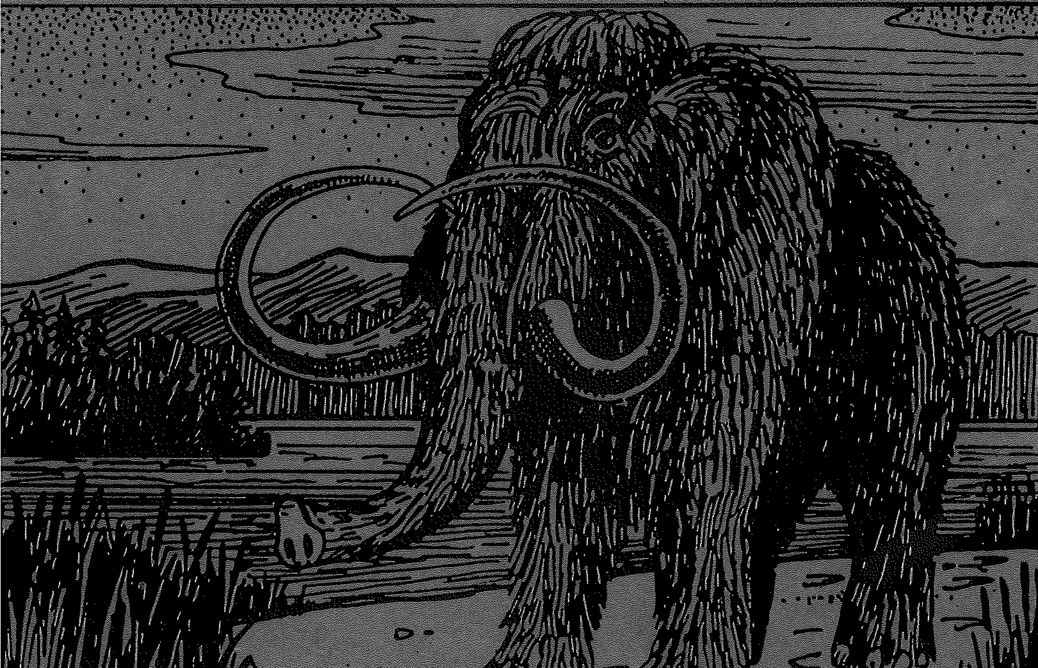
SOUTH-EAST ULSTER

Field Guide

Edited by A. M. McCabe and K. R. Hirons

Quaternary Research Association and
Irish Association for Quaternary Studies



1986

FIELD GUIDE TO THE QUATERNARY DEPOSITS OF SOUTH-EAST ULSTER

Compiled and Edited by
A.M.McCABE and K.R.HIRONS

Annual Field Meeting, Dundrum
County Down, 11–14th April 1986.

Quaternary Research Association and
Irish Association for Quaternary Studies

Cover illustration: An artist's impression of a Late Pleistocene Mammoth. Cover designed by J. Shaw.

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ANNUAL MEETING, 11-14 APRIL, 1986

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UNPUBLISHED MATERIAL

This guide contains unpublished data. Permission to make reference to any of it should be obtained from the authors concerned who are named at the beginning of each section.

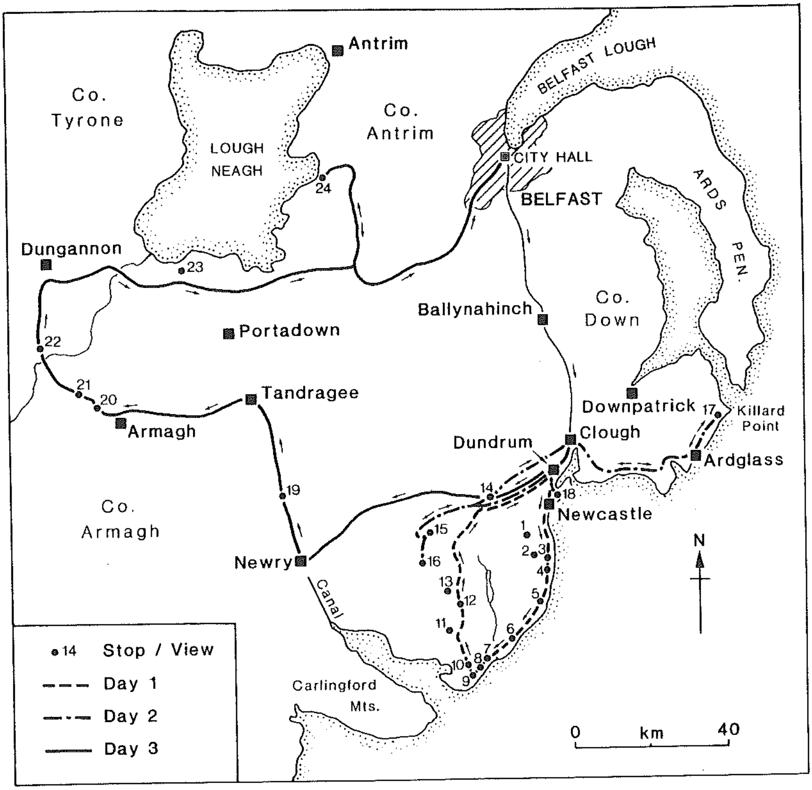

Fig. 1 Field trip route

SOLID GEOLOGY (G.H.N.)

There can be few areas of the world with such varied geology as the north-east of Ireland, for within 100km of Belfast it is possible to see representatives of every geological system and products of almost every major rock-forming process. In terms of the solid geology the area falls into four main landscape units; the basalt plateau of Co. Antrim in the north, the lowlands of the Lower Palaeozoic Down-Longford triangle, with the granitic intrusions of the Mountains of Mourne and Slieve Croob, in the south, and to the west, the Dalradian metamorphic uplands extending from the Sperrin Mountains into Donegal (Fig. 2). In the south-west, a fifth area of lakes and low hills developed on Devonian and Carboniferous strata marks the northward extension of the Central Plain of Ireland. Over large areas this foundation is completely obscured by drift deposits.

1. The Precambrian basement. The oldest rocks in Northern Ireland belong the the late Precambrian, Dalradian supergroup, and are a continuation of the Scottish outcrops. They are mainly schists and schistose grits, with thin limestones and some quartzizites. The latter are more important in the west where they form the most prominent hills. The main outcrops are in the Sperrin Mountains, with a smaller area underlying the barren, high moorland between Cushendall and Ballycastle in the north-east. In both these areas the rounded hills are covered with thick peat and the uplands are dissected by valleys choked with glacial sand and gravel.

2. County Down-Lower Palaeozoic lowlands and granite hills. Rocks of Ordovician and Silurian age underlie most of the south-east of the province. Although in both structure and stratigraphy they are a westerly extension of the Southern Uplands of Scotland they form a much more subdued landscape, planed across by an erosion surface at about 150m and mantled with thick glacial drift. The rocks are mainly graywackes and shales, complex in both stratigraphy and structure.

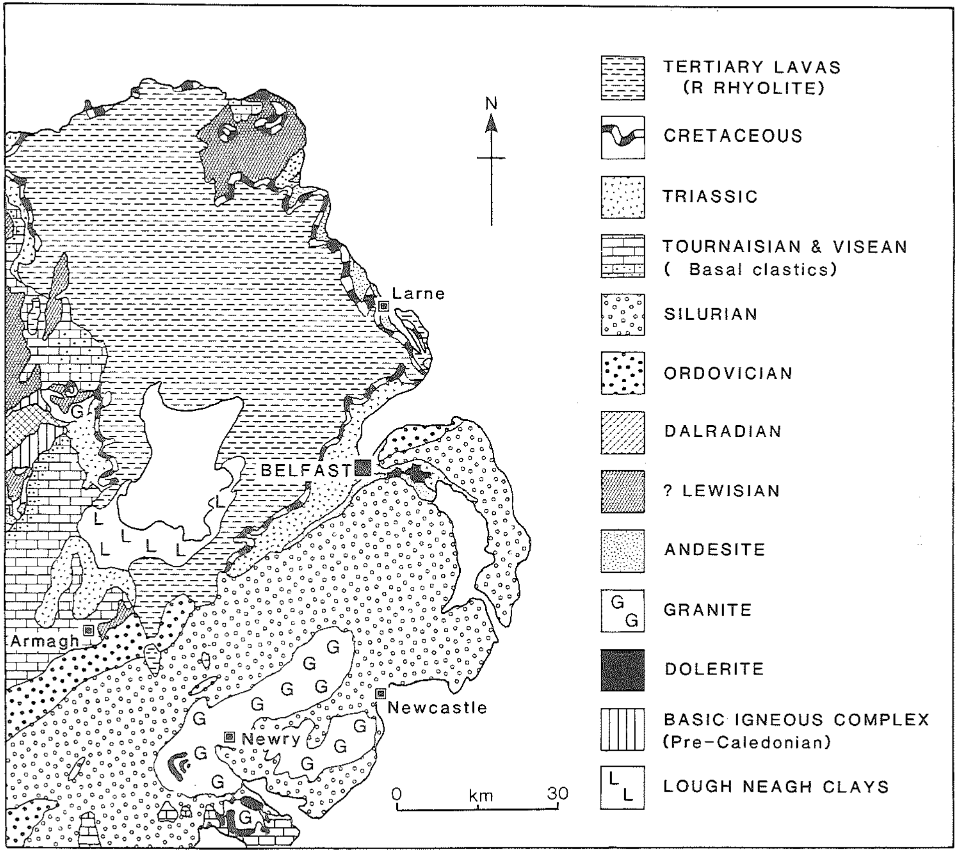

Fig. 2 Solid geology of Eastern Ulster (after Wilson, 1972).

Their most noticeable noticeable influence on the landscape can be seen in the alternation of belts of shale dominated distal, and graywacke dominated proximal turbidite sequences, the latter forming rocky, gorse-covered ridges (often quarried for their high quality roadstone) and roches moutonnées. Into these country rocks have been intruded two granitic masses; the Caledonian Newry Granodiorite running west from Slieve Croob into south Armagh, and the Tertiary granite complex of the Mountains of Mourne.

The 150km^2 of the Mourne granites is the largest Tertiary granite outcrop in the British Isles and consists of five overlapping ring-fault intrusions. The three nearly concentric granite arcs of the Eastern or High Mournes are almost detached from the only partially unroofed Western or Low Mournes by a screen of hornfelsed country rock running south through the Spelga Pass and Deer's Meadow.

In the south, between the Mournes and the sea, lies the Kingdom of Mourne, an area where thick spreads of glacial sand and gravel completely obscure the Silurian bedrock. A geological 'surprise' in this area is the outlier of Carboniferous limestone forming the point (Cranfield) and flat reefs at the mouth of the magnificent fiord of Carlingford Lough.

3. The Basalt Plateau of County Antrim and Lough Neagh Lowlands. The basalt lavas, which cover an area of some 4000km^2 mainly in Co. Antrim, are one of the most striking features of Ulster geology. They are a small remnant of the vast lava fields which covered the north-west of Britain in Tertiary times. Since then, late Tertiary step faulting, which defines the north and east coasts, and considerable erosion of the margins (the lavas must have extended at least as far south as Dundalk), has isolated the Antrim Plateau and formed the spectacular escarpments around its margins. The lava plateau overlies and protects a relatively thin Mesozoic succession (strata which are largely absent elsewhere in Ireland) of chalk, local basal greensand, and Lower Jurassic marine clays. The latter, although only a few tens of metres thick, plays a significant part in the landscape,

forming an important spring line at the base of the chalk. It forms the slide plane for a series of major rotational slumps along the edge of the escarpment and is the source of many active mudflows. The basalt lavas reach a maximum thickness of 1000m and are divided into the Lower Basalt, a widespread formation forming the escarpment overlooking Belfast and the cliffs of the Antrim Coast Road; the Upper Basalt, which occurs mainly as outliers on the higher hills in the north and east, and by an interbasaltic bed of lateritised basalts, residual bauxites and iron ores. In north east Antrim, the profile of the hills often show a prominent step at the position of the Interbasaltic Bed and along this level the brightly coloured spoil tips of old iron ore workings can still be seen. Along the north coast, a more localised series of basalt flows, the Middle or Causeway Basalts, interrupted the interbasaltic hiatus. These basalts are unusually fine-grained and exhibit excellent columnar jointing, most spectacularly displayed in the Giant's Causeway.

Associated with the Antrim lavas is a great range of volcanic features and minor igneous intrusions, including the Slemish plug which rises prominently above the plateau east of Ballymena, a dense swarm of basalt dykes running north - south across the entire area, and the great sill of Fair Head. The latter is well known for its glacially striated rock pavement, and forms, at the north-eastern tip of Ireland, a promontory so distinctive as to be recognisable even on Ptolemy's charts.

Although the geology of Co. Antrim is dominated by igneous rocks, there are three significant exceptions; at Cushendall, on the east coast, where a thick wedge of Old Red Sandstone conglomerates and volcanic rocks accumulated along the northern edge of the Midland Valley; around Ballycastle, in the northeast, where a faulted inlier of coal-bearing, Lower Carboniferous strata rests on Dalradian basement and looks like a westerly extension of the Midland Valley of Scotland, despite its position north of the Highland Boundary Fault; and in the Lough Neagh Basin.

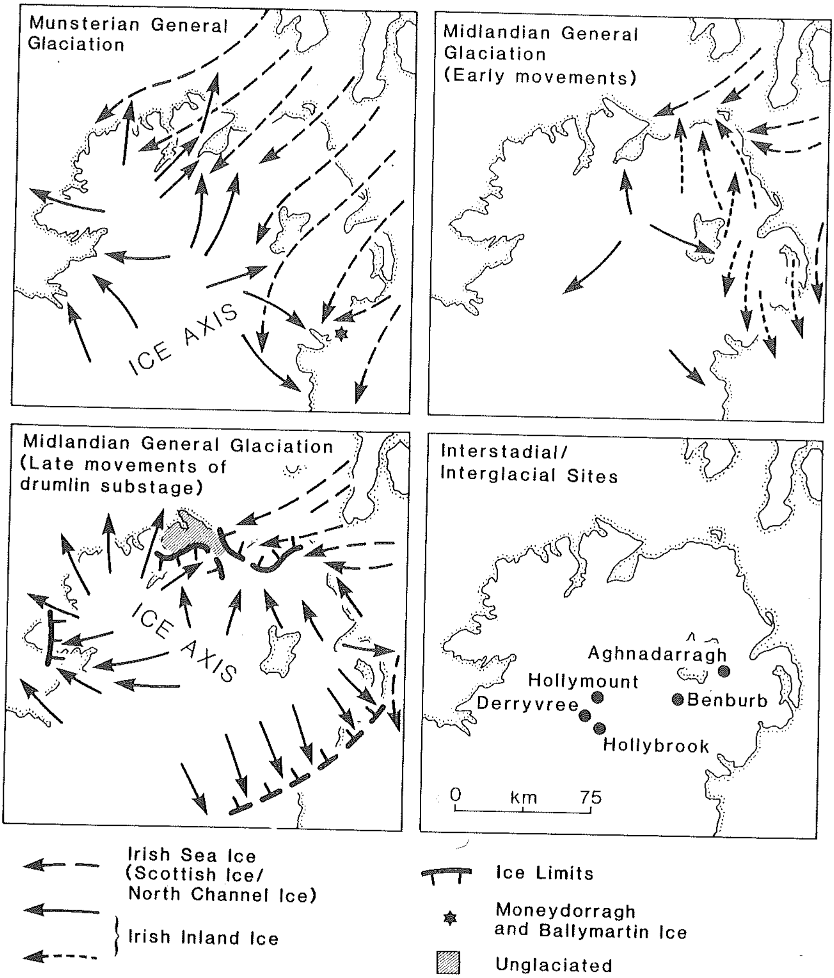

Fig. 3 Major directions of Late-Pleistocene ice flows in Ulster

With the waning of the volcanic activity, the centre of the basalt plateau subsided to become the site of an extensive lacustrine basin during Oligocene times. In this basin were deposited the Lough Neagh Clays, Kaolinitic clays with deltaic sands and gravels and beds of lignite. Some of the lignite seams have recently been found to exceed 6m in thickness and preparations are currently being made to mine reserves estimated at more than 400 million tonnes from an open cast pit near Crumlin, on the east side of Lough Neagh. These Tertiary sediments are poorly exposed. Much of the outcrop lies beneath the present day lake, while on land they are covered with thick glacial drifts and peat. Recent work suggests that the currently mapped outcrop, restricted largely to the Crumlin area and the district to the southeast of the Lough, is very much an underestimate.

QUATERNARY DEPOSITS - AN INTRODUCTION (A.M.M., K.R.H.)

Reconstructions of the Pleistocene chronology of north eastern Ireland have been based on the distribution of till lithofacies, till fabrics, drumlins, erratics, borehole records and on various types of ice limits (Mitchell *et al*., 1973; Stephens *et al*., 1975; Bazley, 1978). However, these summaries not only have different objectives but have been hampered by the relative absence of datable organic horizons and the fact that most lowland landforms date from the Drumlin Substage (Fig. 3). These approaches and the resultant stratigraphies often incorporate the following:

1. Extensions of Quaternary time spans in the absence of datable intraformational organic horizons and distinct marker horizons.
2. Type sites and lithostratigraphic sequences, which in the absence of facies analysis, may be of local importance only.
3. Interpretations tend to be based on conceptual models of terrestrial based ice sheets.

4. Multiple lithostratigraphic sequences are often identified with advance, retreat and readvance of ice sheets. In this respect massive diamictons are invariably considered as basal ice deposits with little discussion of alternative modes of origin.
5. Complex sequences are often split into notional units which are then given a formal status. However, in some cases lithofacies are either laterally equivalent or interbedded.
6. Complex local lithostratigraphies which are known only from a few coastal exposures have been used as the basis for successive ice sheet glaciations and/or advance/readvance phases. This approach has been widely used in Ireland where large mountain masses are located on the periphery of the island. Caution is necessary for a number of reasons. First, lithostratigraphic variability will be influenced strongly by topography. Second, in the absence of good stratigraphy within the mountains (due to intense erosion?) it is extremely difficult to define the contribution of ice from the higher ground. Third, it is in these peripheral zones where isostatic depression is recorded and the possibility exists that some unfossiliferous sequences are essentially glaciomarine in origin.

It should be stressed however that the undoubted weaknesses in direct Pleistocene chronology is largely due to lack of suitable exposures and the presence of thick drumlin sequences.

It is generally agreed that north eastern Ireland was influenced and indeed almost totally covered by two major ice sheets of distinct provenances. The earlier is often attributed to the Munsterian Cold Stage but opinions differ as to its age (Mitchell et al., 1973; Warren, 1985). The latter occurred towards the end of the Midlandian Cold Stage. Evidence for the penultiminate glaciation comes from the distribution of Ailsa Craig microgranite and shelly till which may be found along the eastern fringe of Ulster (Fig. 3).

This pattern suggests that ice from Scotland engulfed much of north eastern and eastern Ireland (Stephens et al., 1975). During the late-Midlandian the influence of Scottish ice was weaker and ice advanced north and south from an axis of ice dispersion in north central Ulster (Stephens et al., 1975). Important shifts occurred in the position of this ice axis during the coarse of glaciation (McCabe, 1969; Dardis, 1982). In some cases multiple tills from drumlin sequences have been used to identify early and late phases of this glaciation (Hill and Prior, 1968; Stephens et al., 1975; Bazley, 1978). However, caution is necessary when drumlin tills are used as direct glacial stratigraphy because drumlin formation itself must be viewed in terms of a dynamic subglacial bedform system which included lodgement, melt-out, subglacial cavity sedimentation , resedimentation, meltwater and debris flow activity (Dardis and McCabe, 1983; Dardis, 1985).

Recent work by Gennard (1984) on a subtill peat deposit at Benburb (Boulter & Mitchell, 1977) has highlighted some of the problems which emerge when an interglacial peat is found in Ireland. It is suggested that the palynological differences and similarities between the peat at Benburb and other Gortian sites may simply reflect the effects of geographical and climatic differences on vegetation within the island. Watts (1985) has emphasised the floristic similarities between the Gortian style of deposit and so-called Hoxnian deposits in England. Warren (1979) strongly advocates that the Gortian must be of last interglacial status largely because there seems to be neither biostratigraphic nor lithostratigraphic evidence of a later interglacial (cf. Mitchell, 1976; Watts, 1985).

Some of the environmental changes which occurred during the last cold stage in the north of Ireland are now emerging. Four important sections at Hollybrook, Hollymount, Derryvree and Aghnadarragh suggest the following tentative chronology:

(i) An Early Midlandian Glaciation in central and western Ulster. The limits of this are largely unknown but the lower tills at Hollymount, Derryvree and Aghnadarragh are unweathered and are overlain directly by organic deposits of early and middle Midlandian age.

(ii) Cold, periglacial conditions. Evidence for this phase occurs at Hollybrook where a head deposit is sealed by a drumlin forming till. The Mammoth remains at Aghnadarragh probably relate to this general phase.

(iii) A warm phase with pine forests and a beetle fauna of warm aspect in the lower peat at Aghnadarragh.

(iv) A deterioration of climate with the formation of the Derryvree silts (30,000 yrs. b.p.). An upper bed of peat at Aghnadarragh is probably of the same general age though no 14C dates are yet available.

(v) The Late Midlandian glaciation which comprises a phase of ice sheet growth prior to the Drumlin Substage and covered most of Ulster.

(vi) Late-glacial periglacial conditions with growth of ice wedges.

The surface morphology over vast areas of lowland Ulster is dominated by a wide variety of drumlins which vary morphologically, spatially and sedimentologically. Recent work on the internal structure and sedimentology of drumlins in Ulster has focused attention on the conditions which prevailed at the ice-substrate interface during drumlin formation (Dardis & McCabe, 1983; Dardis, McCabe & Mitchell, 1984; Dardis, 1985). It was concluded that vast quantities of meltwater were stored at the ice-substrate interface during drumlin formation and this contributed to ice sheet instability. Drumlinisation probably occurred during surging conditions when subglacial hydraulic processes played an important role in drumlin formation.

The drumlin swarms of Ulster (and elsewhere in Ireland) are fronted by large morainic complexes which are composed of complexly interbedded diamicton, mud, sand and gravel sequences (Stephens & McCabe, 1977; McCabe et al., 1984). Although most of these sequences are subaqueous in origin they have been interpreted in terms of terrestrially based ice sheet models. The latter interpretation has been questioned recently by McCabe et al., (1984) who consider that the complex sequences in east and south County Down are glaciomarine in origin. The fact that the sequences are draped and are interbedded with a regional drape of red clay suggests a glaciomarine origin. This idea is supported by the pattern of high level, late-glacial raised beaches which do not penetrate within certain ice limits. Recent 14C and amino acid assessments from glaciomarine shells in County Mayo suggest an age of 17Ka for the maximum of the Drumlin Substage.

Heights of late- and post-glacial beaches along the coast of Ulster reflect the interplays of isostatic and eustatic controls during and after the late Midlandian deglacial (Stephens and McCabe, 1977; Carter, 1982). Carter (1982) has outlined the difficulties of interpretation involved during reconstruction of the precise course of sea-level movements especially along a coast of wide environmental contrasts. Interpretative problems include the sedimentological and geomorphological evolution of the coast in terms of dwindling Holocene sediment supplies palaeo-wave and -tide regimes and likely morphodynamic changes (Carter, 1982).

Late-glacial pollen profiles from northeastern Ireland have usually been zoned using the semi-lithostratigraphic system of Jessen (1949). It has been modified where sequences do not conform to these criteria (Singh, 1970). The biostratigraphic approach Watts (1977) recognised the wide regional variation in late-glacial vegetation and the likely diachroneity of vegetation changes. Inter-drumlin hollow sediments from southeast Ulster have provided late-glacial sequences from three sites including the Irish interstadial type-site at Woodgrange (Singh, 1970; Mitchell et al., 1973). These are undated. At Roddan's Port on the Ards Peninsula radiocarbon dates were obtained from late-glacial inter-drumlin hollow sediments but the assays were problematic (Morrison & Stephens, 1965). Subsequent attempts to resolve the problems using 14C dating of organic fractions was only partially successful (Dresser, 1970).

