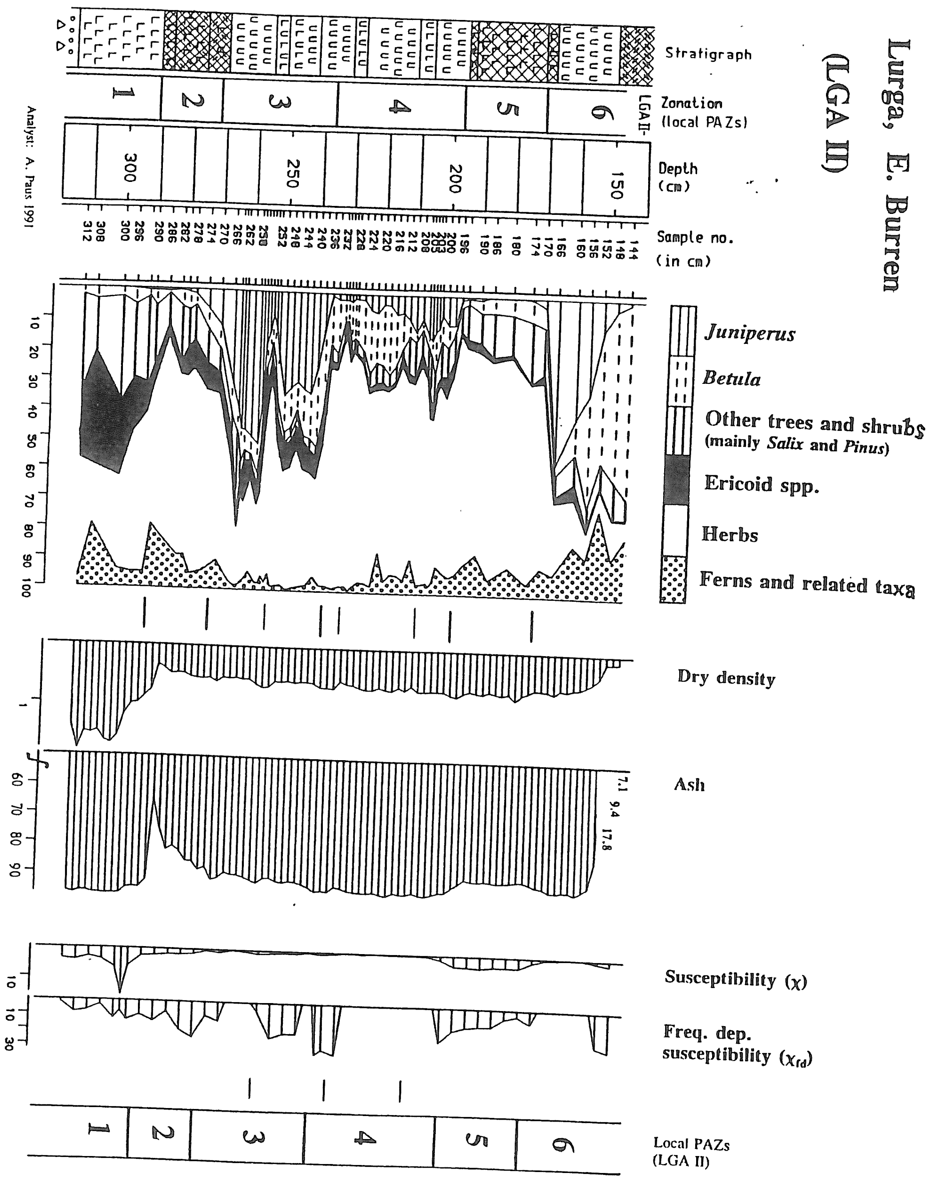


Figure 26. Composite percentage pollen diagram from Lurga (LGAII) and physical measurements from core LGAII.

maritima, *Helianthemum* and *Thalictrum*, indicate the presence of open herbaceous communities. Increasingly unstable edaphic conditions are also suggested by the *Hippophae* curve that is present near the top of the zone.