The problems of assigning a confident chronology to late-glacial pollen assemblages are illustrated by the apparent lack of a single unequivocal 14C date for the late- to post-glacial boundary (Edwards, 1985). Areas of calcareous substrate frequently produce dates at this boundary which are affected by hardwater errors due to incorporation of 14C deficient carbon (Sutherland, 1980) and, in peat deposits, where rootlet penetration in basal peat layers may give falsely young dates (e.g. Goddard, 1971).

Reconstruction of late-glacial vegetation diversities based on pollen evidence has highlighted the contrast between areas of Juniperus-Empetrum scrub and more open grassland dominated communities, (Pilcher & Larmour, 1982). In Ireland the distribution of birch was generally patchy in the late-glacial (Watts, 1977; Mitchell, 1981) and distinctly less complete than in Britain. Attempts to elucidate the local variability of late-glacial vegetation in the north of Ireland are now underway (Turbayne, 1985). The estimation of pollen accumulation rates, which may be very important in open landscapes has already been successfully applied to late-glacial deposits in south eastern Ireland (Craig, 1978).

Sites from the north eastern Ireland have been used in the large-scale reconstruction of European vegetation patterns by Huntley and Birks (1983). However, major problems exist in the detailed study of the local development of post-glacial woodland. These include:

1. Northeastern Ireland lies near the sites of several postulated landbridges between Britain and Ireland which have been invoked as preferred routeways for flora and fauna recolonisation following early post-glacial climatic amelioration (see Devoy, 1985 for map of suggested locations). Recent reviews of the landbridge question (Devoy, 1985; Synge, 1985) disagree on the most likely site and nature of the links (discontinuous, temporary islands between Islay to Donegal or a broad landbridge across the south Celtic Sea). However, the authors agree that any link would have been breached by the start of the post-glacial and, as such, landbridges are probably not a relevant consideration in the recolonisation by major tree species (other than juniper, birch and possibly hazel) which were not in Ireland by this date.

2. It has been suggested that the expansion of Corylus, Quercus and Alnus into the uplands of the north of Ireland was delayed, possibly by climatic factos (Pilcher, 1969; Smith & Pilcher, 1973; Pilcher & Larmour, 1982). Alnus, for example, was able to colonise suitably damp lowland areas in north and east Ulster as early as c.7500 b.p. (Morrison, 1961; Battarbee et al., 1985). However, the major expansion of Alnus pollen in the uplands of central Ulster was delayed for up to 2000 years to around 5500 b.c. shortly before the elm decline.

3. Pinus was present in many parts of the country by 7500 b.p. but was pushed back from much of lowland Ireland after the general expansion of Alnus of produce a distinctly western and northern distribution (Bennett, 1974; Bradshaw, 1985). After c.4000 b.p., remaining Pinus populations showed a general decline and became extinct in many of these refuge areas (but see Watts, 1984; Bradshaw, 1985). This pattern suggests an explanation involving an initial reduction mainly in lowland and waterlogged habitats, possibly related to direct replacement by Alnus (Bennett, 1984). Surviving Pinus on upland, poorer

and better drained soils was reduced later, possibly due to swamping by expanding bogs and the activities of early man (Pilcher, 1969). Reductions have also been attributed to significant changes in the water levels of these lakes between c.6000-8000 b.p. (O'Sullivan et al., 1973; Thompson, 1973). Stratigraphic changes or hiatuses in the sediments of lakes widely dispersed within the Lough Neagh catchment (Hirons, 1983, 1984; Hamilton, 1985) suggest widespread hydrological changes supporting the suggestion of Jessen (1949) and Smith (1970a) of a change to moister climatic conditions c.7000 b.p. (at the start of the Atlantic period). At Lough Neagh, a reduction in water level of up to 12m below present has been suggested when seasonal flooding deposited laminated silts in smaller vestigial lakes. Recent observations on diatomite deposits to the north of the Lough Beg show that water levels must have risen to around present levels by c.7000 b.p. (Smith, 1981).

Few Mesolithic (before c.5500 b.p.) sites are known from south Co. Down but coastal sites further north around Strangford Lough, along the Antrim coast and in the Lower Bann Valley are well known (Jope, 1966; Woodman, 1978, 1985a,b). The question of Mesolithic impact on vegetation and the nature of the Mesolithic/Neolithic transition in Ireland are cause for continuing debate (e.g. Smith, 1970b, 1981; Burenhult, 1980; Woodman, 1980, 1985b; Edwards, 1985b, in press). Central to these debates will be the provision of more complete distribution information for the Mesolithic, particularly inland and lacustrine sites (Woodman, 1985b) and the supplementing of the pollen record, notably with charcoal analyses (e.g. Hirons, 1984a, 1984b; Bradshaw, 1985; Edwards, 1985b).

The interdependence of pollen taxa in the percentage method of pollen data presentation is also problematic in the post-glacial where landscapes are open or where large changes are taking place in the proportions of important species.

Absolute pollen data (accumulation rates or concentration data) may be estimated where firm dating is available and where sediments can be assumed to have accumulated in a reasonably orderly fashion. These criteria are usually best fulfilled in lake sediments but Holland (1975) successfully calculated pollen influx for critical horizons in peat profiles from Co. Down. Using concentration data from sediments of four lakes from Co. Tyrone, Hirons & Edwards (in prep.) were able to confirm the percentage elm decline in absolute terms, demonstrate that herb pollen concentrations increased and showed that other tree types had only minor changes as elm declined.

In Co. Down, Holland (1975) has shown the potential of pollen analysis for answering questions about the spatial and altitudinal differences in forest regeneration following Neolithic clearances. Pollen records from bogs at low altitudes show an abrupt end to farming and complete forest regeneration whilst, at higher elevations, farming declined gradually and regeneration was not complete. The effect of climatic change and long periods of agricultural exploitation would have become critical after Late Neolithic and Early Bronze Age clearances. Climatic thresholds towards moister conditions seem to have been crossed earlier in Ireland than in Britain (Tinsley, 1981). The relative contributions of these two factors to soil deterioration and the spread of peat is a matter for debate. Further investigations, specifically aimed at testing peat initiation hypotheses, are required (Goddard, 1971; Smith, 1975; Edwards, 1985a).

The Early Bronze Age is the first period showing clear evidence for occupation throughout Ireland although the impact has traditionally been considered greater in the uplands where soils may have been lighter and woodland thinner. Thus, low-lying and boggy drumlin areas, such as are found in much of Co. Down, often show little evidence for settlement before the Early Christian period. Palynological studies of such areas in Co. Tyrone do, however, show considerable activity from the Neolithic period (c.5500 b.p.) onwards. The Early Bronze Age there was a particularly important period in terms of forest clearance and initial soil erosion which was not surpassed until the intensification of farming following the English plantations early in the seventeenth century (Hirons, 1984).

Evidence for soil erosion in the Iron Age (c.500 b.c. -430 A.D.) or Early Christian (5th - 12 centuries A.D.) periods in the lowlands of south Co. Down comes from inwashed soil horizons at Magherlagan (Singh & Smith, 1973). The dating of this event is not secure. This is matched with evidence for upland erosion from layers of gravel incorporated into peats and associated with pollen evidence for intensification of farming activity in the Mournes (Smith & Hirons, 1985).

DAY 1 : SATURDAY, 12 APRIL, 1986

THE GLACIAL LANDFORMS AND DEPOSITS OF SOUTH COUNTY DOWN (A.M.M.)

ITINERARY (Sites 1 - 5 are viewing stops);

Site 1 Glen River: Corrie

Site 2 Sl. Donard/Chimney Rock Mt: Solifluction deposits

Site 3 Bloody Bridge: Lateral moraine

Site 4 Dunmore Head: Ridge moraine and outwash

Site 5 Mullartown/Annalong: Late-glacial raised beaches

Site 6 Ballymartin: Glacigenic diamicton sequences

Site 7 Kilkeel: Glacigenic diamicton/mud sequences

Site 8 Derryoge: Glacigenic diamicton/mud sequences; shelly gravel

Site 9 Dunnaval: Late-glacial cliffline

Site 10 Sandpiper: Moraine/subaqueous outwash

Site 11 Tullyframe: Delta moraine

Site 12 Attical: Valley moraines

Site 13 Pigeon Rock River: Corrie/protalus rampart

INTRODUCTION TO THE GLACIAL DEPOSITS OF SOUTH COUNTY DOWN (A.M.M.)

Two main geologic - topographical divisions are present in the landscape of south County Down. The Mourne Plain extends from Annalong (J375198) south-west to the mouth of the structural depression of Carlingford Lough (J242119). The former is mainly below 120m O.D. and is underlain by Lower Palaeozoic sediments with an important exposure of Carboniferous limestone at the mouth of Carlingford Lough. At least two major Pleistocene sequences may be observed - a coastal sequence of channelled diamicton and mud, and an inland sequence of moraine ridges and outwash spreads (Fig. 6). The Mourne Mountains comprise two granite central complexes, the eastern Mourne Centre with three intrusive members and the later western Mourne Centre with two (Fig. 2). The granites intrude steeply folded lower Palaeozoic sediments. Tertiary dyke swarms are common (Emeleus & Preston, 1969). Like other mountain masses, which are located mainly on the periphery of the island, the Mournes undoubtedly owe much of their scenic attraction to intense erosion by independent centres of ice dispersion during repeated cold stages of the Quaternary (Stephens _et al_., 1975; McCabe, 1985).

The location of the Mourne and Carlingford mountains on the eastern fringe of the Ulster lowlands undoubtedly influenced the major directions of ice sheet flow (Fig. 4). They also acted as a major obstacle to ice flow during the early part of the last deglacial phase (Fig. 4). Moraine patterns therefore reflect ice retreat into the mountain catchments, westerly ice retreat to Carlingford Lough and northerly ice retreat along the flank of the eastern Mournes.

Much of the early glacial literature on the Mourne area lacks a firm stratigraphic basis. It was largely concerned with the extent and penetration of extraneous ice into the mountains. For example, Kilroe (1888) believed that both Irish and Scottish based ice penetrated the mountains. Dwerryhouse (1923) considered that the earlier, or Scottish ice, overwhelmed the

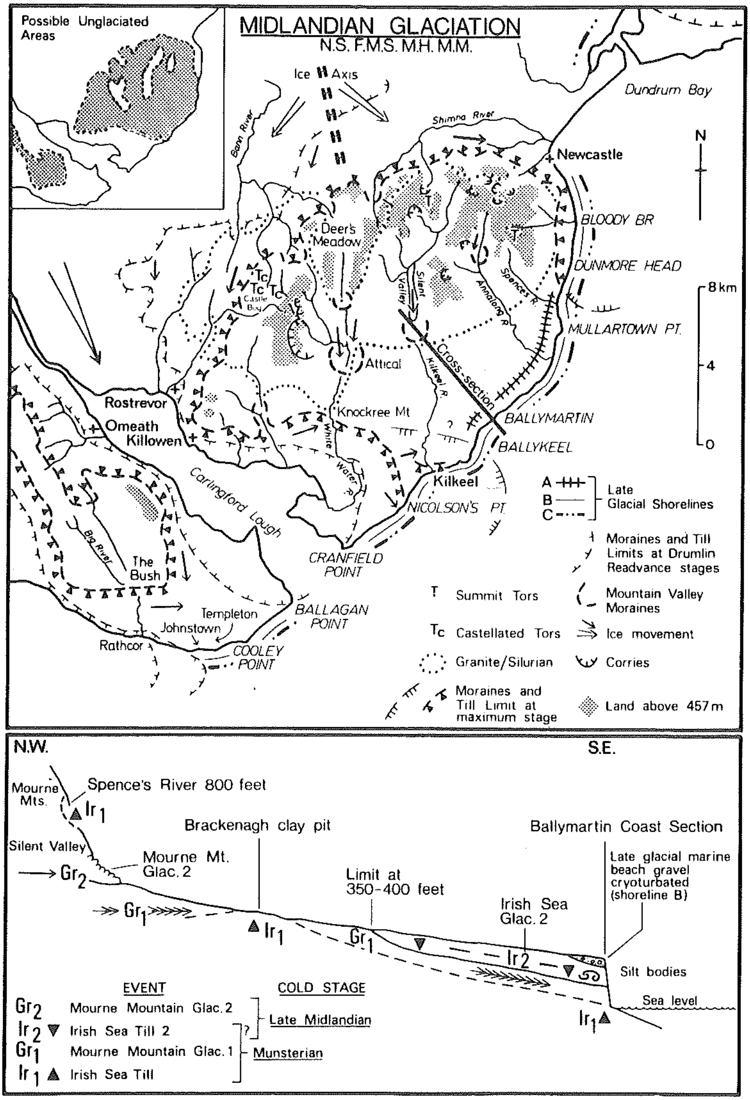

Fig. 4 General directions of ice-movement and ice-limits for the Late-Midlandian glaciation in south eastern Co. Down and the Carlingford Peninsula (Stephens and McCabe, 1977). Alternative limits of the Drumlin Substage are also shown. The lower diagram shows the stratigraphical succession and certain ice limits between the Mourne Mts. and Ballymartin (Stephens *et al.*, 1975).

Mournes on the basis of rounded outlines of the highest peaks such as Slieve Donard (853m). He suggested that the later Irish ice encircled the massif. The views of Dwerryhouse were largely supported by Charlesworth (1939) who pointed out that certain of the high summits with irregular outlines may have remained as nunataks during the glacial period. He also identified the limits of a major 'readvance' in Carlingford Lough and in the eastern Mournes (Charlesworth, 1939, 1955).

In south Co. Down Stephens et al., (1975) have described deposits which they relate to the last two cold stages of the Pleistocene (Mitchell et al., 1973). In general, the shelly-tills are related to the earlier stage (Munsterian) and, during the later stage (Midlandian) ice from central Ulster almost encircled the mountains. They also identified a major expansion of mountain ice across the Mourne Plain which post-dated an onshore ice movement from the Irish Sea Basin. The Late-Midlandian maximum was taken to be delimited by moraines on either side of the Mournes at Kilkeel in the west and at Dunmore Head in the east. The area between these moraines was considered to have been ice-free during the Late-Midlandian (Stephens et al., 1975). More recent observations on Late-Midlandian ice limits have been discussed by Stephens and McCabe (1977) who considered that ice, of the Drumlin Substage, extended south across Dundrum Bay to Dunmore Head with a lobe moving east from Carlingford Lough to Ballykeel and south to Clogher Head (Fig. 4). At the southeastern end of the Carlingford Mountains the fluvioglacial gravel complex in the Bush area of the Big River Valley may represent not the maximum extent of Midlandian ice but an interlobate accumulation between the ice lobes centres in Carlingford Lough and Dundalk Bay. The only ice-free coastal segments at the maximum of the Drumlin Substage would then have extended between Dunmore Head and Ballykeel (Co. Down) and south of Clogher Head (Co. Louth) (Fig. 4 and 5).

Palaeoenvironmental reconstructions of the multiple till sequences (e.g. Ballymartin) in south Co. Down have concentrated on direct glacial deposition from alternating phases of mountain and Irish Sea ice (Synge & Stephens, 1960; Stephens et al., 1975). Furthermore, the tills at Derryoge and Kilkeel have been attributed to ice advance from Carlingford Lough. Stephens et al., (1975) assigned individual lithofacies to specific cold stages of the Pleistocene. This chronology has been accepted in recent stratigraphic summaries (Gellatly, 1985; Warren, 1985). However, facies analysis demonstrates that these sequences lack any substantial breaks in the sediment pile, intraformational organic horizons, weathering phenomena or desiccation features. In such cases it could be argued that the lithostratigraphic approach (e.g. Warren, 1985) involves the division of genetically related lithofacies into formal members which are then given a formal stratigraphic status (cf. Walker, 1984). It will be argued here that these sequences (mud, gravel, diamicton) represent indirect glacial inputs from different geological provenances (Mountain, Irish Sea, Carlingford) into a glaciomarine basin. There seems to be little sedimentological or structural evidence to support a complex series of ice advances or readvances (McCabe, 1975).

Although most of the south Co. Down deposits are unfossiliferous, the absence of marine populations from many mid-latitude, ice proximal Late Pleistocene successions has been attributed to unfavourable environmental conditions for faunal development (Kellog, Truesdale & Osterman, 1979; McCabe, et al., 1984; Powell, 1984). These conditions include, the length of time for species migration towards recently deglacierized areas, ice cover, high rates of sedimentation, lack of sunlight penetration and brackish conditions. In east central Ireland harsh environmental conditions (i.e. absence of marine shells) also prevailed during the formation of emergent raised beach sequences which truncate the glaciomarine deposits (Stephens & McCabe, 1977). In addition, the presence of ice barriers

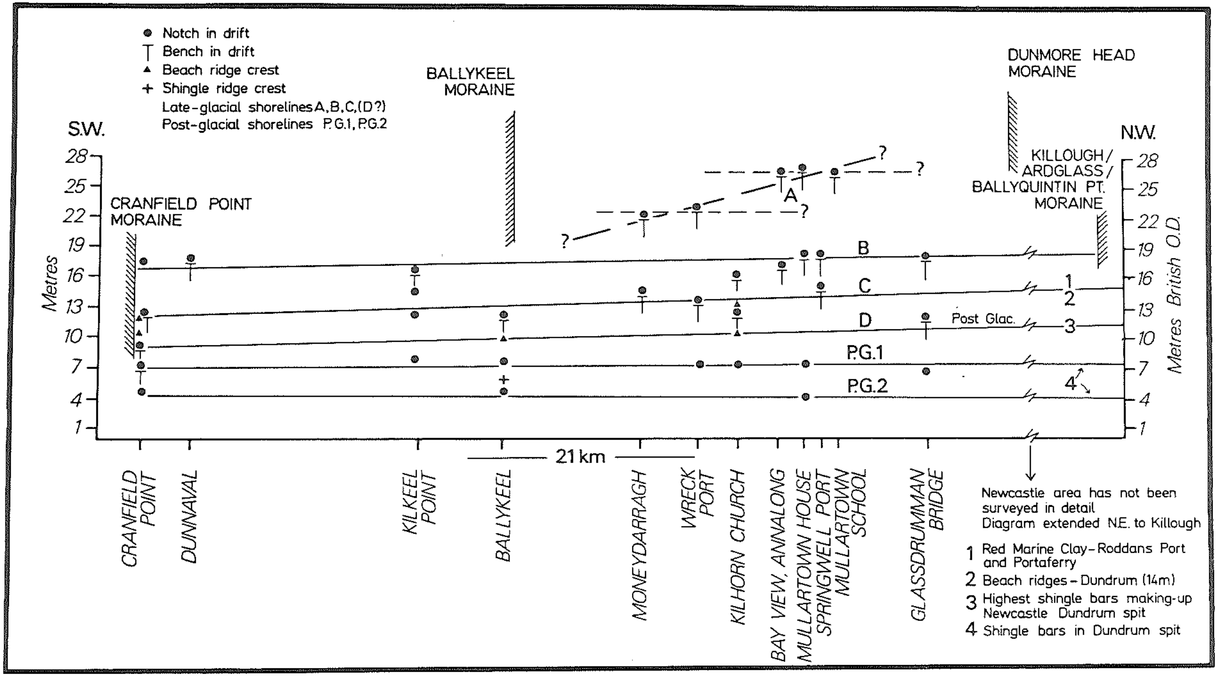

Fig. 5 Arrangement of late-, and post-glacial strandlines on the Mourne coast between Carlingford Lough (Cranfield Point moraine) and the Dunmore Head moraine with possible eastward extensions.

(i.e. Dundlak Bay ice lobe) across certain coastal strips prevented the penetration of marine waters inland at a time of relatively high, late-glacial sea level and deep isostatic depression (Stephens & McCabe, 1977; Synge, 1977). This, and the presence of late-glacial raised beaches immediately outside prominent glacial limits, implies that the limiting moraines were deposited in tidewater glaciomarine environments (Complete melt-out model).

Some problems of the Quaternary of South County Down:

1. Major directions of ice-flow within the mountains can be identified but it is difficult to relate these with the coastal glacigenic sequences.

2. Relationships between the extent of local mountain ice and the major lowland ice sheets are difficult to reconstruct in the absence of definitive stratigraphic markers.

3. The extent of the Late-Midlandian ice sheet is still a matter of debate.

4. Since no subdrift organic horizons have ever been reported the sequences may all be Midlandian in age.

5. Traditionally the multiple 'till' sequences of south County Down have been interpreted as basal deposits of terrestrial ice sheets. Lithofacies variability is associated with discrete ice sheet advances (Stephens et al., 1975). Recently, general discussion has focused on the distinct possibility that some so-called Irish Sea 'tills' may be glaciomarine (Eyles & Eyles, 1984; Thomas & Dacombe, 1985; Eyles et al., 1985; McCabe, 1985).

6. Previous work on the deposits of south County Down have tended to use lithologic criteria in the reconstruction of formal stratigraphies. Subdivisions of this nature artifically divide genetically related lithofacies sequences and hinder realistic interpretations of depositional

environments. For example massive diamicton lithofacies by themselves are not unique to terrestrial glacial environments (Eyles and Miall, 1984, p32). A more realistic approach is to analyse all facies communally in context (Walker, 1984). In south County Down this may be appropriate because there are no major breaks in the exposed glacial succession and the same lithofacies type can occur in a wide range of environments. It is only by analysis of 'sequence context' that environmental interpretation can begin.

For these reasons the south County Down deposits will be described using a lithofacies coding scheme (Table 1) based on that of Eyles *et al.*, (1983).

GLEN RIVER CORRIE (Site 1, J352285; A.M.M.)

A well-defined corrie occurs between Sl. Donard and Sl. Commedagh in the upper catchment of the Glen river (Fig. 4). As with most Mourne corries it faces the north-east and is not bounded by large block moraines. At present there is no information on the number of phases of ice occupancy or the last phase of ice growth. However, it is generally accepted that most of the corries in the Mournes were occupied by ice towards the end of the last cold stage.

SL. DONARD/CHIMNEY ROCK MT. (Site 2, J370284; A.M.M.)

The upper slopes of these peaks are covered by a blanket of angular blocks of granite which extend down to about 120m O.D. By and large these seem to be relic phenomena and probably are associated with frost climates toward the end of the last cold stage (Stephens et al., 1975). However, the precise timing and intensity of periglacial activity is largely unknown from direct field evidence.

BLOODY BRIDGE (Site 3, J380269; A.M.M.)

A well-defined depositional drift limit occurs along the eastern flank of the mountains south from Newcastle to Glassdrumman. It is recognised from the coach by an upper cultivation limit which declines steadily from N. to S. (150-40m O.D.). This landform is a lateral moraine associated with the last ice sheet which swept around the eastern Mournes from the lowlands of central Ulster. Clearly, it represents a late deglacial event and is probably one limit of the Drumlin substage in south Co. Down (Fig. 6).

DUNMORE HEAD/GLASSDRUMMAN (Site 4, J388238; A.M.M.)

The lateral moraine described above ends at the Dunmore Head moraine. The Dunmore Head/Glassdrumman area illustrates the classical model of the ice-contact ridge/proglacial outwash couplet. At Dunmore Head the moraine is channelled by meltwater.