4. LGA II-4: Gramineae–Cyperaceae–*Helianthemum* PAZ
Scrubby vegetation is probably largely replaced by herbaceous communities dominated by grasses and sedges within this zone. The substantial *Helianthemum* curve and the curves of *Selaginella* and *Botrychium* suggest that these communities were quite open. *Betula* pollen concentration shows a more or less continuous decline within this zone, which would suggest that birch may have played only a minor role at this time. There is even the possibility that, like *Pinus*, the *Betula* curve in this zone is mainly the result of long distance transport. The broken lines indicate levels with increased silt which coincides with changes in the pollen assemblages that suggest climatic deterioration. The rise in *Juniperus* in the uppermost part of the PAZ may be in response to a climatic amelioration immediately preceding the Younger Dryas cold period.

5. LGA II-5: *Artemisia–Thalictrum* PAZ
The rise in *Artemisia*, *Thalictrum* and Caryophyllaceae, and the more or less continuous presence of *Dryas*, *Saxifraga* and *Sedum* pollen mark the return to cold conditions characteristic of the Younger Dryas period (c. 11 000 to 10 000 B.P.). Highly unstable soil conditions are reflected in the high silt content of the sediment.

6. LGA II-6: *Juniperus–Betula* peak zones
The re-establishment and expansion of *Juniperus* scrub followed by the rise in *Betula* recorded in this zone is presumably in response to a rapid rise in temperature that is generally accepted to have taken place at the beginning of the Holocene. The significance of the lithological change from marl to peat that is recorded within this PAZ probably reflects a lowering of water-table level. This may simply be a consequence of sediment accumulation or it may be caused by changes in precipitation and evapotranspiration in the early Holocene. The possibility that the development of a karst hydrology is also involved cannot be excluded.

It is of considerable interest to know how far the changes in lithology and pollen assemblages recorded here are site specific or do they indeed reflect changes that are regional in character and hence most likely attributable to climatic change? The consistency of the main lithological features in several basins in the area north of Tubber – e.g. the organic-rich layer near the base of the sequence, the silt-rich layers (1 conspicuous layer at base; upper two faint) within the marl deposits, the silty Younger Dryas layer followed by marl which after about 20 cm, gives way to peat – suggests that LGA II profile is recording changes that are of regional significance. It remains to be demonstrated if the pronounced erosional phase recorded in the middle of LGA II-3 (early Allerød, *sensu lato*) is equivalent to the Older Dryas event that has been recognised by many palaeoecologists in north central Europe.

Mollusc and ostracod evidence (J.G.E. and H.I.G.)

For the mollusc and ostracod analyses, a 5 cm diameter core was used [LLM I(A)] that was taken within 50 cm of LLM II using a Livingstone sampler. Alternate 5-cm thick samples were analysed from between 160 and 300 cm. Additional samples were analysed for