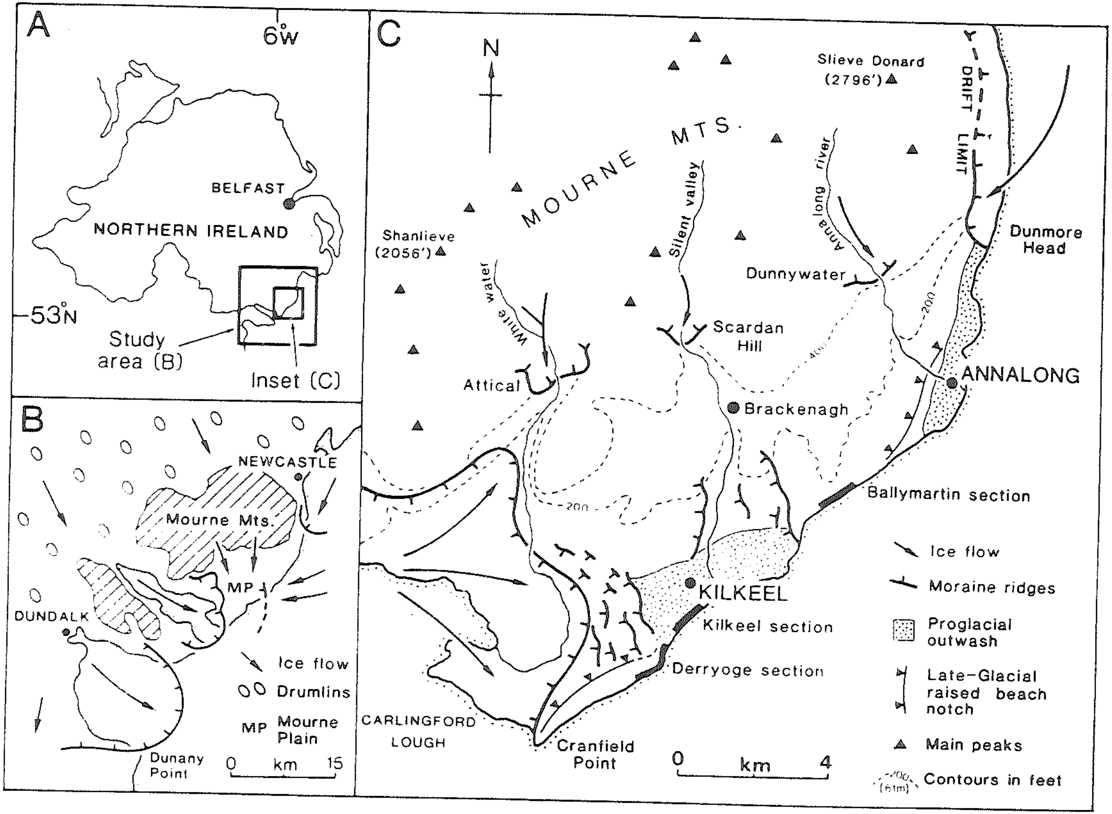

Fig. 6 Location of sections, moraines and deglacial patterns in South Co. Down.

However, at Glassdrumman a nested series of small NW/SE trending ridges occur at right angles to the contours and reach to Ca. 70m O.D. They consist of a wide variety of poorly sorted sand and gravel interbedded with lens-shaped diamicton units. Rapid lateral and vertical changes in lithofacies types are common. Evidence of glacitectonic deformation occurs only on the ice proximal (northern) side of the main ridges. This, together with the presence of large boulders within all lithofacies, suggests that the moraine formed close to the ice margin in a zone of extreme fluctuations in meltwater discharge. Clast types are mainly derived from the Lower Palaeozoic country rock which flank the granite core of the Mournes.

Southward these ridges grade into a flat spread composed of cross-bedded pebbly gravel. The feature may be traced south to the outskirts of Annalong village (J374200). The palaeoenvironments (subaerial/subaqueous) of this deposit are unknown due to lack of exposure.

ANNALONG (Site 5, J372206; A.M.M.)

The outwash spread of gravel around Annalong has been notched at 28, 19 and 9m by lateglacial marine action (Stephens & McCabe, 1977). The highest notch can be observed one hundred metres west of the main road on the northern and southern outskirts of Annalong village. This high level feature occurs for only 5km outside the Dunmore Head ice limit (Fig. 5). Lower notches and raised beaches may be observed at the Half Way House at Annalong and occur fairly continuously between Dunmore Head and the mouth of Carlingford Lough. The associated emergent beach facies truncate a subaqueous complex (glaciomarine?) at Kilkeel and Derryoge.

BALLYMARTIN (Site 6, J341162; A.M.M.)

This section (D 8) (Fig. 6) consists of a diamicton complex (Dmm, Dms, Dms(c)) which is interbedded with stratified sand and gravel (Fig. 7; Tables 1 and 2). Contacts between individual lithofacies are interbedded, gradational or planar erosional. No glacitectonic structures were observed. The erratic assemblage indicates that the bulk of the deposit is associated with debris supply from Irish Sea ice. However, one intra-formational diamicton unit (Dmm) towards the base of the section consists mostly of Mourne granite (70%) and points to an input from mountain based ice.

At the eastern end of the section a silt rich (60-80%) diamictic mud (Fmd), which crops out at present beach level, contains dispersed clasts, marine shell fragments and an erratic suite of Irish Sea provenance (Fig. 7). It is separated by a sharp planar contact from the overlying diamicton which consists of granite cobbles (<30cm) set in a pebble to granule matrix of granite detritus. Cobble shape varies from glacially facetted to subrounded. Coarse tail grading is weakly developed. A second facies derived from granite occurs 150m to the west and consists of massive green mud with numerous streaks of granitic or quartz granules.

The thick diamicton sequence which comprises the bulk of the eastern part of the exposure is dominated by lithofacies Dms, Dms(c) and Dms(r) (Fig. 8). They are characterized by stacking of beds, rapid lateral and vertical interbedding, fold noses, numerous sand lenses and streaks, discontinuous stone lags, vertical pipes infilled with sand and crude parting lamination. Individual units vary from centimetres to 3m in thickness and generally dip westwards. The upper part of the diamicton sequence is cut by a channel (4 x 2m) which is infilled by inversely to normally graded boulder gravel.

The basal stratified sand and gravel of the western part of the section interbeds laterally with stratified diamictons. The latter are thin sheets interbedded with stringers of sand. At the slipway the sequence coarsens up from massive and faintly laminated sand to lithofacies Sh and pebbly gravel. Near vertical pipes infilled with streaked silty sand truncate

Table 1 : Lithofacies codes and their sedimentary characteristics in late-Pleistocene glaciomarine deposits, County Down. The coding scheme is based on Miall (1977) and Eyles *et al.*, (1983)

CODE	LITHOFACIES TYPE	SEDIMENTARY CHARACTERISTICS
Dmm	Diamicton, massive	Structureless, very-poorly sorted mud/sand/gravel admixture; dispersed clasts; glacially bevelled clasts common.
Dmm(c)	Dmm with evidence of current reworking	Microstructures produced by traction currents.
Dmg	Matrix-supported, graded.	Clast content generally graded.
Dms	Diamicton, stratified.	Matrix-supported; stratification is pronounced and more than 10% of unit thickness; often graded; generally stacked beds; pronounced winnowing.
Dms(r)	Dms with evidence of resedimentation.	Fold noses, rafts of deformed silt/clay laminae rip-up clasts.
Dms(c)	Dms with evidence of current reworking.	Often winnowed, interbedded with silty, sandy and gravelly beds showing evidence of traction current activity.
Gc	Gravel, clast-supported	Massive or imbricated) See text and logs for grain size and grading characteristics.
Gms	Gravel, matrix supported	Massive)
Gm	Gravel, crudely bedded	Horizontal/inclined bedding)
Gt	Gravel, stratified	Trough crossbeds)
Gp	Gravel, stratified	Planar crossbeds)
Sm	Sand, massive	Silty-sand; dish structures; mean grain size -1Ø
Sh	Sand, horizontal lamination	Stratified; generally normally graded; mean grain size +2Ø; well sorted
St	Sand, trough-stratified	Low angle crossbeds (< 10°); dunes
Sp	Sand, planar crossbeds	Coarse to medium sand, may be pebbly
Sr	Sand, rippled	Type A, B and S ripple drift, cross-lamination
Sd	Sand, deformed	Soft sediment deformation structures
Fl	Mud, laminated	Alternating clay, silt and fine sand laminae
Fm	Mud, massive	Clast deficient
Fmd	Mud, diamictic	Massive; clasts dispersed

TABLE 2 : Lithofacies associations in Late-Pleistocene glaciomarine sequences, south County Down.

SITE	LITHOFACIES ASSOCIATION	MAJOR LITHOFACIES	MINOR LITHOFACIES	INFERRED PALEOENVIRONMENTS
Derryoge	Diamicton (D-1,2,3,4)	Dmm, Dms Dms(c)	Gms, Gc Gm, Sp, St, Fmd,	Ice proximal cohesive debris flows and I.R.D. Limited melt-water influx. Major inputs from Carlingford ice.
	Mud (T 1,2 3)	Fl	Dms(r) Sh	Ice distal rhythmites of underflow and/or plume origin. Minimal I.R.D. Intraformational soft sediment deformation. Cohesive debris flows along flanks of diamictons.
Kilkeel	Diamicton (D 5,6,7)	Dmm, Dmm(c)	Fmd, Sp	Ice proximal cohesive debris flows and I.R.D. on diamictic mud base deposited from suspension rain-out. Major inputs from Carling-ford ice
	Mud (T4,5,6)	Fl,Dms,	Gp, Gm, Sm, Sp, St Dms(r)	Ice-distal rhythmites of under-flow and/or plume origin. Lateral slumping and mass flow from margins of diamictons. Top sand spread from traction currents. Minimal IRD.
Ballymartin	Diamicton (D - 8)	Dms, Dms(c) Dms(r)	Gm, Gp, Sh Fmd, Dmg	Prograded sequence of cohesive debris flows interbedded with high density sediment gravity flows/mass flows/traction current stratified deposits. Minimal IRD though dropstone horizons occur. Major inputs from mountain and Irish Sea ice.

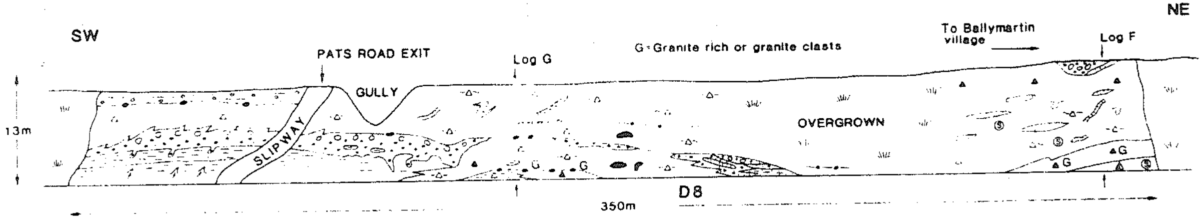

Fig. 7 Ballymartin section. See table 1 for lithofacies code.

the sand laminae but are truncated by the overlying gravel (Gm). The sand/gravel contact is characterised by bulbous pipes of pebbly gravel which penetrate the sand to about 1m. The gravel is very-poorly sorted, crudely stratified and either massive or inversely graded. The largest clasts are granitic cobbles with smaller clasts Silurian in origin. The overlying stratified diamicton which interbeds with the gravel contains a high proportion of rounded clasts similar in size and form to those of the gravel.

KILKEEL (Site 7, J310137; A.M.M.)

This section comprises three, mesa-shaped highs (D5, 6 and 7) composed of diamictons and two mud trough infills (T4, 5) (Fig. 9). The diamictons consist mainly of local Silurian sedimentaries (70-85%) and small amounts of Carboniferous limestone (<8%) which indicate deposition from ice out of Carlingford Lough. However, the largest clasts are always isolated, granitic in composition and are set in matrix derived from Silurian bedrock. Additional evidence of input from mountain ice occurs as thin sheets (<10cm) and lenses of granite detritus interbedded within the diamictons. At intervals along the base of the section and on the foreshore a silty-clay rich (70-80%) diamictic mud crops out intermittently and forms a blanket beneath the cliff sequence. It contains marine shell fragments, chalk, flint and Ailsa Craig microgranite.

Diamicton Association. The diamictons consist mainly of interbedded Dmm and Dmm(c) lithofacies. Matrices are sandy with a wide range (pebbles-boulders) of dispersed, glacially bevelled clasts. Clast fabrics are random. Lithofacies Dmm(c) is characterized by massive and inversely to normally graded beds (<1.5m) which are often separated by 10-20cm bundles of undeformed, silty-clay laminae. Crude partings in the form of discontinuous boulder and gravel lags occur throughout the sequence. Occasional, sharply defined vertical pipe infills of pebbly sand or massive pebbly gravel truncate

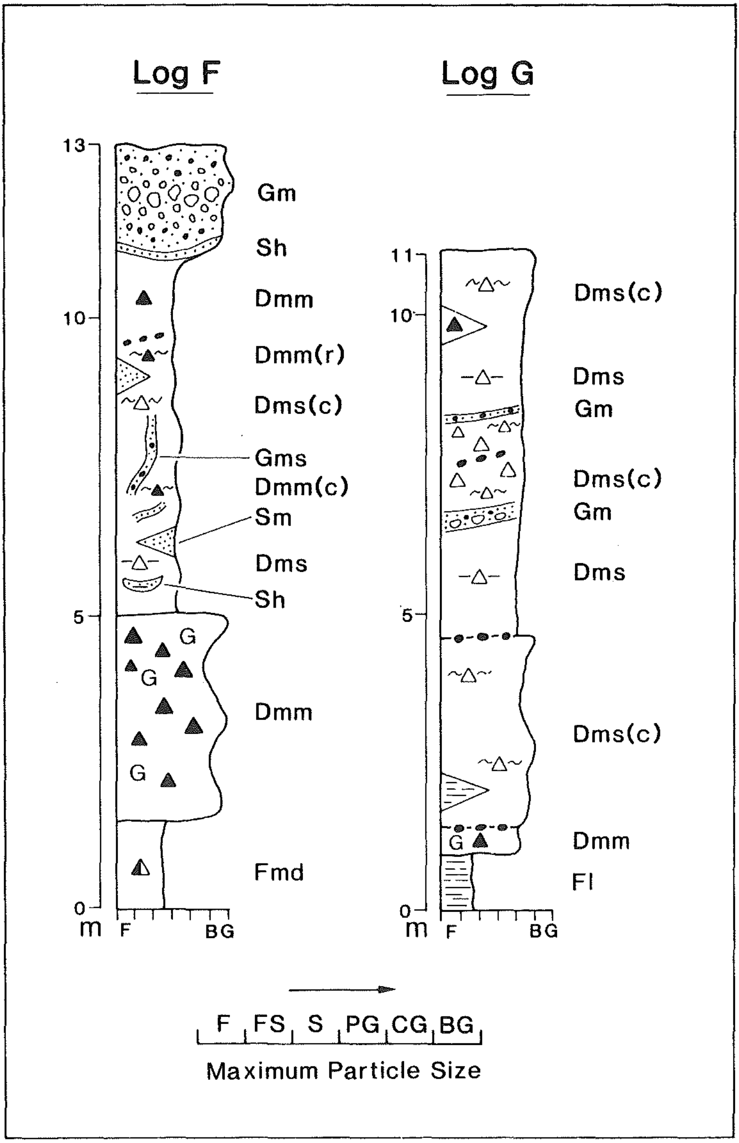

Fig. 8 Generalised logs from Ballymartin sequence.

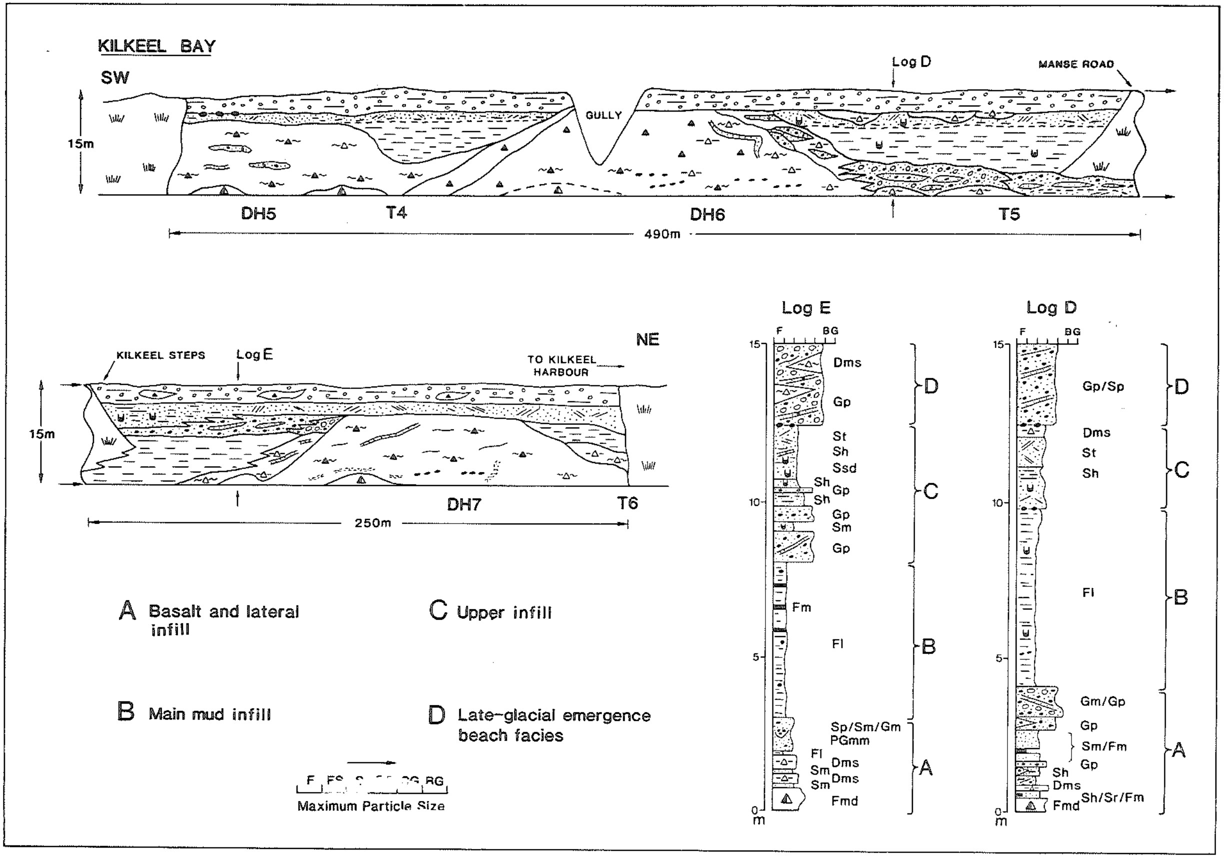

Fig. 9 Kilkeel Section. See table 1 for lithofacies code.

the near horizontal bedding of the diamictons.

Mud Association. Four distinct infill types have been recognised from the trough sediments (Fig. 9; Table 2):

1. On the western flank of D7 up to 3m of interbedded Dms, Fl, Sm and Sp, lithofacies dip at 10-15° west towards the axis of T6. The basal contact with the diamictons of D7 is sharp and undulating. Westward this unit is interbedded with the main trough infill (Fl). Contacts within the interbedded sequence are sharp with little sign of deformation structures except microfaults and folds within lithofacies Fl. Stratification is occasionally disrupted by small channels (<1m) infilled with lithofacies Sp/Sm/Gm. Lithofacies Dms occurs as sheets which average 15-25cm in thickness and consist of pebbles (<10cm) set in a silt-granule matrix. Discontinuous partings of sand or granitic granules are common within the stacked diamicton beds. The latter show variable grading patterns which include massive, inverse to normal and inverse types.

2. A sequence of fold noses and overfolds consists of sheets (10-25cm) of Sm/Sp/Dms occurs on the eastern flank of D6 (Fig. 9). Eastward this flank sequence grades into a basal infill sequence of Sm/Sp/Sh/Gp. The sand beds are predominantly massive and parallel laminated with minor occurrences of 'A'-type ripples and coarsen up into pebble and cobble gravels (Gp).

3. The main infill along the axis of T6 consists of parallel laminated sands, silts and clays (Fl) which are similar to those at Derryoge (See Fig. 11). However, convolute bedding is always localised and mud beds (Fm) are thicker (<5cm) especially toward the top of the sequence.

4. An upper infill of interbedded sands and gravel is well exposed at the top of T5. The junction with the underlying muds is sharp and in places channelled. A well-defined lateral and vertical facies change (Gp/Gm→Sh/St) occurs

gradually from the flank of D7 toward the axis of T5. The gravels occur as stacked beds (10-25cm) which fine up from cobble to pebble grade. Stratification within the massively and inversely graded gravel beds is emphasised by thin streaks of coarse/medium sand. The sand content increases laterally and vertically as the gravel fraction fades towards the axis of T5. Interbedded Sh and St lithofacies form a continuous unit over the lower infills. Occasional, isolated clasts and lenses of Dmm occur within the sands. Diapiric structures are associated with the diamicton units.

DERRYOGE (Site 8, J303127; A.M.M.)
At this exposure the diamicton association occurs as four complexes which are mesa-shaped in section and are separated by three trough infills (Fig. 10). The upper surfaces of D1, 2 and 4 are horizontal and were eroded by marine action during lateglacial emergence. The flanks of the diamicton complexes slope at 10-20^{o}. Lithofacies Fl is continuous between T2 and T3 and drapes the undulating surface of D3. Stone counts (80% Silurian sedimentaries, 4% Carboniferous limestone) and moraine orientations (Fig. 6) farther inland indicate that the diamictons are associated with ice from Carlingford Lough. Small percentages (< 4%) of granitic pebbles are present.

Diamicton Association. This consists mainly of matrix supported diamictons (Dmm, Dmm(c), Dmg, Dms, Dms(c)). Where present, major bedding planes are sharp and flat-lying (<5^{o}). Texturally the diamictons vary widely between matrix dominated (Dmm, Dmm(c)) and clast-to-matrix units (Dms, Dms(c)) with higher concentrations of pebbles and cobbles. Massive types predominate and grade vertically and laterally into stratified varieties. For example, at the base of the Spa Well section, Dms(c) units consist of small, glacially bevelled clasts (<4cm) in a silt-sand matrix (Fig. 11). Diamicton units are often

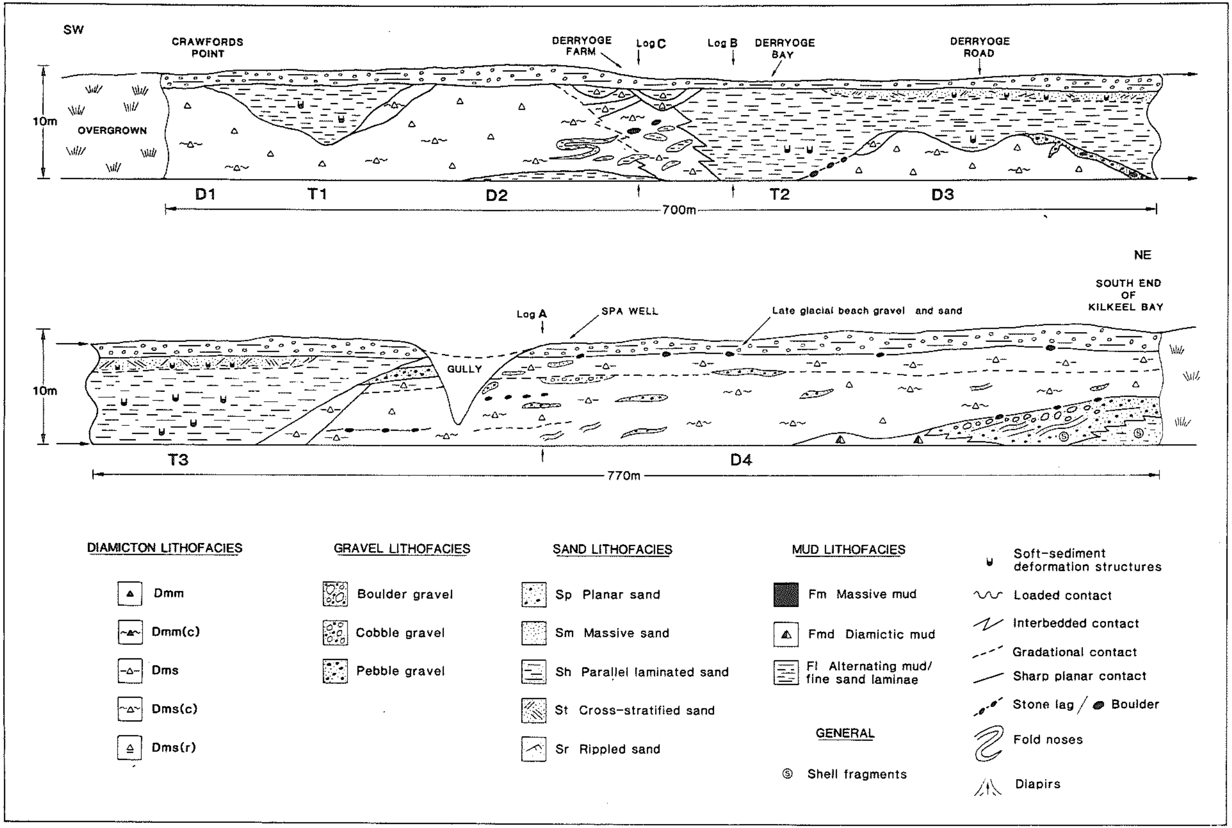

Fig. 10 Derryoge section. See table 1 for lithofacies code.