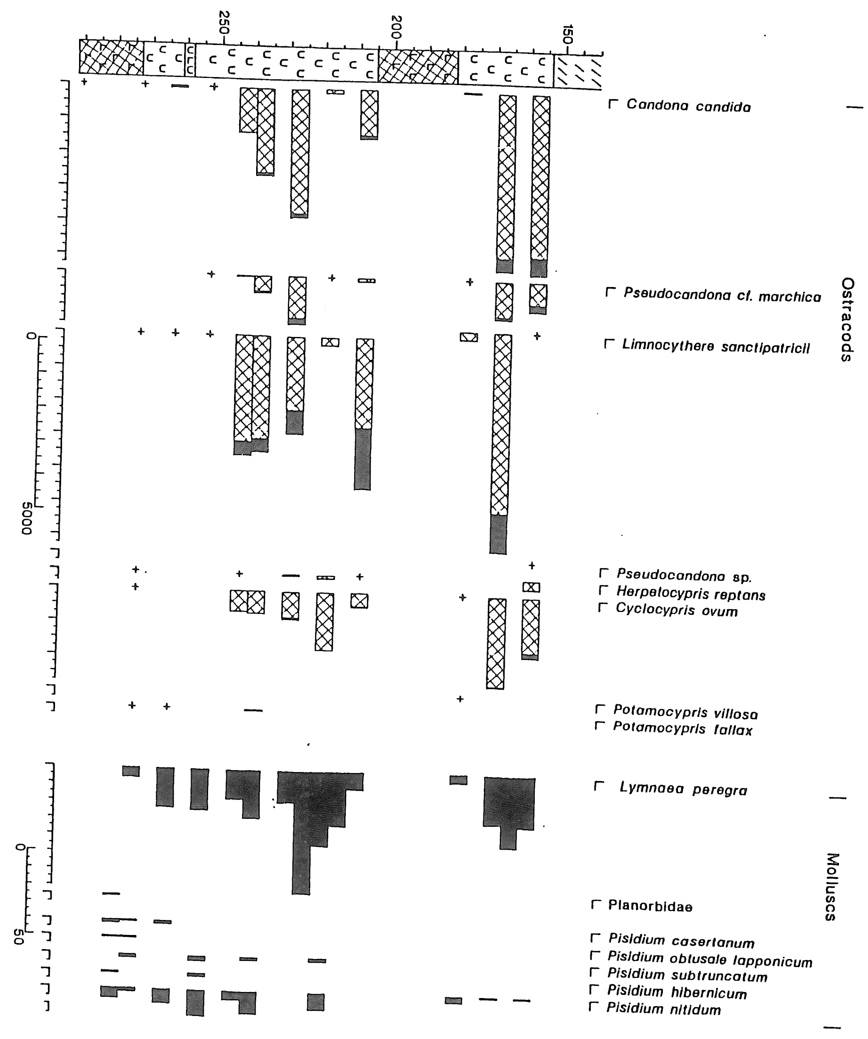


Figure 27. Ostracod and mollusc counts from core LGAII (A) from Lurga.

molluscs(160-165, 210-215, 220-225, and 275-280 cm).

The molluscan fauna is a very impoverished lacustrine one, consisting mainly of *Lymnaea peregra*, with five species of *Pisidium*, mainly *P. nitidum* (Figure 27). The low species diversity almost certainly reflects the immediate location rather than the basin as a whole because many other species are known from the Woodgrange (=Allerød, *sensu lato*) period in Ireland.

In the lower part of the sequence, *Pisidium* are relatively abundant in comparison with *Lymnaea peregra*, probably indicating a stable muddy substratum in the lower or eu-littoral. The presence of the cold-climate arctic form, *P. obtusale lapponicum*, is noteworthy. Higher up, both in the Woodgrange deposits and the early Holocene, the fauna is predominantly *L. peregra*. The reduction in *Pisidium* is possibly due to the formation of marl which clogged the filter-feeding apparatus of the organisms. The absence of a rich phytic fauna indicates a paucity of plant remains and a location away from the upper littoral. The absence of fauna in the Younger Dryas deposits may be as much due to lack of preservation as to a real absence at this time.

It should be borne in mind that to make a comprehensive study of the molluscan fauna of lake marls, it is necessary to analyse several cores across the basin to get a full picture. This was not possible in this instance.

The ostracod fauna within the cores is extremely rich, although of a low species diversity. Ostracod valve counts are based upon calculations made from the operation of a randomised sampling regime.
The ostracod fauna is predominantly composed of the bottom-dwelling species *Limnocythere sanctipatricii*, *Pseudocandona* cf. *marchica* and *Candona candida*, augmented by the phytic species, *Cyclocyris ovum* and *Herpetocypris reptans*. In addition, *Potamocypris villosa* is present in the Holocene deposits, and *P. fallax* during the Woodgrange period. Throughout the sequence, the ratios of juvenile valves to those of adults indicate *in situ* preservation of benthic taxa, but suggest some small degree of sortage of phytic taxa.

The benthic species are typical of the shallow eu-littoral of cool water-bodies. All species are present in Great Britain and Ireland today, with the possible exception of *P.* cf. *marchica*, which has a continental distribution. It is of interest that the faunal succession following the Younger Dryas is essentially identical to that of the Woodgrange period, however, as with the molluscs, ostracods are absent from the Younger Dryas deposits.

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