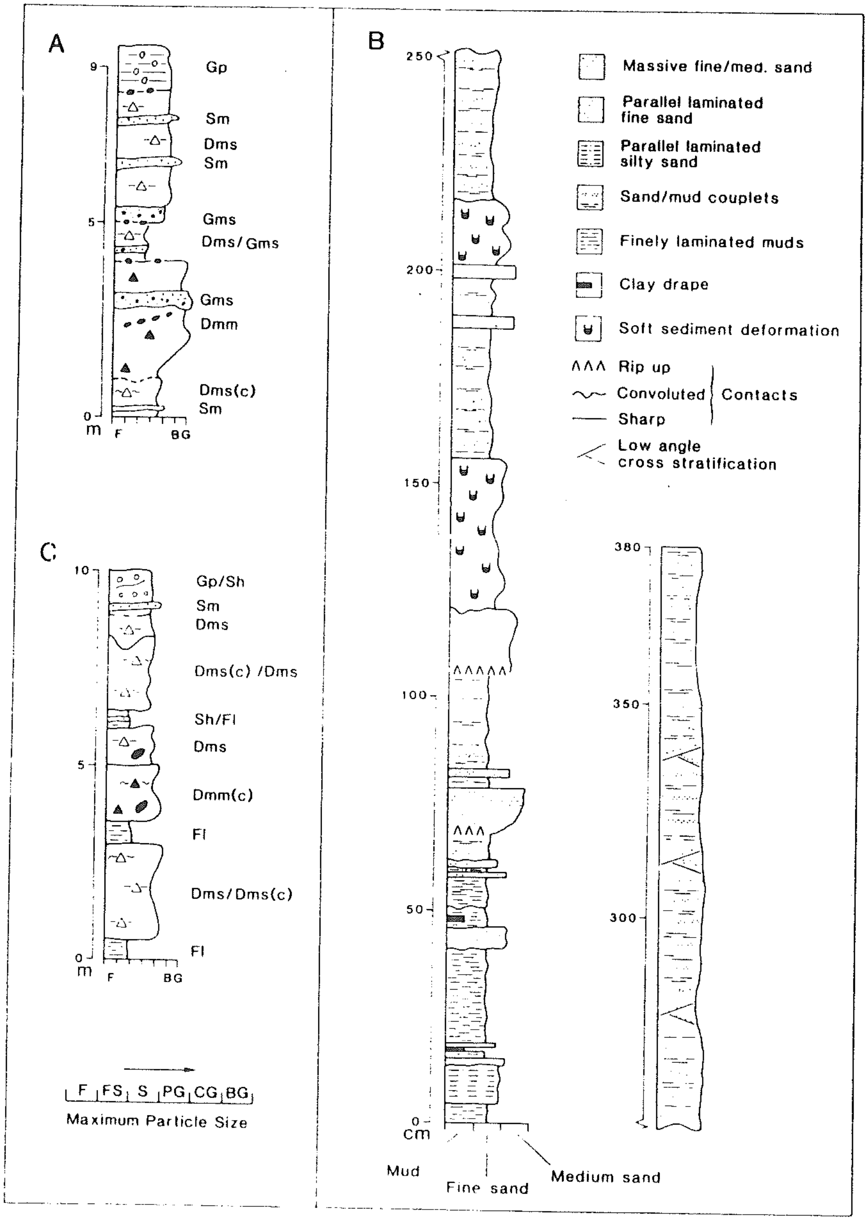

Fig. 11 Logs from Derryoge exposure. See Fig. 10 for location along the section.

separated by bundles (3-10cm) of undeformed sand laminae (Sh) which are continuous for 10-15m. Lithofacies Dms(c) grades up into a thick tabular unit of Dmm containing large (0.7m) dispersed clasts and discontinuous cobble lags. It is noticeable that the smaller clasts tend to be Silurian sedimentaries and the cobbles/boulders are granite. The upper surface of lithofacies Dmm is planar and is overlain by a lag of pebble gravel. The uppermost diamicton consists of stacked beds (10-30cm) of Dms separated by numerous, thin sandy streaks. Individual beds consist of pebbles in a silty-sand matrix and are generally either massive or inversely graded. An emergent beach facies (Gp) truncates the sequence.

The basal deposits of D4 consist of an interbedded sequence of sand (Sp, Sm) and gravel (Gp) which dips west at 10-15^{o}. The gravel is clast-to-matrix supported, coarsens up to cobble grade with dispersed boulders and interbeds with sheets (<30cm) of Dms and diamictic mud (Fmd). These lithofacies contain small amounts (<3%) of Irish Sea erratics (Chalk, flint, Ailsa Craig microgranite) and abundant marine shell fragments. The surface of this unit is sharp and is marked by a prominent stone lag. The overlying diamictons are similar to those in log C (Fig. 11).

The junction between D3 and the overlying mud lithofacies is marked by a lag of either boulders or gravel (Fig. 10). A clear upward decrease in matrix support occurs from the diamicton core into the overlying clast and clast-to-matrix supported gravel. Where the gravel (1-1.5m) occurs in sheet form it is either massive or inversely graded. Pockets (1m x 0.7m) of clast supported cobble gravel occur as discrete clusters which seem to have been 'punched' into the diamicton surface. Pebble gravel penetrates the diamicton as narrow pipes with sharp, near vertical junctions. Megaclasts (<1.5m) occur within the finer grade gravel and, in some cases, penetrate the underlying diamicton surface.

Mud Association. Trough infills (T1-3) consist mainly of alternating beds of laminated mud (Fl) with thin, wedge-shaped units of stratified diamictons along the flanks of the diamicton complexes. Structures suitable for palaeocurrent analysis are not available. Lithofacies Fl probably formed a regional drape over the diamictons which was later eroded (except D3).

At the western flank of D4 a wedge of Dms abruptly truncates the diamicton core and dips toward the centre of T3. Individual diamicton beds are 10-50cm in thickness, bounded by sharp planar contacts, and are composed of dispersed pebbles in a granule/ coarse sand matrix. The wedge is overlain unconformably by lithofacies Fl. In contrast, stratified diamictons and muds are complexly interbedded with fold and slump structures along the eastern flank of D2. Lithofacies Dms occurs as stacked sheets (<0.5m) or as crudely bedded (0.2-0.5m) catenary channel infills (2m across). Silty or sandy interbeds are common between stacked Dms beds.

Along the trough axes the parallel lamination of lithofacies Fl has been disrupted by a wide variety of soft-sediment deformation structures. The latter range from wavy lamination to complexly folded and overturned bundles of laminae, slumps, intraformational ball and pillow structures and pseudonodules. In many cases vertical pipes of streaked silt indicate that the primary lamination is thoroughly mixed. Clasts up to cobble grade are dispersed throughout the deposit.

In T_2 the primary sedimentary structure of lithofacies Fl has not been subjected to widespread soft-sediment deformation and is similar to the other infills. In the lower part of the sequence Fl and Sm units are parallel laminated, variable in thickness (1-17cm) and may be traced laterally for 60m (Fig. 11). Contacts are sharp, and rarely gradational.

Individual units consist of thin (0.1-0.5cm) laminae of parallel laminated sand, silt and mud. Sand and mud couplets are the most prominent feature and always consist of a thinner sand laminae (<2mm) and a graded mud top (<5mm). This sand to mud thickness ratio tends to be fairly constant. Intraformational loading and convolute bedding occur at various points in the sequence.

At the top of the sequence the horizontal lamination is occasionally replaced by low angle cross stratification. Sand laminae range from 1-3mm and overlying mud laminae range from 4-9mm. All contacts are sharp except where disrupted by microloading features. The sand laminae consist largely of fine sand and the mud grades from very fine sand to silty clay. Wispy and discontinuous microlaminae occur within all mud units. Two hundred couplets occur in 1.6m of sediment towards the top of the measured log (Fig. 11).

DISCUSSION AND INTERPRETATION (Sites 6, 7 and 8)

General depositional environment. Although non-fossiliferous sequences cannot be surely identified as marine (Andrews & Matsch, 1983) their areal extent, patterns of isostatic depression and associated high late-glacial sea levels in Co. Down (Stephens & McCabe, 1977) suggest that the deposits described are glaciomarine in nature. The general stratigraphic context of the sequences below the marine limit (Ca.30m O.D.), the sediment geometry and the overlying emergent beach facies supports this interpretation. Furthermore, there is an absence of sedimentary evidence typical of subglacial terrestrial sequences (cf. Miall, 1983; Eyles & Miall, 1984). A composite depositional model is shown in figure 12 and may be used as a framework for the following discussion.

Diamicton association. This association is characterised by a general vertical sequence of diamictic mud→sand/gravel→diamicton. Lithofacies relationships (sediment continuums; graded, interbedded and planar contacts) and internal structures within this

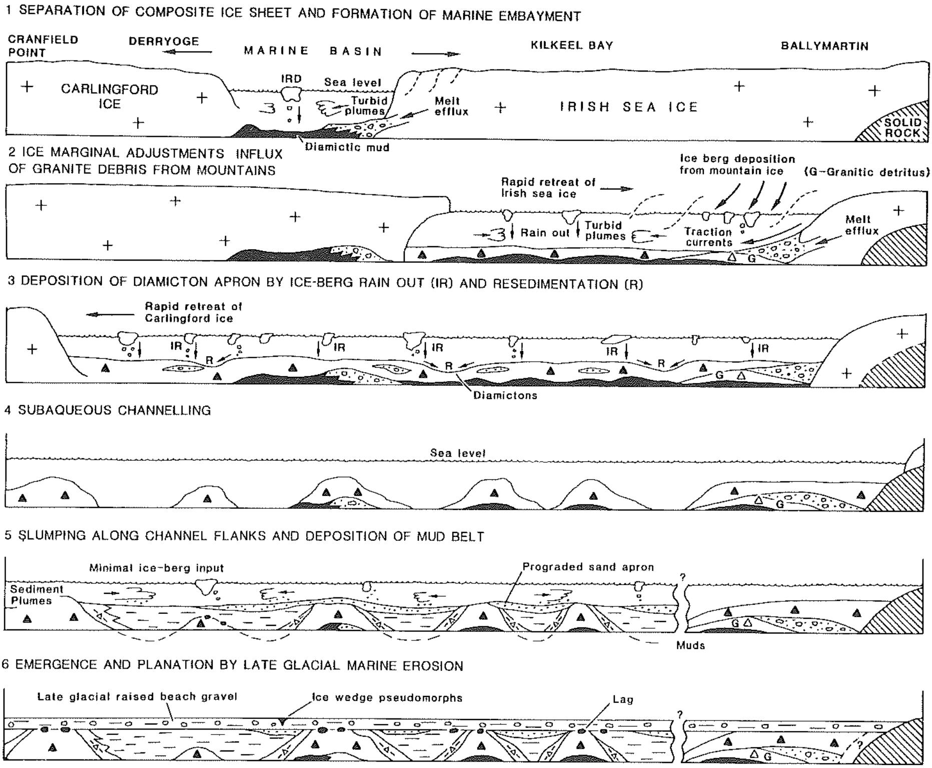

Fig. 12 Composite model of depositional environments in South Co. Down.

sequence indicate that the sediment pile evolved with only minor sequence breaks. Lithofacies characteristics and geometry can be associated with combinations of four main non-glacial processes:

1. Suspension Deposition From Sediment Plumes and Ice-Rafting. Diamictic muds (Fmd) occur at the base of the exposed succession (Fig. 12). Their high silt clay content and interbedded relationship with sand and gravel at Derryoge and Ballymartin suggest rapid deposition from turbid sediment plumes. Dispersed clasts in the mud suggest ice-rafting and thin sandy streaks are probably the result of weak bottom current activity. Muds of this type have been described from present day glaciomarine situations (Molnia, 1983; Orheim & Elverhøi, 1981) where they are interbedded with a wide range of stratified units in ice proximal settings (Powell, 1981, 1984).

2. Direct subaqueous meltwater deposition. Sequences with very low sorted sediment/diamicton ratios in glaciomarine settings have been explained by the cold nature of the glacial regime (Domack, 1982), by ice sheet uncoupling (Anderson et al., 1984) or by rapid retreat rates (Powell, 1981). However, in a tidewater setting it is extremely unlikely that meltwater effluxes were absent. The low sorted sediment/diamicton ratio in the County Down sequences may be the result of widely spaced meltwater exits along the ice margin. This explanation is to some extent supported by the fragmentary nature of coarsening-up sequences (sand pebble/cobble gravel) which may represent remanié parts of this transport system. The presence of numerous rounded clasts within some diamicton units indicates resedimentation of stratified deposits.

The stratified part of D4 coarsens from sand to clast-to-matrix supported cobble gravel. This suggests rapid deposition from high density, sediment gravity flows (Lowe, 1982). Similar lithofacies have been interpreted as proximal facies of subaqueous outwash fans (Rust & Romanelli, 1975; Cheel & Rust, 1982). The interbedded relationship of these lithofacies with diamictic mud indicates the close operation of processes of rainout and high density sediment gravity flows in a glaciomarine setting.

The stratified sand and gravel sequence of D8 is characterised by upward coarsening, loading of gravel into sand, interbedded diamicton units and gradual vertical transition into sheets of lithofacies Dms. This close juxtaposition of sediment types suggests a genetic relationship between a wide range of sediment gravity flow processes which include turbidity currents, high density and cohesive sediments gravity flows (Middleton & Hampton, 1976; Lowe, 1982). Rapid process changes of this nature may reflect changes in the locus of meltwater flow and concomitant debris flow activity associated with local slope instability.

3. Debris flows/ice rafted detritus. The bulk of the diamicton association consists of interbedded sequences of Dmm, Dmm(c),Dmg, Dms, Dms(r). The latter two lithofacies are generally stacked, contain small fold noses, undeformed bundles of parallel-laminated silty sand, sand streaks, stone lags and flow stratification. Contacts are sharp or gradational. These properties indicate a sediment gravity flow origin, probably by cohesive debris flow. Internal discontinuities simply relate to minor phases of non-deposition or erosion, the episodic nature of the flow processes and traction current/winnowing events. Similar lithofacies have been described in the literature and generally ascribed to a subaqueous flowage (Dreimanis, 1979; 1982; Hicock et al., 1981; Eyles & Eyles, 1984). The low angles (<5°) of most bed traces suggest that the diamictons formed by cohesive debris flow activity on very low angle slopes (Middleton & Hampton, 1976; Hodine & Johnston, 1976). The range of clast grading patterns (normal or inverse) is difficult to evaluate but may be associated with varying flow matrix support prior to freezing or short flow paths (Lowe, 1982).

Several other processes contributed to the sedimentation and stratification of the diamicton sequences. First, bundles of parallel-laminated sands are probably associated with bottom current deposition between debris flow activity. Second, near vertical pipes of pebbly sand which are truncated by overlying bed traces are suggestive of water escape from saturated sediment (Postma, 1983). Third, certain intraformational stone lags and gravel lenses are mainly granitic whereas the surrounding diamicton matrix is derived from Silurian sedimentaries. These units are associated with ice rafted detritus (I.R.D.) from mountain ice. Although most of the diamictons are thought to be resedimented some of the tabular Dmm and Dmm(c) units contain a significant proportion of I.R.D. in the form of granite clasts and lenses of granitic detritus. However, since these units commonly grade into or interbed with stratified diamictons it is often difficult to determine their precise origin.

4. Iceberg dump. The surfaces of the diamicton highs (except D3) are horizontal, marine trimmed, and unconformably overlain by stone lags and an emergent beach facies. However, the surface of D3 was well below wave base and is 'pebbly dashed' with a wide variety of gravels. An iceberg dump or iceberg lag origin is suggested since the presence of megaclasts cannot be readily explained by winnowing of adjacent diamicton beds alone (Thomas & Connell, 1985).

Mud Association. This association occurs as channel infills betwen diamicton highs and accumulated after channelling of the diamicton association but prior to late-glacial emergence (Fig. 12). Originally, it probably formed a regional drape over all diamicton highs since it overlies D3 and is continuous between T2 and T3. Contacts with the diamictons are either planar or marked by flank slumping off the diamictons and do not reflect a synchronous growth pattern. The infills occur mainly as three superimposed lithofacies which have either gradational are interbedded contacts.

1. Lateral and basal infills. The flanks of most diamicton highs are characterised by wedge-shaped units of stacked, planar sheets or shallow channel fills of interbedded Dms/Sh/Fl/Sp/Gm lithofacies with dip towards trough axes. Literature review suggests that they represent a range of sediment gravity flow processes (Hicock et al., 1981; Powell, 1981; Wright et al., 1983; Elverhøi, 1984) associated with flank instability. In several cases large scale flank slumping has incorporated lithofacies Fl (main channel infill) which indicates that the flanks of the diamicton highs were continuously readjusting as the troughs infilled. A distinctive prograded facies transition from Dms/Dms(r)/Sp/Sm (folded) Sm/Sh/Sp/Gm (planar) occurs from the eastern flank of MB6 toward the axis of T6 (Figs. 9, 10). This reflects a downslope transition from sliding and slumping debris flow freezing detached turbulent suspension flows/turbidites/traction currents. Similar patterns have been identified from intercanyons in the Weddell Sea though on a much larger scale (Wright & Anderson, 1982). Irregular topographies on the flanks and surfaces of diamicton highs are likely settings for such composite and transitional sediment gravity flow processes (Elverhoi, 1984; Powell, 1984).

2. Main infills. They consist largely of alternating beds of fine sand, silt and clay (Fl). Widespread soft sediment deformation structures, especially along the trough axes, testify to high rates of deposition and a resulting low-strength mud substrate. The absence of pebbly mudstones indicates that either ice-rafting was minimal (cf. Domack, 1984) or bergs moved quickly out from the mud belt. Isolated clasts which occur spordically throughout the sequence are I.R.D. The dominant mechanisms associated with the range of soft-sediment phenomena observed include liquefaction/fluidisation, reverse density gradation, dewatering, slumping and shear stress variations (Lowe, 1976; Mills, 1983).

Where soft sediment deformation is restricted to individual beds the mud sequence is in situ (Fig. 11). Here the absence of coarsening or thickening upward cycles and the overall fine grained nature of the deposit indicates a depositional basinal environment away from any channel influence. In addition the fairly regular thickness relationships between sand and mud laminae probably indicate that the sand and most of the mud was transported from grounded ice margins into the basin. If the mud fraction represented the normal background sediment of the basin a wider variation in laminae thickness would be expected (Walker, 1985). The sharp contacts between successive sand/mud couplets may indicate that each corresponds to distinct sedimentation events from a stratified water body (Mackiewicz et al., 1984). Within each couplet the sharp contact between sand and mud units indicates a phase of non-deposition or an increase in the proportion in sediment contribution from tractional to suspension sources. However, the laminated mud couplets are remarkably similar in texture, thickness, cyclicity and laminae characteristics to the interlaminated ice-proximal (0.5km from glacier) glaciomarine sediments described by Mackiewicz et al., (1984) from the Muir Inlet, Alaska. These laminae couplets have been termed cyclopels (Mackiewicz et al., 1984) and are thought to result from interactions between overflows/underflows and tidal currents within a glaciomarine environment. The discontinuous nature, streaked appearance and intensity of the very fine laminae within the mud part of each couplet may be the result of silt and clay sorting by weak oscillatory currents close to the bed (Krank, 1981; Mackiewicz et al., 1984). Mackiewicz et al., (1984) have also pointed out that the sand/mud ratio of a proximal cyclopel is high and that of a distal cyclopel is low. The measured log from Derryoge (Fig. 11B) indicates a gradual decrease in the sand/mud ratio (5 to 2) which probably reflects either increasing ice marginal retreat or grounding and distance from the sediment input. This idea is supported to some extent by the presence of coarser sand units at the base of the sequence and an increasing similarity in couplet thickness up-sequence. The lateral extent of individual couplets (<60m) may be due to the spatial spread of each turbid plume within the water column.

3. Upper infill. The gradual upward transition from muds into parallel laminated and trough cross-bedded sands and decreasing silt content indicates water shallowing, increasing proximity to prograding sand aprons and a decrease in suspension sedimentation. In one case (T6) a lateral and vertical facies transition from Gm→Sh/St suggests that small, subaqueous aprons encroached onto the main basinal infills. Isolated clasts and diamictic units within the upper infill represent a continued, though small, IBRD input.

Sediment geometry. It has been argued above that the diamictons are largely the result of debris flow activity and ice-rafting (IRD). However, these origins are apparently inconsistent with the 10-20° flank slopes of the mesa-shaped, diamicton accumulations and their flat-lying bedding planes. It is suggested here that they are not morainal banks (Constructional relief) in the sense of Powell (1984) but were formerly an extensive apron which was modified by subaqueous channelling prior to the formation of the regional mud drape (Fig. 12). There is little evidence to suggest that relative sea level lowering contributed to this phase of erosion. However, a considerable body of evidence indicates that submarine fan-valley systems of similar size to those of the Mourne Plain can be attributed to turbidity current activity (Nelson & Kulm, 1973; Normack, 1974; Howell & Normark, 1983). Furthermore, Hay et al.,(1983) have shown that glaciomarine basins receiving sediment-laden meltwater are characterised by an increased magnitude of turbidity current surges and continuous turbidity current flow. Dissection of the diamicton apron is probably linked with these mechanisms. Truncation of the total sequence is the result of marine erosion during Late Pleistocene emergence (Fig. 12).

Debris sources. It has been argued above that the diamicton highs are not ice-marginal morainal banks as described by Powell (1984). Morainal banks formed at grounding zones would probably contain a greater range of interbedded lithofacies, coarser sediment types including dumped debris, a higher sorted sediment/diamicton ratio and at least some evidence of glaciotectonic activity. The diamicton association (mud sand/gravel diamicton) is probably more typical of I.R.D., resedimentation and ice-rafting some distance seaward from successive ice grounding zones. The Mud Association represents a more distal facies (Fig. 12). Powell (1984) has suggested that debris redistribution can occur beneath an ice-shelf. However, a continuous ice cover over this marine basin is unlikely because the ice masses were in a state of rapid recession (Stephens & McCabe, 1977; McCabe, 1985) and open to marine influences from the Irish Sea Basin. It is also difficult to see how granitic debris could be transported 4km to the depositional site if an ice-shelf occurred at this time. The main debris sources or debris release mechanisms for the County Down sequences are difficult to explain. However, regional studies have shown that the deposits described are part of an extensive belt of glaciomarine sequences which front the drumlin belt in east central Ireland (McCabe, 1985). Studies of drumlin stratigraphy suggest that ice sheet uncoupling and surging occurred during the final stages of drumlin formation when large quantities of debris/fluid mixes were transported in basal positions towards the ice fronts. The type of conveyor mechanisms may explain how large quantities of debris are transported to the ice margin but the transitional facies between terrestrial and glaciomarine settings are largely unknown.

CONCLUSIONS

1. Separation of the composite ice sheet (from Irish Sea, lowland and mountain sources) in south County Down resulted in a glaciomarine basin centred on the Mourne Plain. Indirect inputs from the three ice masses resulted in a complex sequence of mud,

sand/gravel, and diamictons which accumulated in various ice-proximal and ice distal positions. Lithofacies variability and distinct erratic suites are not associated with distinct cold stages of the Pleistocene or even phases of ice sheet glaciation (cf. Mitchell et al., 1973; Stephens et al., 1975; Warren, 1985). Formal stratigraphic schemes should not be based on these types of succession as glaciomarine sequences should be identified and separated from direct glacial stratigraphy (Andrews, 1978).

2. The mesa-shaped diamicton highs are not morainal banks (Powell, 1984) which accumulated at grounding zones but are the result of subaqueous channelling of a blanket of poorly-sorted diamictons. The diamicton association formed seaward of grounding zones by plume deposition (Fmd), high density sediment gravity flows (Gc, Gms, Gm), cohesive debris flows (Dmm, Dms) and ice-rafting Dmm. The fact that no typical ice grounding sequences have been identified supports the idea that extensive resedimentation of debris occurred. The restricted occurrence of stratified sand and gravel within the diamicton association does not imply that the ice was cold based. It is suggested here that their relative absence is due either to sediment by-pass into deeper parts of the basin or to the intensity of resedimentation processes or to the wide spacing of melt effluxes.

The mud association occurs as trough infills between the diamicton units and consists of slumped facies along the margins of diamicton highs, a thick sequence of sand/mud couplets in trough axes and an upper infill of sand. The sequence formed by debris flow activity along the diamicton flanks, deposition from turbid plumes and underflows along trough axes, and traction current activity when small sand aprons encroached on the main mud infill. I.R.D. was minimal at this time and fine-grained nature of the mud drape suggests an ice distal setting.

3. In recent years numbers of models of glaciomarine

environments have increased considerably (see Gravenor et al., 1984, for list of references) and testify to the diversity of glaciomarine sedimentation. Although the model presented (Fig. 12) reflects specific combinations of regional environmental inputs it is not an analogue for the Irish Sea Basin and should be regarded as a local summary (cf. Walker, 1984).

4. The restricted occurrence or absence of a particular lithofacies from a sequence highlights difficulties in the reconstruction of former ice sheet regimes from stratigraphic sequences. For example, the general absence of sand and gravel from ice proximal sequences may relate to rapid sediment dispersal and by-pass patterns rather than to prevailing ice regimes. In addition the basal unit in many facies models and hypothetical facies sequences (e.g. Powell, 1984; Fig. 3) is depicted invariably as sub-glacial or lodgement till. In many cases this assumption is misleading because: basal parts of many coastal sequences are not exposed; lodgement processes may not be widespread in marine based, ice proximal situations; ice conveyor mechanisms and sediment gravity flow processes will redistribute all genetic varieties of sediment (McCabe et al., 1984).

5. Lithofacies variability in south County Down reflects patterns of ice sheet separation and sediment redistribution in a glaciomarine setting rather than widespread climatic amelioration. In such cases it will be difficult to use certain glaciomarine sequences as climatic proxies (cf. Andrews and Matsch, 1984).

6. The facies model (Fig. 12) and facies variability emphasises the need for critical appraisal of stratigraphic type sites in the Irish Sea Basin and, in all probability, in other areas subjected to similar regional environmental controls (cf. Eyles & Eyles, 1984; Eyles & Miall, 1984). Within large depositional basins such as the Irish Sea facies analysis is critical since both terrestrial and marine based ice probably

occurred during advance and retreat phases of the last cold stage.

DUNNAVAL (Site 9, J290122; A.M.M.)
A continuous and well-defined lateglacial fossil beach notch (18-19 O.D.) may be traced for 2km from the Cranfield moraine north-east to Dunnaval and Derryoge Harbour (J301122). At Derryoge the fossil cliff is not visible but raised beach gravel overlies glacigenic deposits. This contact is sharp and horizontal for 4km between Derryoge and Kilkeel (Fig. 10). The lateglacial strandline does not occur inside the ice limit marked by the Cranfield Point/Ballagan moraine which formed at the margin of a large ice lobe centred in Carlingford Lough (Fig. 6). This field evidence probably indicates that the moraine itself was deposited in a glaciomarine environment. It is also significant that the seaward portions of the moraine ridges east of Cranfield Point have been truncated by lateglacial marine erosion and replaced by a broad coastal terrace of sand and gravel. This topographic contrast is well seen at Dunnaval and Ballynahattan (J282116).

SANDPIPER PIT (Site 10, J279119; A.M.M.)
The large Cranfield Point moraine occurs as a nested series of arcuate ridges which swing from Cranfield Point northwards and north-westward to Mourne Park (J275157) over a distance of 6km. The eastward bulge of the moraine shows that it was deposited along the frontal margin of an ice lobe centred in Carlingford Lough (Fig. 6). Ice proximal (western) slopes are steep and are backed by lower ground which was occupied formerly by the ice lobe. The crest of the moraine is rounded and grades gently eastwards into a large spread of stratified sediments in the Ballynahaltan.

The Sandpiper pit is located about 300m east of the moraine crest. It is difficult to see any major topographic change from ice proximal to the ice distal situations. Numerous temporary exposures indicate that the four major lithofacies associations present (Fig. 23) maintain a fairly regular stratigraphic relationship over a distance of 0.7km:

1. Lithofacies Gp/Sp/Sh. These lithofacies occur along the base of the pit, are interbedded and up to 2m in thickness (See Table 1 for code). The gravel is matrix supported, pebbly and generally contains clasts between 1-5cm. Occasional clasts up to 20cm have been observed. Bedding planes are either flat-lying or low angle crossbeds and are continuous for 20-50m. Stacks units (190-20cm) of parallel laminated sand (Sh) alternate with cross-bedded sand and form about 60% of this lithofacies grouping.

Toward the distal (eastern) end of the pit these lithofacies show a decrease in gravel content and an increase in parallel laminated and rippled sand sequences with numerous drape laminae. At a few locations the parallel laminated sand is cut by channels (2 x 3m) which are infilled with massively bedded sand. Soft sediment deformation structures, diapirs, rhythmically bedded sand, silt and clays, isolated clasts ($<$10cm) and water escape structures are common in ice distal locations.

2. Lithofacies Dms. A sharp planar contact occurs between this lithofacies and the underlying sand and gravel. No glacitectonic deformation was observed along this contact. Texturally, the stratified diamicton consists of dispersed pebbles set in a sandy matrix (it could be argued that this Dms is a pebbly-sand with a low mud content). Individual beds are laterally continuous for 20-50m, flat-lying, often wavy and 2-10cm in thickness. Sand partings emphasise the crude stratification. Beds are generally massive, though inverse to normal grading occurs in the thicker beds. Occasional small channel infills occur within this sequence.

Lithofacies Dms is characterised by at least two distinct clast

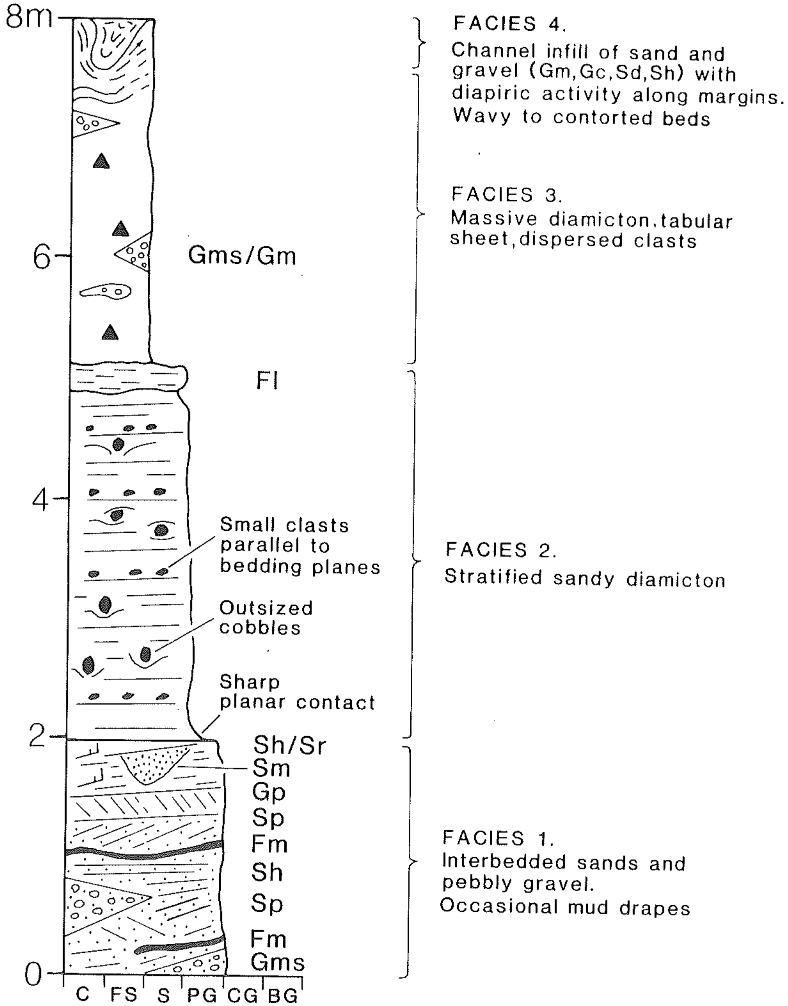

Fig. 13 Generalised log from Sandpiper Pit.

fabrics. Most of the pebble sized clasts tend to lie parallel to the bedding planes with flat-lying, strong A/B fabrics (110-150°). The larger pebble and cobble sized clasts occur sporadically throughout the sequence, deform underlying beds and are often in a vertical position.

3. Lithofacies Dmm. Lithofacies Dms grades upward into a massive diamicton which forms the surface of the outwash spread. It is rather variable (1-4m) in thickness but forms a fairly continuous tabular sheet. Occasional sand and gravel lenses are present. At several ice distal locations a prominent bed of lithofacies Fl separates Dms/Dmm lithofacies.

4. Lithofacies Gm/Gc/Sd/Sh. These lithofacies occur as small channel fills which penetrate both Dms and Dmm units. They vary in section from symmetrical, saucer-shaped forms (4 x 1m) to asymmetric forms (3 x 2m) with overhanging sides. Channel margins are strongly erosional. The basal fills generally consist either of massive pebbly gravel or cobble lags. The main fills are an admixture of parallel laminated and wavy sand with lenses of pebbly gravel or granules. Thin lenses of massive diamicton are present. Near the moraine crest fills tend to be dominated by crudely-bedded pebble and cobble gravel which often show varying degrees of clast clustering. Bedding traces are wavy and often contorted. Commonly, the sediments bordering the channels show evidence of diapiric activity and soft-sediment deformation. Channel orientations occur between 270-340° and indicate palaeoflows directly away from the ice margin.

It has been argued above that the ice margin at Cranfield ended in a glaciomarine environment. The lithofacies arrangement in the Sandpiper pit suggests the following palaeoenvironmental interpretation:

1. The basal sand and gravel (Gp/Sp/Sh) are associated with traction current activity. Outsized clasts are I.R.D. The

channels infilled with massive sand are characteristic of mass emplacement in a subaqueous environment (Rust & Romanelli, 1975).
2. The stratified diamicton is probably associated with sheet flow generated by underflows directly from the ice margin. Underflows capable of forming sandy diamictons of this type have been observed in glaciomarine environments where sediment concentration from meltwater effluxes is in excess of $34gl^{-1}$ (Mackiewicz et al., 1984). The general absence of silt and mud may be attributed to active current winnowing and to sediment bypass in sediment plumes. This fraction may have been deposited as cyclopels preserved in the coastal mud drape between Derryoge and Kilkeel. If this is the case, the mud drape along the coast is the distal equivalent of the Sandpiper deposits. The fact the clast A/B axes tend to parallel the inferred palaeoflow pattern away from the ice margin probably implies that these beds were deposited from high-density, sediment gravity flows (Hein, 1982). Outsized cobbles are unlikely to be transported by very thin flows. An ice rafted origin is suggested.

3. Lithofacies Dmm is fine grained, contains outsized clasts and is not disturbed by glacitectonic activity. This and its sequence context suggests deposition by ice-rafting and turbid plume activity.

4. The origin of the surface channel cutting and infilling is difficult to evaluate. However, they seem to have developed while the substrate was waterlogged judging from channel overhangs (subsidence during growth), soft-sediment deformation structures and diapiric activity along channel margins.

TULLYFRAME (Site 11, J261171; A.M.M.)

The northern limit of the Carlingford ice lobe occurs as a large lateral moraine along the southern slopes of Knockshee and Formal mountain (Fig. 6). This limit may be traced across the middle reaches of the White Water valley as a large ridge moraine at Tullyframe. At this location the valley is almost blocked by the moraine whose crest is at Ca.100m O.D. Fluvioglacial erosion has removed the deposits between Tullyframe and the solid ground of Knockchree to the east.

The ridge is at least 25m in height and is composed of a wide range of gravel and sand lithofacies interbedded with discontinuous diamicton beds. Most major bed contacts are planar and dip to the northeast or east. Lithofacies arrangements suggest it is deltaic in nature and prograded northeast into a water body impounded in the upper reaches of the White Water valley.

Five wedge like structures 2-3m apart and up to 4m in depth disturb the gravel beds some 6m below the surface of the pit. They are about 1m across at the top and taper downwards. Groups of sand and gravel beds sag towards the wedge axes with angles of dip decreasing upwards. The overlying beds are in a primary position. Features of this type are probably pull-apart structures and should not be interpreted as intraformational or syngenetic ice-wedge pseudomorphs. In the case of deltaic environments they simply reflect delta face slumping and readjustment.

ATTICAL (Site 12, J279199; A.M.M.)

The limits and deposits associated with the last major phases of mountain glaciation in the Mournes are well seen along the upper reaches of the White Water river catchment (Hannon, 1974; Stephens et al., 1975). At this time a composite valley glacier developed in the Pigeon Rock (J2523) and Deer's Meadow (J2626) catchments and moved south down the White Water valley to

Ballymageogh (J270192). Lateral moraines of this phase occur on the eastern flanks of Finlieve (J255190). The major cross valley moraine is a large arcuate ridge between Ballymageogh and Attical (J279199). Temporary exposures indicate that parts of the moraine are deltaic in nature with well-developed avalanche front, cross-stratified gravel and sand. Clast type is principally Mourne granites.

When the ice contracted north a nested series of small cross-valley moraines were formed. Their precise depositional environment is unknown but they appear to be ice marginal in origin. With farther retreat the composite glacier separated into individual ice masses located in the White Water valley, the Pigeon Rock valley and the Yellow river. Small, cross-valley ridges probably mark successive ice marginal accumulations. Three well-defined corrie complexes occur at valley heads along the eastern slopes of the Slieve Bug - Eagle Mountain range.

PIGEON ROCK RIVER VALLEY (Site 13, J251223; A.M.M.)
Colhoun (1981) has described a small ridge at about 380m O.D. which is located below the steep rock wall 0.5km southeast of the summit of Eagle Mountain (J249227) and west of the Pigeon Rock valley (Fig. 14). It is about 250m in length with a crest width of 3-5m and is bordered by steep slopes (35-45^{o}). The ridge consists of angular granite blocks (0.5-2m) and granite sand. It overlies a large scree deposit which thins upward toward the steep headwall (50-58^{o}) of the Eagle Mountain cirque (Fig. 14). The most noticeable feature of the rock wall is the sharp angular appearance of the jointed granite outcrops which supplied debris to the screes and ridge below.

Colhoun considers that the highest summits of Shanlieve and Eagle Mountain above 610m were not glaciated during the Late-Midlandian but supported an extensive snowfield. This supplied snow to the corrie glaciers of Aughnaleck and Eagle Mountain which are situated in heavily shaded locations of north eastern aspect.

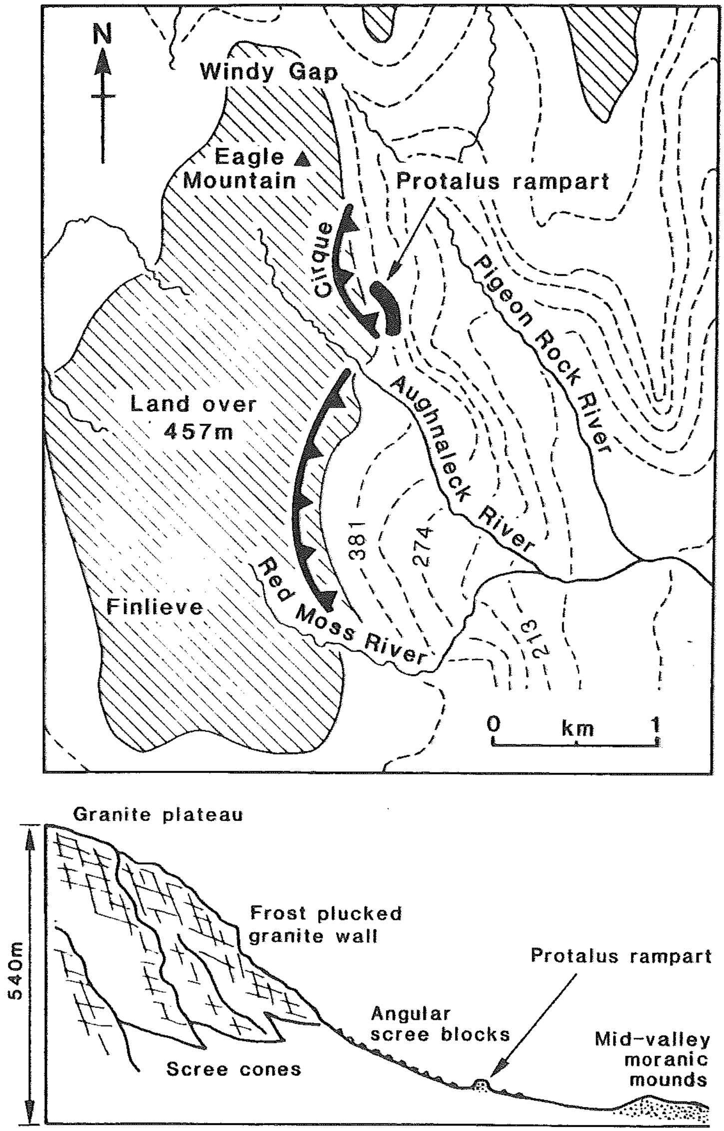

Fig. 14 Some glacial features of the Pigeon Rock River area (after Colhoun, 1981).

On the basis of morphological and locational criteria Colhoun has suggested that the arcuate ridge within the Eagle Mountain corrie is a protalus rampart. The spatial arrangement of the rampart suggests it bounded the margin of a perennial snowbank that had a leeward orientation of 50° and was 10-15m in depth. It has been argued that the rampart formed during the Nahanagan interstadial (11,500 yrs. b.p.) on the basis of the general rise of Zone III snowlines in Ireland (Colhoun, 1981). However, features of this type could be either of glacial or periglacial origin.

DAY 2 : SUNDAY, 13 APRIL, 1986

ITINERARY

a.m. ARCHAEOLOGY, ENVIRONMENTAL ARCHAEOLOGY AND SETTLEMENT HISTORY

Site 14 Drumena: Cashel and Souterrain (J.A.S.)

Site 15 Goward Dolmen: Neolithic portal tomb (J.A.S.)

Site 16 Rowan Tree River: Weathered granite, tors, alluvial fans, upland catchments (K.R.H., B.S.)

p.m. GLACIOMARINE SEQUENCES, POST GLACIAL 'SPIT' AND SAND DUNE COMPLEX

Site 17 Killard Point: Glaciomarine sequences (A.M.M.)

Site 18 Dundrum: Post glacial 'spit' and sand dune complex (J.D.O.)

AN INTRODUCTION TO PREHISTORIC AND EARLY CHRISTIAN SETTLEMENT IN SOUTH COUNTY DOWN (K.R.H., J.A.S.)

The Mourne Mountains are an area where material remains of all periods are rare. Traditionally, transhumance (locally 'booleying') has formed an important part of the mountain economy (Evans, 1978). It is possible that peat growth has covered evidence of other land-use in areas of blanket bog. Little attention has been directed at the study of the extensive blanket peat deposits in the Mourne Mountains, despite important work on the dating and genesis of blanket peats in other parts of Northern Ireland (Goddard, 1971; Smith, 1975). Several important questions about the former extent of woodland, the date of peat initiation and the nature of man's impact remain to be addressed in the context of the Mournes. The general sequence of events over the last few millenia can be inferred from the pollen diagram (Fig. 15) prepared from a bog at c.525m below summit of the Mourne's highest peak, Slieve Donard (850m, Fig. 19).

On pollen evidence alone it is difficult to assign a date to the base of this diagram but the end of the declining <u>Pinus</u> curve is dated at four sites between the Mournes and Slieve Croob (c.10km, to the north) to between 3640±50 b.p. and 3325±75 b.p. (Holland, 1975) and at the Rowan Tree River (below and Fig. 20) to 3095±55 b.p. (Hirons & Smith, unpublished data). Thus it would seem reasonable to assign a date between 3100-3650 to that feature. The base of the pollen profile is possibly much older than this judging from high Coryloid and <u>Pinus</u> values and no <u>Alnus</u>. This suggests that its base may be early Atlantic in age although this would need confirming by radiocarbon.

Turner (1984) found that a low-growing, open woodland was able to grow on the fell-tops up to 893m in the north Pennines at the 'climatic optimum' but after 5000 b.p. climatic deterioration promoted a gradual breakdown of forest. It is likely that the

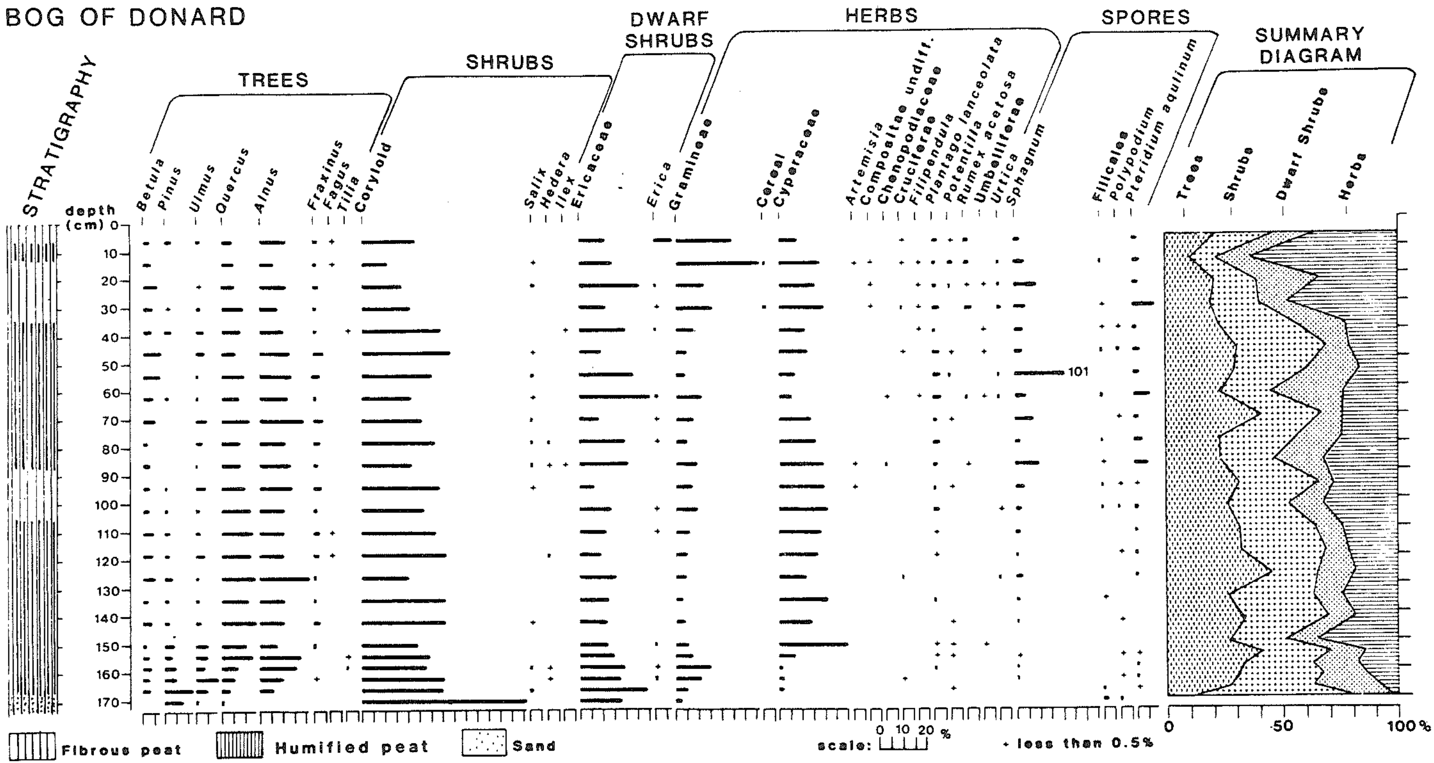

Fig. 15 Pollen diagram from the Bog of Donnard (Selected species).

highest peaks of the Mournes supported woodland of some type during the early part of the postglacial and with tree pollen up to 42% of total pollen, some tree growth is suggested near the Bog of Donnard during the peat accumulation. The diagram documents a very gradual decline of small amounts of elm and pine followed by an expansion of birch after 80cm in the diagram. This spread of birch is apparent in other Mourne Mountain pollen profiles (Fig. 23) as is the characteristic decline in oak, alder and Coryloid (hazel/bog myrtle) above 40cm in the diagram. At other sites at lower altitudes the decline of Coryloid pollen is associated with Early Christian farming activities. The gradual increase in Plantago lanceolata, Rumex and cereal pollen demonstrate the increasing intensity of anthropogenic activities even within this area of 'High' Mournes since the end of the Pinus curve.

Late Mesolithic (possible second half of the 4th millennium b.c.). In contrast to the northern half of the county, and to coastal and riverine areas south of the border, south Down possesses few findspots of Mesolithic material. One large 'Bann flake' of supposedly Late Mesolithic date is known from Dundrum (Woodman, 1978), and a small flintwork assemblage, again of possible Late Mesolithic date, has recently been discovered at Annalong (Sheridan, 1986). The Mesolithic material from Cranfield, which is mentioned in the Archaeological Survey of Co. Down (Jope, 1966; 1969), has been dismissed by Woodman (1978).

The paucity of material in this area may be attributable to the severe coastal erosion which has taken place since the Boreal-Atlantic marine transgression particularly between Cranfield Point and Kilkeel, and on parts of the Lecale coastline. Another possible reason is that, outside the sandhills around Dundrum, there had been less activity by 19th and 20th century collectors than in other parts of N.E. Ireland. Nevertheless, the fact that these two findspots occur in coastal areas accords with the overall distribution pattern of Mesolithic material,

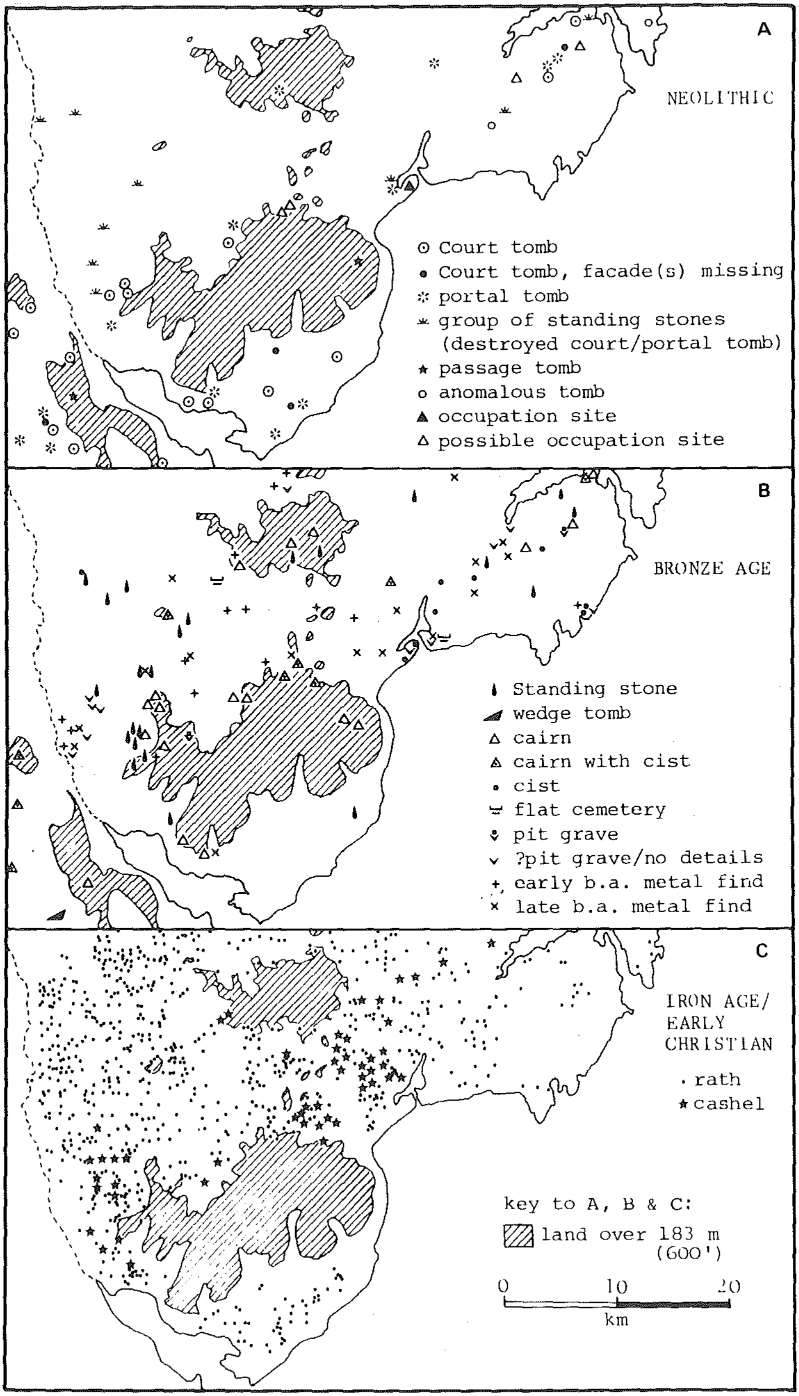

Fig. 16 Prehistoric and Early Christian sites in south County Down.

which displays a strong bias towards coastal, riverine and lacustrine areas. The presence of the Bann flake at Dundrum, and the general character of the flintwork at Annalong, suggests that marine resources were being exploited. Indeed, it is not impossible that the Annalong material relates to activity of a highly temporary nature, featuring the catching, cooking and consuming of fish.

Neolithic (c.3500 b.c. - 2000 b.c.). Evidence for Neolithic activities in South Down (Fig. 16A) is more abundant than that of the Mesolithic and includes the following:

1. Traces of habitation sites in and under the sand dunes at Dundrum (including a hearth, radiocarbon dated to 2825±140 b.c. (U B -412) and 2615±135 b.c. (UB-413); (Cruickshank, 1980; cf. Collins, 1952, 1959).
2. Megalithic monuments include court tombs, portal tombs, and a passage tomb. These served both as burial places and as ceremonial markers.
3. Pollen evidence for clearance and agriculture (Kirk, 1973).

It is reasonable to assume that the distribution of court and portal tombs with its emphasis on fertile lowland areas reflects the former settlement pattern. However, some high-altitude settlement is evident from the discovery of a possible Neolithic occupation site on top of Knockiveagh, the presence of the famous portal tomb at Legananny, and pollen evidence which suggests high-altitude cereal growing on Slieve Croob (Kirk, 1973). The destroyed passage tomb on the summit of Slieve Donard may have functioned as a massive status symbol of a powerful local group, in much the same way as the huge Boyne Valley monuments, or Queen Maeve's tomb on Knocknarea, Co. Sligo.

Bronze Age (c.2000 b.c. - c.500 b.c.) Bronze Age sites are also fairly numerous, although the archaeological record is heavily biased towards funerary, rather than domestic evidence (Fig. 16B). Habitation sites are known from the Downpatrick area, Sheepland and the Dundrum sand dunes. Some of the numerous stray finds of metalwork may derive from domestic contexts (Collins, 1952, 1959; Jope, 1966). To judge from the meagre economic evidence, it seems that the previously-established practices of mixed agriculture combined with hunting, fishing and gathering continued. The cultivation of barley at this time is attested by grain impressions on pottery from other areas. Burial sites range from single pit- and cist- graves, to flat and mounded cemeteries, in a variety of locations. The numerous hilltop cairns attest to the practice of placing some tombs (high-status individuals or groups?) in prominent positions. Not all rich or 'high status' burials occur in such eminent locations. This is suggested by the discovery of an adult male with a Food Vessel Bowl, a bronze knife/dagger, a copper or bronze awl and two thumb-scrapers in a cist at Carrickinab (Collins, 1968). The other type of Bronze Age site to be found in South Down is single standing stones. Their function is much-debated; some see them as sites of astronomical significance, others as territorial markers, yet others as burial sites. Convincing evidence is hard to obtain but in at least one excavated sample at Drumnahare traces of a human burial have been found in the vicinity of the stone. Given the paucity of direct evidence about Bronze Age settlement patterns in this area one cannot yet determine whether any significant changes occurred during this phase. However, one can suggest that some degree of social ranking was present from the beginning of the Bronze Age, as indicated by the gold basket-shaped ear ring from Dacomet (Deehommed). Late Bronze Age items such as the 'craftsman's hoard of bracelets found on Cathedral Hill, Downpatrick, and the two sheet-bronze cauldrons from Raffrey bog and Donaghadee, to the north of our area suggest that this ranking continued or even increased in the Late Bronze Age.

Pre-Christian or Early Iron Age (c.500 b.c. - c.430 A.D.). With the exception of the Dane's Cast linear earthwork, and a few sites whose Early Iron Age date remains to be demonstrated (e.g. the

Mound of Down, outside Downpatrick), the evidence relating to this period is entirely artifactual. Claims that the hillfort on Downpatrick Cathedral Hill is of pre-Early Christian date have recently been challenged. Although it is possible that some earthen and stone farmsteads (raths and cashels) were built at this time, there is not convincing evidence to support this idea.

The artifactual evidence, however, suggests a social organisation and a way of life which can be related to evidence from Navan Fort, Co. Armagh. The bronze, three-piece horse bit found at Ballynahinch, and the sheet-bronze trumpet found at Ardquin are aristocratic and probably ceremonial artifacts, and the several iron swords to the north of our area represent the prestigious weaponry of a warrior class. According to the mythical tales of the Ulster Cycle, Down was part of the Kingdom of the Ulaid which was frequently at war with the kings of Tara. The long linear earthworks in Cos. Down and Armagh may have been constructed during this time.

The discovery of a heavy cast bronze armlet of Scottish type near Newry and of a Romano-British pin of probably 4th century date in the Dundrum sandhills indicates cross-channel movements at this time. Some of these were for the purpose of trade, some for colonisation, and others for refuge from the various political upheavals in both Britain and Ireland.

Early Christian period (5th - 12th centuries A.D.). Much more is known about the settlement patterns of this period (Fig. 16C). It has been suggested that most raths (earthen enclosures), cashels (stone-built enclosures and crannogs (artifical island settlements in lakes) were constructed during these centuries. In addition the first ecclesiastical sites were established during this period.

The numerous small raths in South Down are scattered fairly densely over the lowland areas (up to c.180m). Cashels are less numerous but are functionally similar and tend to occur in stony areas or in areas of thin drift at similar altitudes. These simple, fairly small sites are thought to have been enclosed farmsteads belonging to individual families of the landowning freeman class. When excavated, they usually contain a house with related structures and a yard. Many examples possess an underground stone-built structure known as a souterrain. The main function of the souterrains was refuge in times of raiding, but they were also well-suited to the storage of foodstuffs. Cattle-keeping was undoubtedly an important element in both subsistence agriculture and the maintenance of social status. Although cattle herds were a target for inter-group raids, one must not forget that these farmers were also engaged in other agricultural activities, such as sheep-keeping and cereal growing.

Some earthen enclosures are larger than the norm, and/or have multiple ditches and banks (e.g. Lisnagade). These may have been the residences of more wealthy and important families. Other large earthen or earth-and-stone enclosures (e.g. Kilmelogue) housed early ecclesiastical centres, and usually contained a church, a refectory and cells for the resident religious community, and sometimes also huts for lay followers. At Downpatrick on Cathedral Hill, the early monastic settlement appears to have been protected by fairly substantial defences. The need for such protection was certainly felt during the eighth and subsequent centuries A.D., when the increasingly wealthy Church became the target for native and Viking attacks. One response to such attacks was the construction, from the 9th to the 13th centuries, of tall round towers. The stump of one such tower can be seen at Maghera, near Dundrum.

<u>DRUMENA</u> (Site 14, J312340; J.A.S.)
This cashel is located (Ca. 150m O.D.) on the north-eastern slope of a mountain overlooking Lough Island Reavy. The site consists of a 2.7-3.6m thick dry-stone wall which encloses an

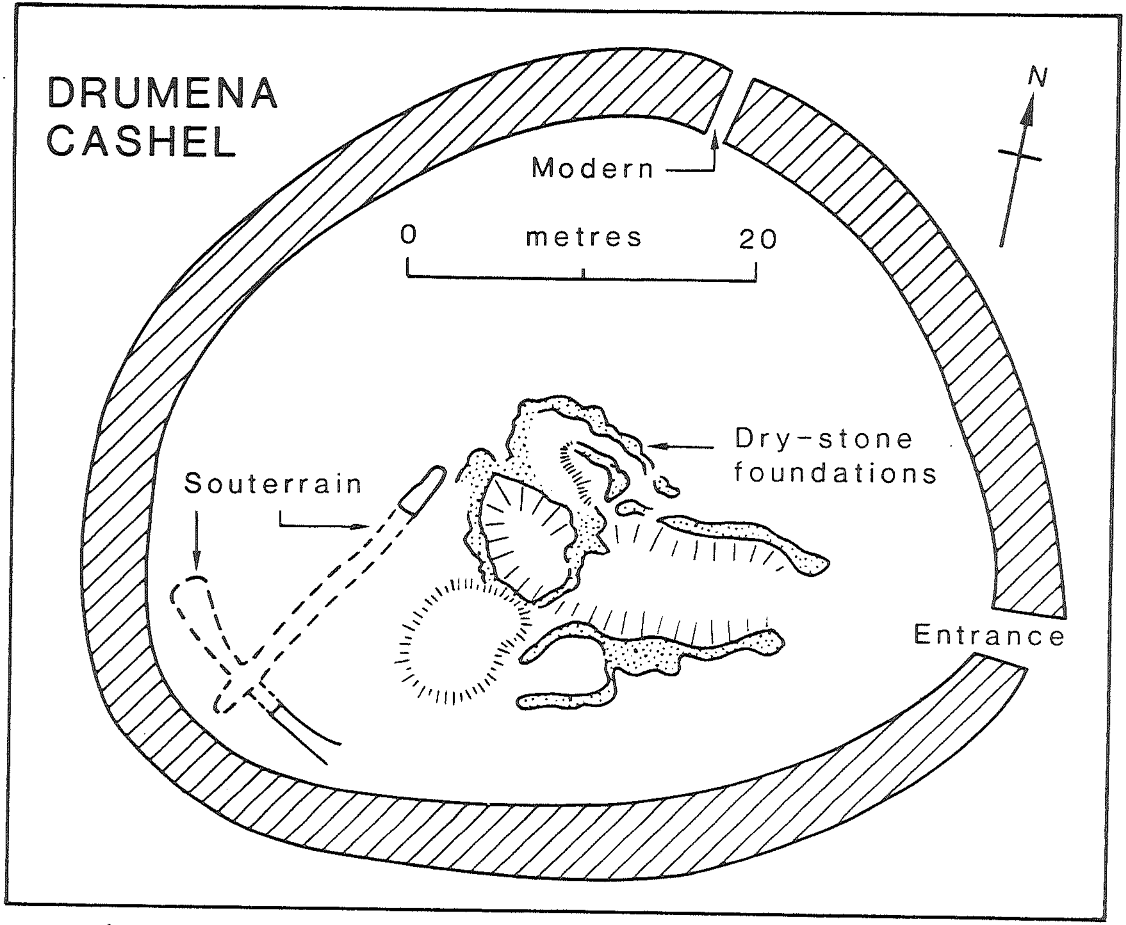

Fig. 17 Site diagram of Drumena Cashel and Souterrain.

oval area c.41 x 33m. The original entrance is thought to have been in the east, where a 2.5m gap in the wall can be seen. The modern, narrow entrance is probably a recent addition. In the south-western quarter there is a T-shaped souterrain. This is of dry-stone construction, and has a stone lintelled roof. Its original entrance was to the S.E., at the end of the short side passage. The main passage which trends form N.E. to S.W. towards the centre of the site, is about 2m in height. The wedge-shaped chamber near its south-western end possessed a small opening for ventilation. In the central and southern half of the enclosure, excavations in 1925-6 revealed a confused area of dry-stone foundations and numerous hearths, probably representing a house site and associated structures.

Although the excavated finds are not closely datable, the site is almost certainly of Early Christian date (5th - 12th century A.D.,), and is an enclosed farmstead belonging to a family of the landowning class. The plan and construction of the enclosure, and the presence of a souterrain within suggests that this site was designed to cope with the kind of raiding activities which were apparently endemic at the time (cf. the mythicised cattle raids of the Tain).

The site, which is a good example of its type, was partly restored after its excavation in 1925-6, and is now in State care. Another cashel exists about 360m to the S.W., and a further 50 are known in south Down. These stone-built enclosures are, however, greatly outnumbered by their earthen counterparts (Fig. 18C). The choice of whether to build in stone or earth seems to be due mainly to the nature and availability of the local building material.

GOWARD (Site 15, J244310; J.A.S.)
This is an impressive example of a type of Neolithic tomb known as a portal tomb. Structurally, it consists of a long rectangular chamber surmounted by a massive granite capstone (now slipped from its original position), plus vestiges of a former crescent-shaped facade leading from the front 'portal' area (Fig. 18). The chamber comprises two side stones c. 1m in height, a frontal blocking stone (c. 1.5m), and a collapsed stone at the back. The latter could originally have been either an upright or a second, small capstone. The 1.5m thick capstone now rests on two tall orthostats (c. 1.7 and 2.0m) which probably formed part of the facade.

Excavation inside the chamber prior to 1834 uncovered a cremation urn and an arrowhead. If the vessel was indeed an urn, this suggests the presence of a secondary burial of Bronze Age date. The construction date of the tomb is likely to have been in the 3rd millennium b.c. and one might expect its original contents (if any) to have comprised burnt or unburnt disarticulated human bones, together with grave goods such as pots or sherds, flint artifacts, and perhaps an item or two of stone (e.g. beads).

The apparent possession of a forecourt facade links Goward portal tomb with another class of Neolithic megalith, the court tomb. Elsewhere (e.g. at Kilfeaghan), other features such as the presence of a long stone cairn confirm this connection. The available evidence suggests that the court and portal tombs are alternative, probably contemporary, variants on the same basic theme. Some degree of regional preference is apparent, with portal tombs forming a distinct, distribution pattern around the Irish Sea basin whilst court tombs cluster in the northern third of the country. The monumental character of both court and portal tombs suggest that they were more than simply burial places. It is quite possible that they served as territorial markers, with groups using the fact that their ancestors were buried in them to legitimate their rights to the adjacent land.

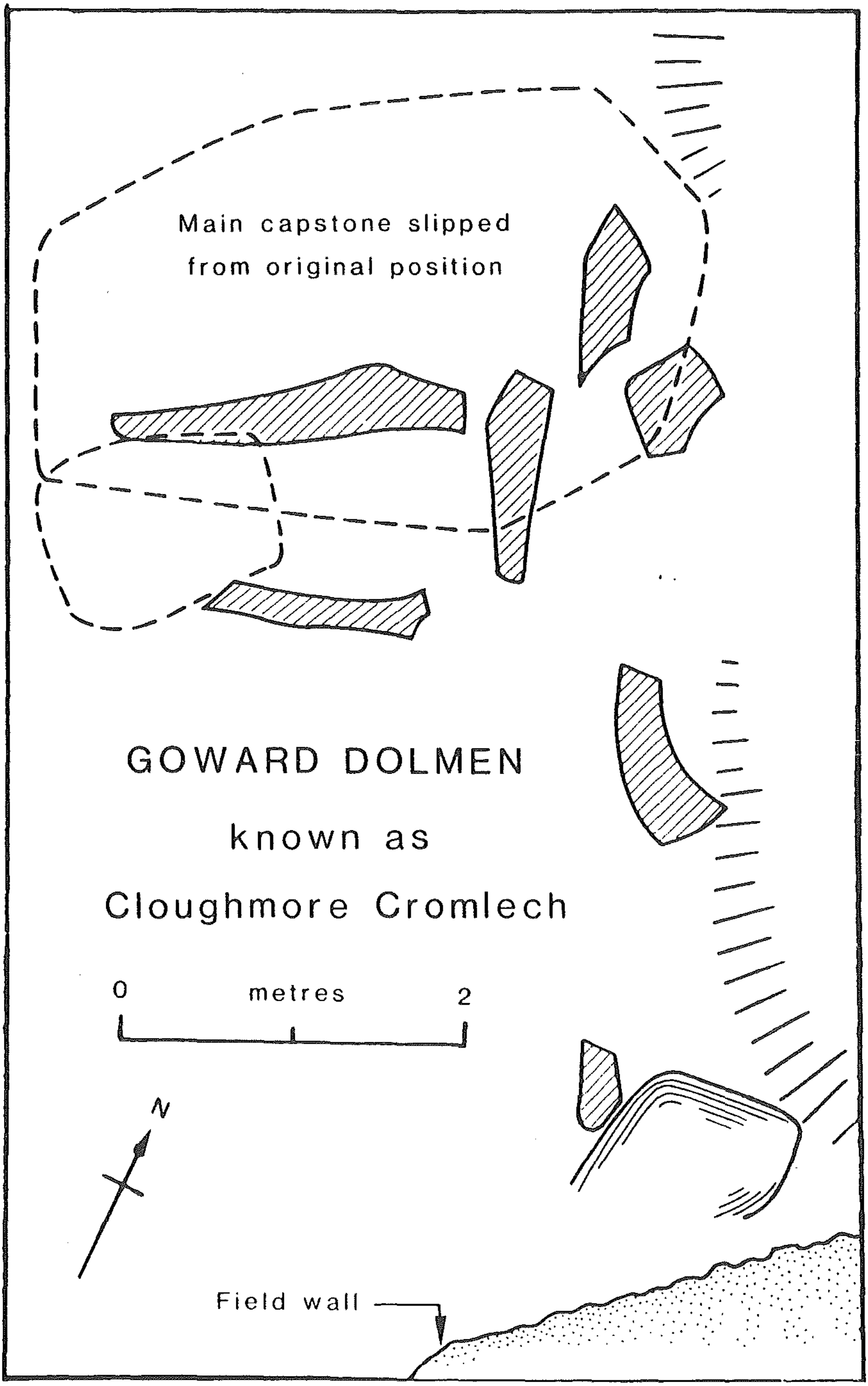

Fig. 18 Site diagram of Goward Dolmen.

THE ROCKY RIVER CATCHMENT (Site 16, J245255; K.R.H., B.J.S.)

Introduction. The Rocky River is a tributary of the River Bann which rises on the northwestern margin of the Mourne Mountains (Fig. 19). That part of the catchment area within the Mournes covers about $0.6km^2$ and ranges in altitude between 130 and 638m. It rises near the summit of Eagle Mountain and has two principal tributaries, the Rocky Water and the Rowan Tree (Fig. 20).

The basin is underlain mainly by a Tertiary granite complex which crops out as a series of summit tors around the catchment watershed. Two of the five Mourne Granites (Emeleus, 1955) which occur in the catchment are exposed near the stream channels and are in places deeply weathered (maximum c. 4m). The only other rock to occur within the catchment is a limited outcrop of Silurian sandstones and mudstones near the eastern watershed. Palaeozoic rocks may once have completely overlain the granite complex but their major outcrops now lie to the north of the catchment at Deer's Meadow and beyond the Mournes.

The valley sides in the upland catchment are steep and peat deposits are extensive. Major bogs occur in the Rowan Tree catchment (Black Bog) and at the head of the Rocky Water below Pierce's Castle (Castle Bog). Both bogs lie on presumed remnants of Tertiary erosion surfaces on which Proudfoot (1954) recognised ten. Black Bog lies on Proudfoot's surface E (298-360m) and Castle Bog on surface C (421-476m). These major bogs have been largely removed by peat cutting for fuel. Other peats within the catchment have been severely eroded. Apart from the areas of peat cover, soils are restricted to isolated patches of shallow ($<$50cm), coarse-textured, podzolic soils between rounded and sub-rounded granite boulders. These vegetated boulder fields extend down in many instances to partly fill the river channel.

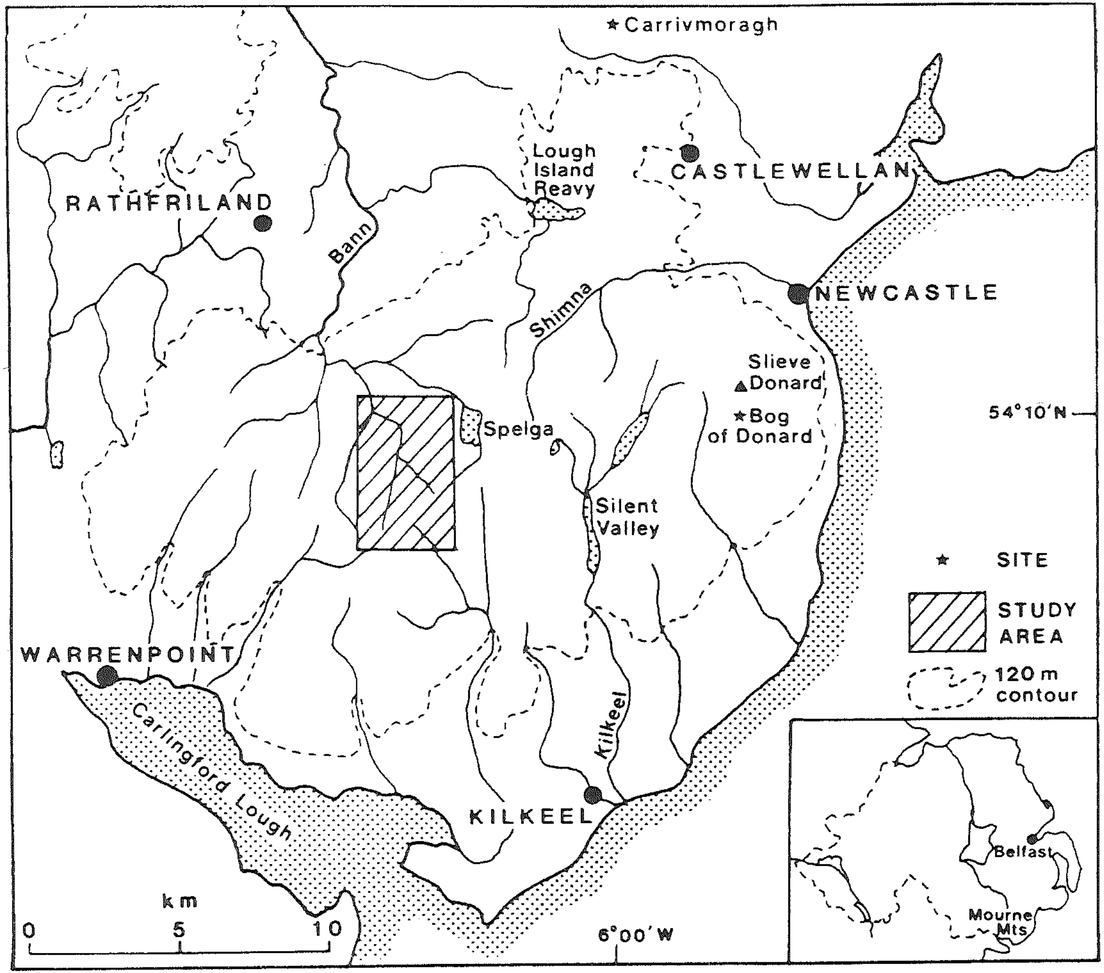

Fig. 19
Location map of
Rocky River area.

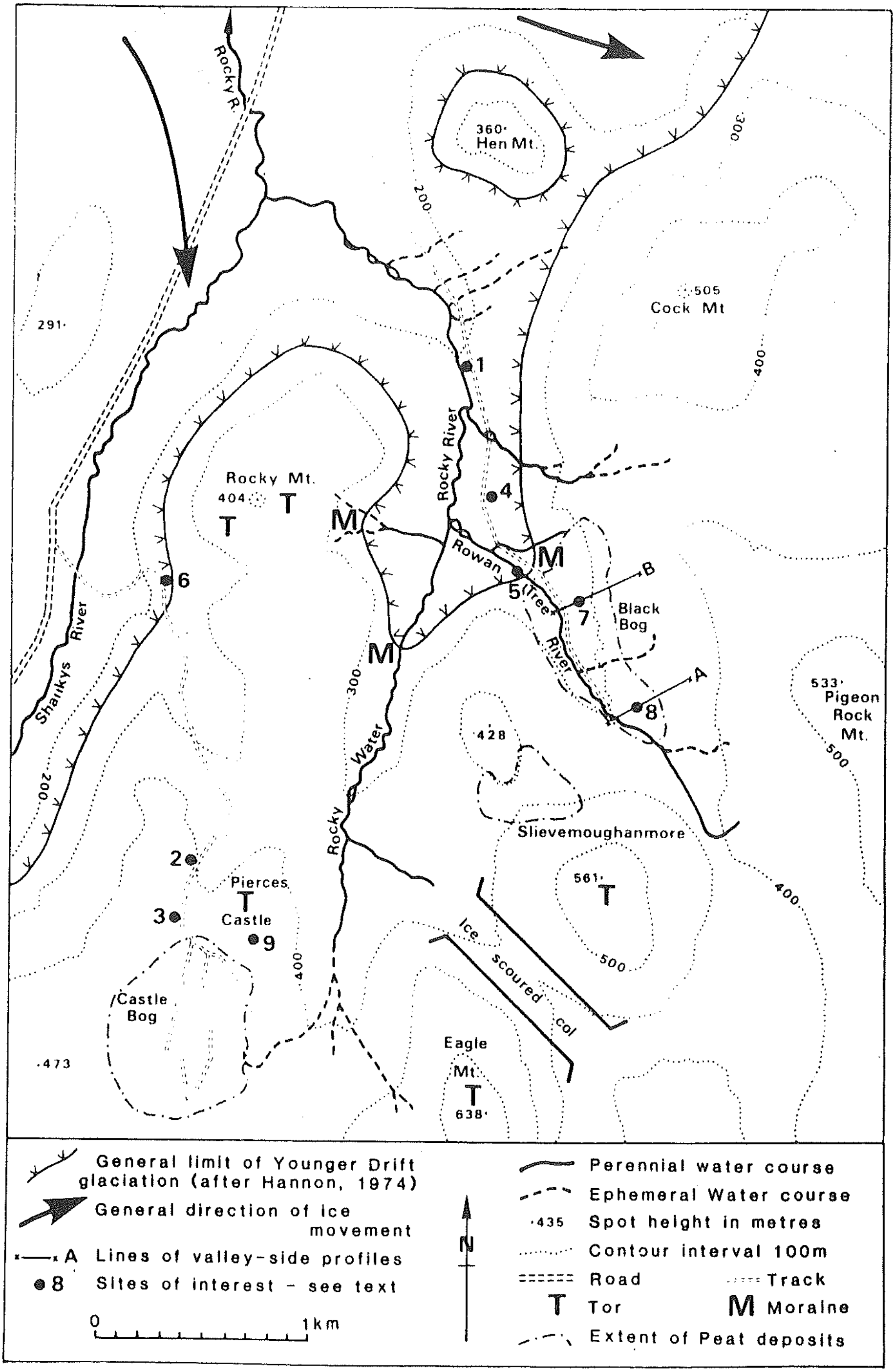

Fig. 20 Glacial and post glacial features of the Rocky River area.

Granite Weathering. Numerous sections in deeply weathered granite have been exposed along stream channels and in small quarries excavated for road fill in the Rock River catchment (Fig. 20; Sites 1, 2, 3). The grus of sand and gravel which occurs on all slopes and at all altitudes, is the product of granite weathering. This suggests that such weathering has been extensive in this part of the Mournes even where in situ weathering products no longer survive. Weathering profiles vary considerably, but a composite profile is summarised in Table 3. An upper horizon consisting of differing combinations of soil, glacial and periglacial deposits overlies a sandy, structureless, but in situ grus which crumbles in the hand. Beneath this, and often separated by a sharp boundary is a more coherent, partly decomposed material that retains the general appearance of the parent rock but crumbles under the impact of a hammer. Neither of these horizons has been observed to contain corestones but beneath them is a zone of angular joint blocks that could have provided the numerous granite boulders which mantle many of the slopes.

The nature of weathering is 'arenaceous' (Millot, 1970) being characterised by the granular disintegration of the granite with some limited alteration of mica, but little alteration of the mainly potash and soda feldspars, and no observed dissolution of quartz grains. The major constituent of the fine fraction (2mm) is sand (usually $>$90%) which indicates only limited clay production. Disaggregation decreases with depth from zone I to II as shown by down-profile variation in particle size of loose debris (Table 3) although there is a suggestion of elluviation of clay and calcium down the profile from weathering products in the upper weathering zone. X-ray diffraction and differential thermal analysis of the clay-sized fraction shows predominantly kaolinite and halloysite in both zones and lesser peaks for the more complex 2:1 clay chlorite and muscovite. Trace amounts of gibbsite present in the disaggregated upper zone at site 2 could be indicative of a higher degree of weathering compared to the

PROFILE CHARACTERISTICS	Thickness ranges observed	Size distribution of loose fraction (%)		Size distribution of fine fraction <2mm (%)			Composition of <2μm size fraction (XRD & DTA)		
		>2mm	<2mm	Sand 2mm–20μm	Silt 20–2μm	Clay <2μm	Strong Peak	Minor Peak	Trace
Peat <u>OR</u> Coarse Podzolic Soil	<75cm								
Granite rich head <u>OR</u> Sandy till with pebbles/boulders of granite and Palaeozoics	0–2m								
<u>Weathering Zone I</u> Structureless, disaggregated granite with decomposition of micas and partial decomposition of feldspars. Retains a high percentage of cloudy but otherwise unweathered feldspars. Dark red iron-staining along joints, together with clay accumulations. Contains veins of quartz and unweathered microgranite with some displacement downslope, but in general weathered material remains <u>in situ</u>. No corestones	0–>2m	45 46 52	55 54 48	94.0 89.6 94.8	4.0 6.4 5.2	2.0 4.0 0.0	Kaolinite Halloysite	Muscovite Chlorite	Gibbsite
<u>Weathering Zone II</u> Partially decomposed but coherent granite retaining the structure of the parent rock. Decomposition is restricted to grain boundaries and primary joints are still visible. Feldspar grains, in particular remain largely unaltered, though there is iron-staining between grains and along joints No corestones observed	0–>2m	73 82	27 18	96 88.5	1.5 5.7	2.5 5.8	Kaolinite Halloysite	Muscovite Chlorite	
Joint bounded granite blocks, no visible alteration of micas and feldspars but iron-staining along joint faces.	0–>1.5m								
Unweathered granite with incipient joints									

Table 3 : Composite table illustrating weathering profiles and deposits found on granite in the northwestern Mourne Mountains.
<u>Note</u> : all deposits are not necessarily found at the same exposure, and chemical and particle size data is representative of the horizons and not drawn from the same section.

lower zone.

The observed pattern of clay minerals, the amounts of clay and the physical characteristics of the Rocky River weathering profiles are similar to those occurring in the weathered granites of Dartmoor (Brunsden, 1964). They have been interpreted as a result of sub-aerial weathering under humid tropical conditions during the mid-Tertiary (Linton, 1955). However, kaolinite-rich, arenaceous and corestone-free profiles such as those observed in the Rocky River have been reported under formation in southern New South Wales (Dixon & Young, 1981). Other doubts about the humid tropical origin of Dartmoor weathered profiles are also relevant to the Rocky River profiles. Thus, the presence of gibbsite and low clay content may not necessarily indicate humid tropical weathering regimes (Eden & Green, 1971; Green & Eden, 1971). An alternative interpretation is that weathering on Dartmoor may have taken place during warmer, temperate episodes within the Quaternary and/or under mesahumid, sub-tropical conditions during the Tertiary or early Pleistocene (Eden & Green, 1971). Similar environmental interpretations have been placed upon 'sandy grus' profiles in Buchan (Hall, 1985) who proposed that the weathering took place under humid temperate conditions possibly as late as the Middle Pleistocene.

The presence of till and head deposits which are thought to date from the last (Midlandian) glaciation overlying the weathering granite (Table 3) would place the deep weathering prior to the last glaciation. However, weathering profiles often occur on steep, exposed slopes in areas (e.g. below Castle Bog) that were overridden and scoured by ice during the penultimate (Munsterian) glaciation (Hannon, 1974). This may suggest that much of the observed deep weathering occurred during the last Interglacial, possibly under humid temperate conditions (Smith & McAlister, 1986).

Glacial and Periglacial Phenomena. Hannon (1974) suggested that the northwestern Mournes were overridden by Scottish ice during the penultimate glaciation (Munsterian). He believed that the ice-scoured col (400m O.D.) between Eagle Mountain and Slievemoughanmore was formed during this phase (Fig. 20). During the last glaciation, ice from the north and northwest, partly filled the Rocky River catchment to a height of c.260m O.D. Areas above this remained ice-free and are characterised by a range of periglacial phenomena. These include extensive, vegetated debris flows and screes, summit and valley side tors, granite-rich head and possible solifluction lobes and terraces in the headwater of the Rowan Tree catchment.

A series of mounds mapped by Hannon (1974) were considered to be lateral moraines of late-Midlandian age. These are clearly seen where they cross the valleys of the Rocky Water and Rowan Tree, and are curved downvalley with steep, north-facing slopes. A section through this moraine can be seen where it is breached by the Rowan Tree channel (Fig. 20, Site 5). At this site up to 1.5m of granite and Palaeozoic boulders, set in a sandy matrix, overlie deeply weathered in situ granite. Similar deposits can be seen along the valley-side of Shanky's River below Rocky mountain at a height of approximately 265m. This moraine is cut through by the track leading to Castle Bog (Fig. 20, Site 6), to expose a considerable thickness of granite boulders and Palaeozoic pebbles set in a coarse textured, sandy, grey coloured matrix. On slopes below the moraine two terrace features of similar composition mark stages in the downwasting of the late-Midlandian ice sheet (Hannon, 1974).

Below the ice-limit in the Rocky River catchment there are isolated exposures of till containing a mixture of granite and Palaeozoic cobbles with occasional pebbles of Tertiary basalt. The latter two erratics imply a southerly ice flow direction during till deposition. The larger debris are set in a predominantly sandy matrix (74% sand, 19% silt and 7% clay) in which quartz and feldspar grains derived from the disaggregation of granite are visible. An exposure of this till occurs in a cutting beside the track leading up to the Rowan Tree River (Fig. 20, Site 4). The upper 75cm or so of this exposure has been considerably modified by podzolisation with prominent iron and clay pans in the profile.

Summit tors at Hen Mountain and Pierce's Castle (Fig. 20, Site 9) show curvilinear sheeting, vertical and horizontal joints which facilitate sub-division of the granite outcrops into masses of rectangular blocks. Much of the overburden of weathered granite has been stripped away from these features. This may be associated with periglacial conditions during the Midlandian when most of the tors and summit areas would have remained ice-free. No evidence has yet been found, however, for extensive frost shattering either of the slope debris or of the tors themselves. The flat, peat covered platform surrounding Pierce's Castle has not been stripped of granitic grus to the same extent as the steeper slopes surrounding Hen Mountain. This is possibly due to its higher elevation (c.420-440m as against around 300m) which may have kept this area ice-free during the last glaciation and earlier glacial episodes.

These observations suggest that the tors are etched out by subsurface, joint related weathering and exposed by subsequent subaerial erosion (cf. Linton, 1955). It is unlikely that exposure of the tors, or deep weathering of some 150m (the height difference between exposures on Hen Mountain and in the Rocky River) could have been accomplished during two alternating episodes of weathering and erosion. It is more probable that there have been several episodes before and during the Quaternary when either weathering or incision and stripping were dominant. Indeed, the occurrence of in situ weathered granite on slopes throughout the catchment, suggests that the pattern of weathering has in part been dictated by the pattern of erosion and the local topography.

Post Glacial History of the Rowan Tree Catchment. The Rowan Tree is a small tributary of the Rocky River with an area just over $1km^2$. The catchment is characterized by an upper, steep headwater area, a middle section having a broad peat-covered floodplain, and a lower steep section where the river valley passes from medium grained granite (G^4) onto microgranite (G^5) (Fig. 21). The lower section is in places incised into bedrock and the valley sides are overlain by a mixture of till and granite debris. The limit of Late Midlandian ice is marked by hummocky ridges across the Rowan Tree Valley at c.260m (Hannon, 1974). This moraine tended to pond water which resulted in the accumulation of reedswamp peats in shallow water which now underlie deeper remnants of peat in the upper Rowan Tree Valley.

Vegetational and Environmental Change. Blanket and valley peats occur throughout the catchments of the Rowan Tree and upper parts of the Rocky River. Micro- and macro-subfossils stratified within the peats allow the reconstruction of postglacial vegetational and environmental changes. Postglacial deposits of blanket peats range from c.50cm on the steeper valley sides to over a metre on lower slopes. Most slopes are severely eroded with extensive-gully development especially where Castle Bog drains into the Rocky River and the bog on the shoulder of Slieve Moughanmore (Tomlinson, 1981). The Black Bog in the Rowan Tree River valley is much reduced by cutting for fuel and surviving peat has a maximum depth of around 2m. Profiles exposed at the Black Bog have the following general stratigraphy:

1. Basal reedswamp peat developed in the deeper sections with Phragmites rhizomes and Betula remains.
2. Highly humified peat with occasional Pinus stumps.
3. A yellow brown, Phragmites-rich reedswamp peat of variable thickness. This layer is present in some parts of the catchment and occasionally extends to near the surface.
4. An upper horizon of fibrous (cf. Sphagnum, Eriophorum,

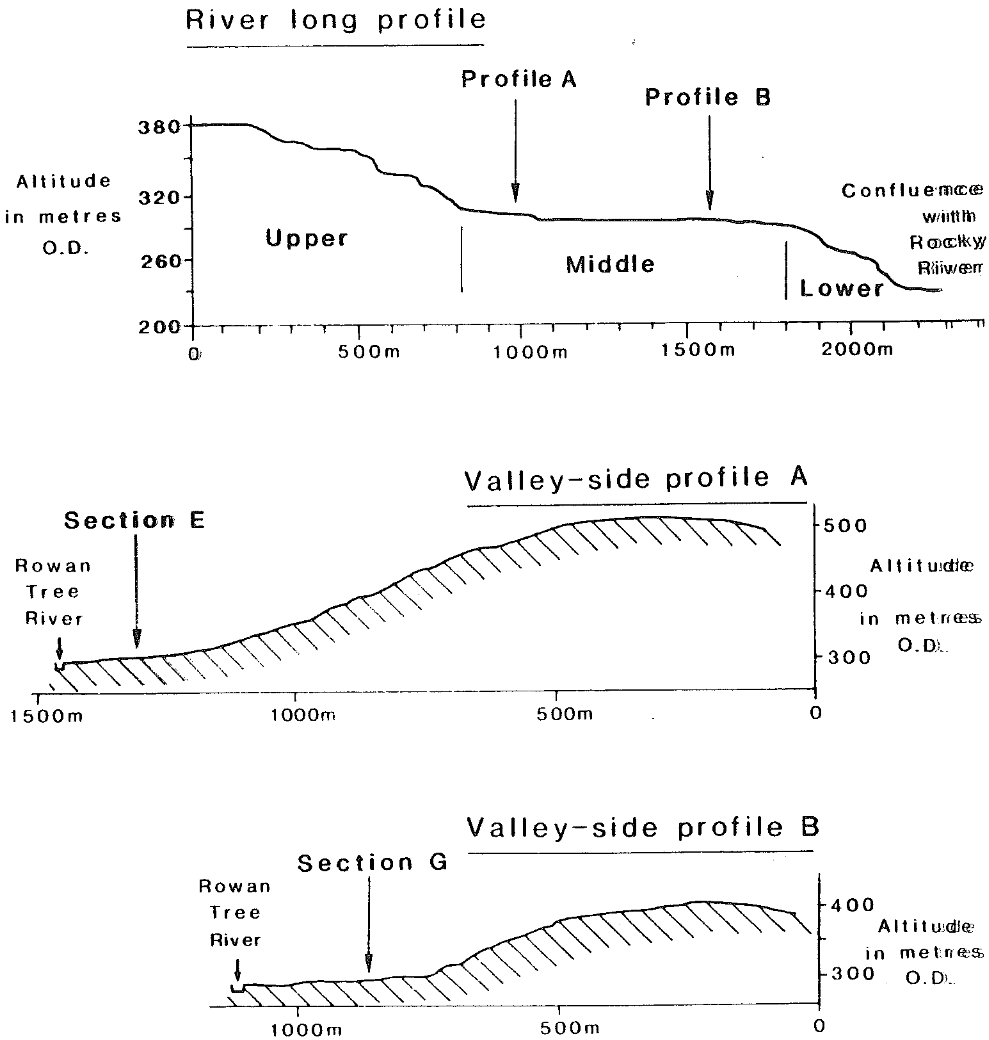

Fig. 21 Stream and valley profiles from the Rowan Tree River valley.

Ericaceous) peat.

Pollen analyses have been carried out on peat profiles from two sites in the Black Bog. These are located at site 7 (profile G and 8 (profile E) (Fig. 20) and are shown schematically together with valley-side characteristics in Figure 22. Profile G was collected from the deepest remaining peat and, on pollen evidence, is believed to cover the whole postglacial period. Profile E, towards the headwaters of the catchment, began to accumulate some time later than G and is characterised by gravel lenses within the upper profile (Fig. 22). In the site E pollen diagram selected species are presented as percentages of total pollen (Fig. 23). The loss-on-ignition curve (8 hr at 550 C) highlights layers of increased inorganic content within the profile. Inferred vegetational and environmental data for the locality are based on a combination of evidence from sites E and G (Table 4). The peat profiles have been divided into a sequence of four pollen analytically defined phases for discussion.

Phase 1. An immediate postglacial period of pioneer vegetation as assemblages of open *Juniperus* and *Empetrum* scrub are succeeded by *Betula* and *Salix*. This phase is only found in the deepest peat section (max. 2m) at site 7 with reedswamp peat including birch remains and containing much aquatic pollen suggesting shallow water with reedswamp and carr development. This is succeeded later by *Sphagnum* bog.

Phase 2. Hazel became established at the start of this phase and was followed by high forest trees of elm, pine and oak. Peat accumulation at site 8 (E) began early in this phase. Pine stumps found in and beneath the peat confirm the presence of pine on dry bog surfaces and on marginal areas with ivy, bracken and heather. Hazel probably colonised the drier and more base-rich soils prior to suppression by oak and elm at many sites.

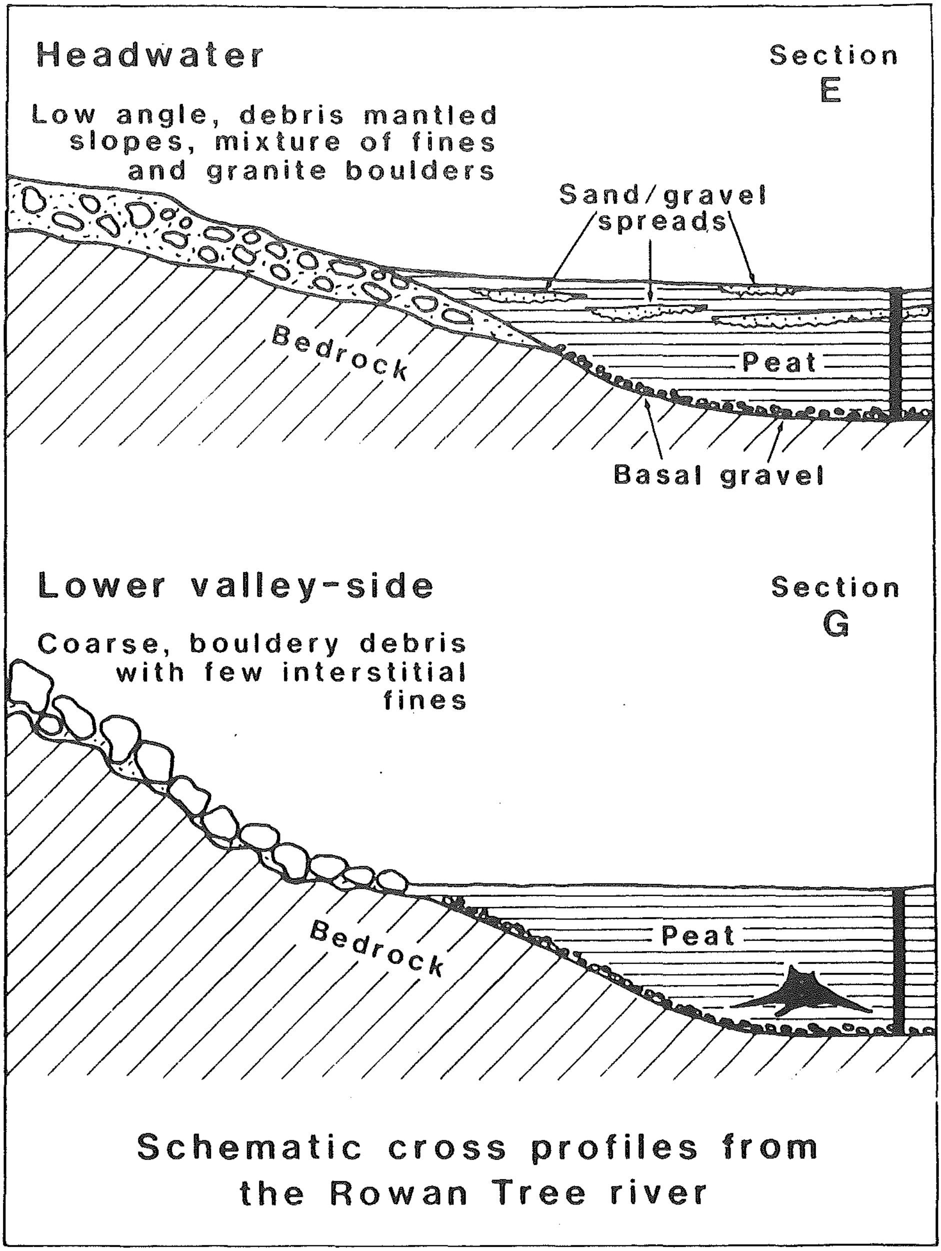

Fig. 22 Schematic profiles of sediment types from the Black Bog and Rowan Tree River valley.

PHASE	DRY LAND/TREE VEGETATION	LOCAL/MIRE VEGETATION
4	PINE INCREASE INCREASE OF WEEDS & CEREALS REDUCED HAXEL-TYPE BIRCH-ASH-ELM REGENERATION OAK-ALDER REDUCED ALDER MAXIMUM	EXPANSION OF HERBS DEPOSITION OF GRAVEL LAYERS TEMPORARY INCREASE IN SEDGES
3	INCREASE OF WEEDS ASH EXPANSION ELM DECLINE-PLANTAIN PRESENT HOLLY ALDER EXPANSION - PINE REDUCED	SPHAGNUM INCREASE TEMPORARY INCREASE IN SEDGES SPREAD OF PEAT AT
2	+ OAK + IVY + PINE + ELM HAZEL	ROWAN TREE RIVER AND LOWER IN VALLEY PINE STUMPS IN PEAT PINE + BRACKEN + CALLUNA + HERBS SPHAGNUM REDUCED PEAT ACCUMULATION STARTS AT SITE 8
1	BIRCH-WILLOW-FERNS JUNIPER-EMPETRUM HERBS	SPHAGNUM + CALLUNA PONDWEEDS + HORSETAILS + BULRUSHES + FERNS GRASSES + SEDGES + HERBS + LYCOPODIUM SELAGO

Table 4 : Vegetation phases in the Rowan Tree Catchment

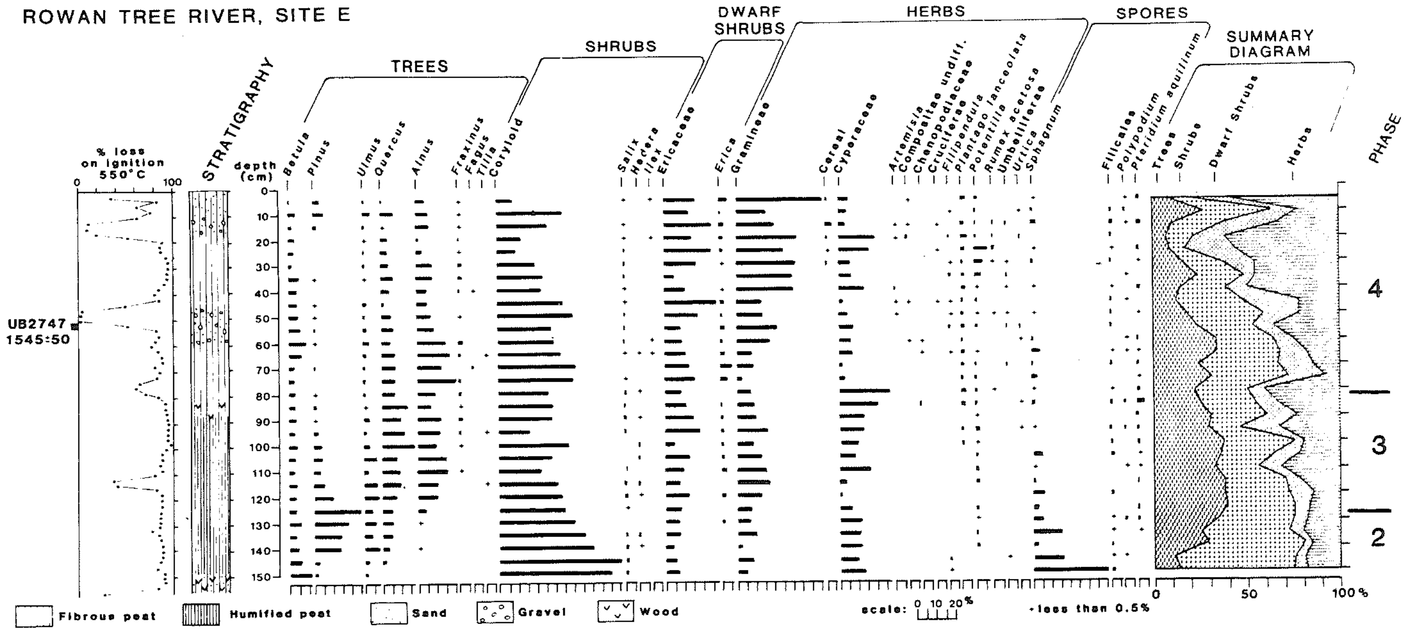

Fig. 23 Percentage pollen diagrams from section E (Fig. 22), Rowan Tree River valley. Principal taxa are expressed as a percentage of total pollen.

Phase 3. At the start of this phase an increase in wetness probably contributed to the reduction of pine and, possibly, the slow expansion of alder into the locality. There is a gradual and fluctuating decline of pine and elm during this period and an increase in herbs associated with anthropogenic activity, e.g. Plantogo lanceolata, Urtica, Chenopodiaceae, Rumex and Pteridium. Ash first appears in the record in this phase. These observations suggest the presence of man and a gradual opening and change in composition of the local woodland.

Phase 4. Several episodes of increased intensity of agricultural activity are indicated in this most recent phase. These are generally characterized by reduced elm and birch pollen and more frequent herb pollen particularly of plantain and cereals. A reduction in hazel-type pollen, starting at 50cm at site E, coincides with a gravel spread (c.15cm in thickness) within the peat. This event in the pollen record is characteristically associated with gravel spreads in other profiles investigated in the Rowan Tree River. A 14C date of 1545±50 b.p. (UB-2747) from below the spread at site E suggests that gravel was deposited there sometimes after c.400 a.d. An increase in pine at the top of the profile indicates that peat accumulation continued until after the start of recent afforestation in the area sometime in the 18th century.

Gravel Spreads and the Geomorphic Impact of Vegetation Change. Towards the headwater of the Rowan Tree floodplain, spreads of sand and gravel within the peat profiles indicate that episodes of fluviatile deposition alternated with phases of peat accumulation (Fig. 20; Site 8). The sand and gravel spreads are discontinuous, and are rarely more than 10-15cm in thickness by 2m in width. No evidence was found to suggest that the lower boundaries are erosional. Their wave-like appearance suggests that the sand/gravel buried a pre-existing vegetation cover. Particle size analysis of the spreads reveals considerable uniformity between samples with a well-developed modal size range

(~60%) between 1-4mm. This is similar to the size distribution of *in situ* weathered granite from the catchment which may indicate that the spreads are derived from the working of the weathered bedrock with little preferential sorting. The temporal and spatial discontinuity of the sand/gravel spreads suggests that deposition does not represent a single, widespread catastrophic event in the catchment. They seem to have formed during episodic erosion or sediment release from specific areas on adjacent hillsides in response to a change in the geomorphic regime in the upper parts of the catchment. During the course of several episodes debris spread out over the lower floodplain to form colluvial fans whose outlines can still be identified from aerial photographs. The absence of gravel spreads in profile G could relate to the lack of a suitable source of erodable material or to its situation lower in the valley in a perhaps less geomorphologically sensitive area than the headwaters (Site E).

Changes in the geomorphic regime would appear to originate from the valley sides. These involved an increase in the erosivity of the hillslope environment and/or an increase in the erodibility of hillslope materials. Both of these changes could reflect a reduction in the vegetation cover together with ground disturbance. This would increase the frequency and amount of surface water run-off through a reduction in infiltration and interception while, at the same time, reducing the protection afforded to the underlying soil. In turn this could result in upslope erosion and debris transport over the low angle valley floor without necessitating any significant change in the bog itself.

Pollen analyses from the peat profiles (Fig. 23) suggest that the beginning of sand/gravel accumulation coincided with a period of marked vegetation change in pollen phase 4. This change involved a reduction in hazel-type pollen and an increased frequency of plantain, bracken and other indicators of open and broken ground. Shortly after gravel deposition there was a major increase in grass and sedge pollen and then cereals. This suggests an intensification of anthropogenic activities and possibly clearance of hazel-scrub from the valley sides.

Inorganic layers have been described from bogs at several other sites. At Carrivmoragh (5km, N.W. of Castlewellan, J315416, Fig. 19), Holland (1975) dated a 15cm layer of organic mud with clay and charcoal between 3295±50 b.p. (UB-866) and 3035±50 b.p. (UB-865). Pollen changes associated with the layer were attributed to frequent burning and increasing grazing pressure in the Middle Bronze Age. In the North Yorkshire Moors, Simmons et al., (1975) reported 'inwash stripes' in soligenous channel mires which are dated from the Mesolithic to post-Iron Age. These inorganic layers are usually associated with pollen evidence which records the opening to the forest canopy and the expansion of weedy species and are attributed to the activities of early man rather than to climatic changes (Simmons et al., 1975).

A late 4th or early 5th century A.D. date for the onset of gravel deposition and intensification of agriculture at site E assigns it to the Iron Age/Early Christian period when the rath-builders opened up large areas of Co. Down (Evans, 1978). The lack of evidence for permanent settlement in the upper parts of the Rocky River Valley itself raises the possibility that seasonal transhumance farming may have occurred during these phases.

The discrete vertical nature of the sand/gravel spreads, combined with their limited spatial extent and the apparent absence of any internal structure or sorting, probably implies that each spread represents a relatively short period of accumulation, perhaps as a result of one extreme run-off event. Such an explanation is supported by field evidence of present-day patterns of small scale, episodic erosion and deposition within the Mourne Mountains. In certain geomorphologically sensitive areas such as steep slopes, or where man has modified the environment with footpaths and tracks, similar releases of gravel have been observed in response to extreme meteorological conditions. These suggest that a pattern of gradual accumulation followed by sudden release might provide a type of threshold model which explains the episodic development of gravel spreads in the Rowan Tree catchment.

Loss-on-ignition changes in profile E (Fig. 23) show that, while there are no sand/gravel spreads belows the major layer at 40-55cm, two other inorganic-rich layers occur at 110-115cm around the time of the elm decline, and around 72-80cm at the time of the Pinus disappearance. Preliminary observations suggest that these two layers represent inwash episodes rather than changes in peat-type or humification. Two episodes of bog flushing by groundwater are therefore suggested but they reflect much less pronounced environmental/geomorphic changes than those represented by the gravel spreads. Both of these earlier events occurred at times when man's activities could have been responsible. The first dates to the early Neolithic when the court-tomb builders (the culture who constructed Goward Court-Tomb) were active in the lowlands. The second occurred sometime in the Bronze-Age and, although poorly represented in the archaeological record, coincides with the continuous presence of plantain and bracken in the palynological record. However, as both events occurred during times of postulated climatic shifts (Lamb, 1977), the palaeoenvironmental picture is far from clear.

KILLARD POINT (Site 17, J602423; A.M.M.)

Introduction. This moraine is one of a series of ridges which mark former ice marginal positions in the northwestward retreat of Late-Pleistocene ice in east-central Ireland (Stephens & McCabe, 1977). These moraines are sedimentologically complex (gravel, diamicton, mud) and formed in areas subject to deep, isostatic depression. Although, many of these deposits have been explained in terms of terrestrial models their sedimentology and structure indicate remobilisation and transport of glacigenic debris from grounding zones into deeper water.

The Killard Point moraine formed at about 17,000 b.p. when ice wasted north as far as south Co. Down. During this phase, the drumlins of the Co. Down lowlands (<100m O.D.) were associated with a southeasterly ice-flow pattern from central Ulster (Fig. 24). The Killard Point moraine is located 1km in front of the drumlin belt and parallels the present coast for Ca.10km. The moraine morphology is subdued which may indicate erosion and washing during high late-glacial sea levels. The sequences are unfossiliferous but are thought to be glaciomarine in origin (McCabe et al., 1983).

Sedimentology. It is clear that the lithofacies types present (Table 5) may be grouped into three major lithologic associations: diamicton, gravel and sand (Figs. 25, 26; Table 6):

1. Diamicton association. This overlies a Silurian pavement moulded by ice flow to the southeast. The association is characterised by a wide range of grain sizes (mud-boulders), interbedded lithofacies, variability of bedding type and a clast assemblage derived from local Silurian strata (Fig. 25).

Lithofacies Fl occurs at the base of the section and is overlain by massive and stratified diamictons (Dmm, Dms). Stratified diamictons consist of stacked, planar beds, 2-6cm in thickness. Clast freighting is evident from large, isolated clasts (< 30cm) parallel to, but projecting above bedding planes. The diamictons have been channelled and are draped by laminated pebbly mudstone (Fd) and red, massive clay (Fm). Large clasts show penetrative deformation of underlying beds.

2. Sand association. This consists of a vertical sequence of alternating mud and sand beds (Fl), parallel-laminated sand (Sh) and massively bedded sand (Sm). Flame structures, roll-up beds and water escape structures are common. Lonestones and 'till'

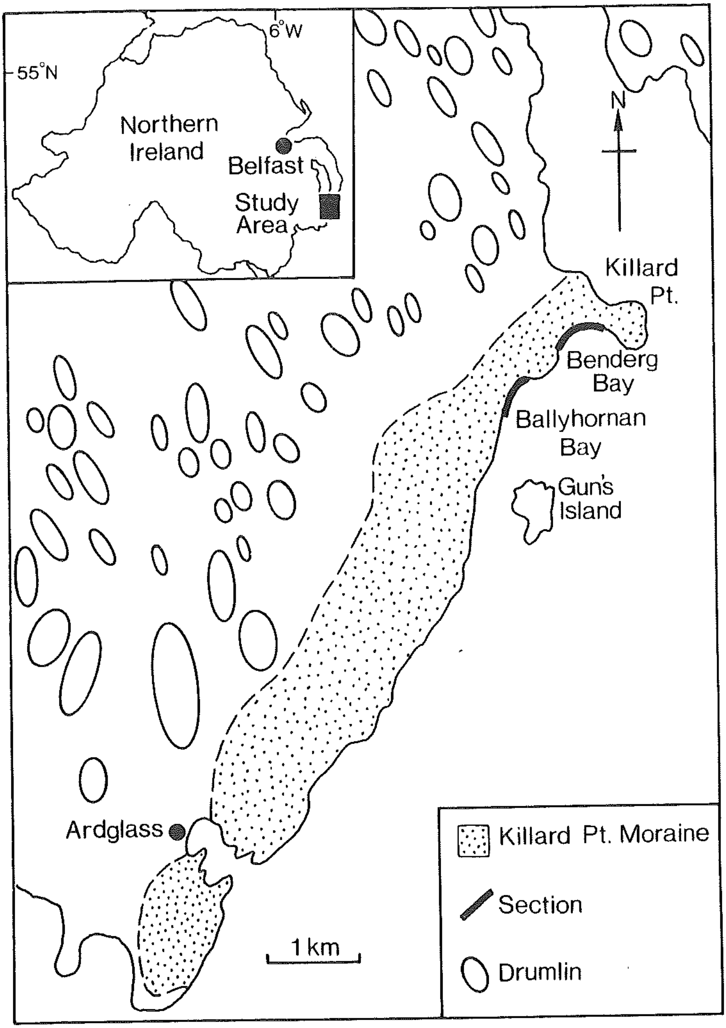

Fig. 24 Location of the Killard Point moraine, Co. Down.

TABLE 5. Summary of glaciomarine lithofacies types, Killard Point.

CODE	DESCRIPTION
Diamicton (D):	Poorly-sorted, mud-sand-gravel admixture
Dmm	Matrix-supported, massive structureless
Dmm(s)	As Dmm with shear or fold structures
Dms	Stratified, occasionally graded, matrix-to-clast supported, evidence of winnowing
Gravel (BG - boulder/cobble grade or PG-pebble grade):	
BGmm	Matrix supported, massive, unstratified, matrix from granules to pebbles
BGmg	Matrix supported, stratified. Grading : normal (n), inverse (i), normal to inverse (n-i), inverse to normal (i-n).
BGcm	As BGmg but clast-to-matrix supported.
BGcg	As BGmg but clast supported.
Sand (S) : Fine to medium grade	
Sm	Massive, unstratified
Sh	Parallel laminations or partings
Sr	Rippled
Sg	Graded
St	Cross-stratified
Ssd	Soft sediment deformation
Mud (F) : Fine grained units mainly silt and clay	
Fm	Massive mud; unstratified
Fl	Clay, silt and sand laminae, alternating beds
Fd	Laminated pebbly mudstone or laminated mud with clasts

Table 6. Lithologic associations in the Killard Point moraine.

Lithologic Association	Major lithofacies	Minor lithofacies	Interpretation
Gravel	BGmm, BGmg BGcg, BGcm PGmm, PGcm	Fm. Fd. St	High density sediment gravity flows.
Sand	Fl, Sh, Sm.	Fm. Ssd	Turbidity currents and sediment gravity flows of low to intermediate viscosity.
Diamicton	Dmm, Dms	Fm. Fd BGcg (i)	Remobilisation of glacigenic debris. Slumping and cohesive debris flows.

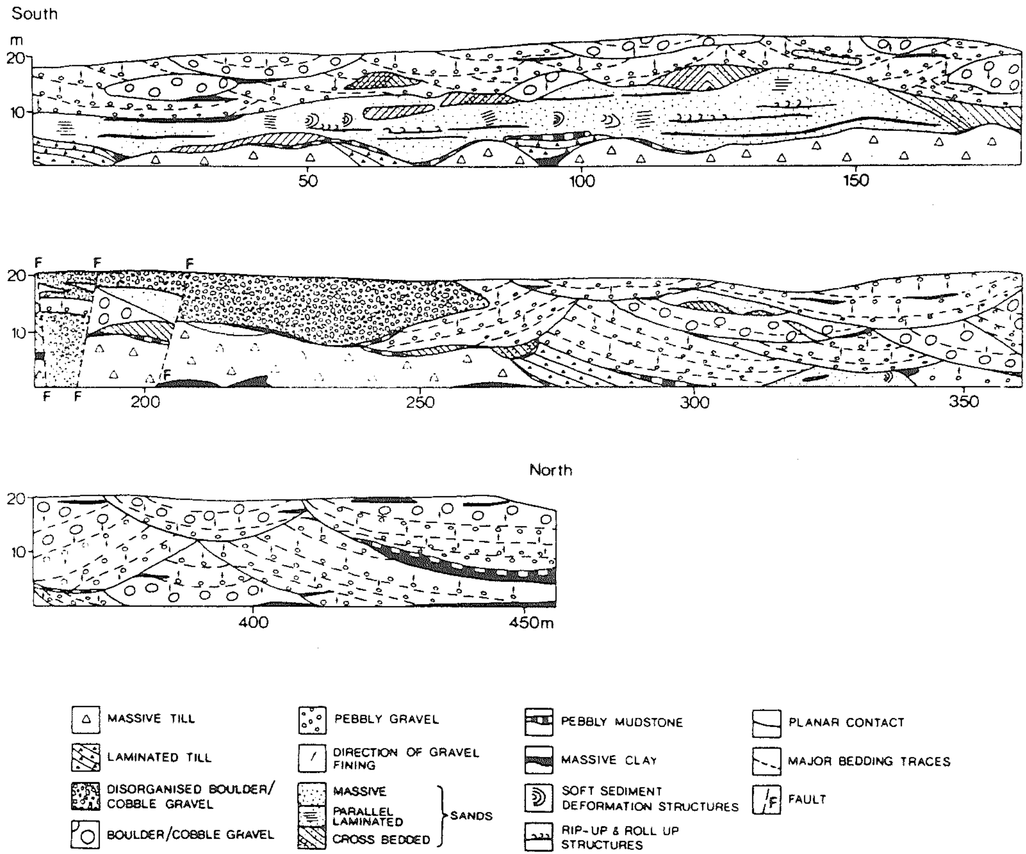

Fig. 25 Benderg Bay section. See Table 5 for lithofacies code.

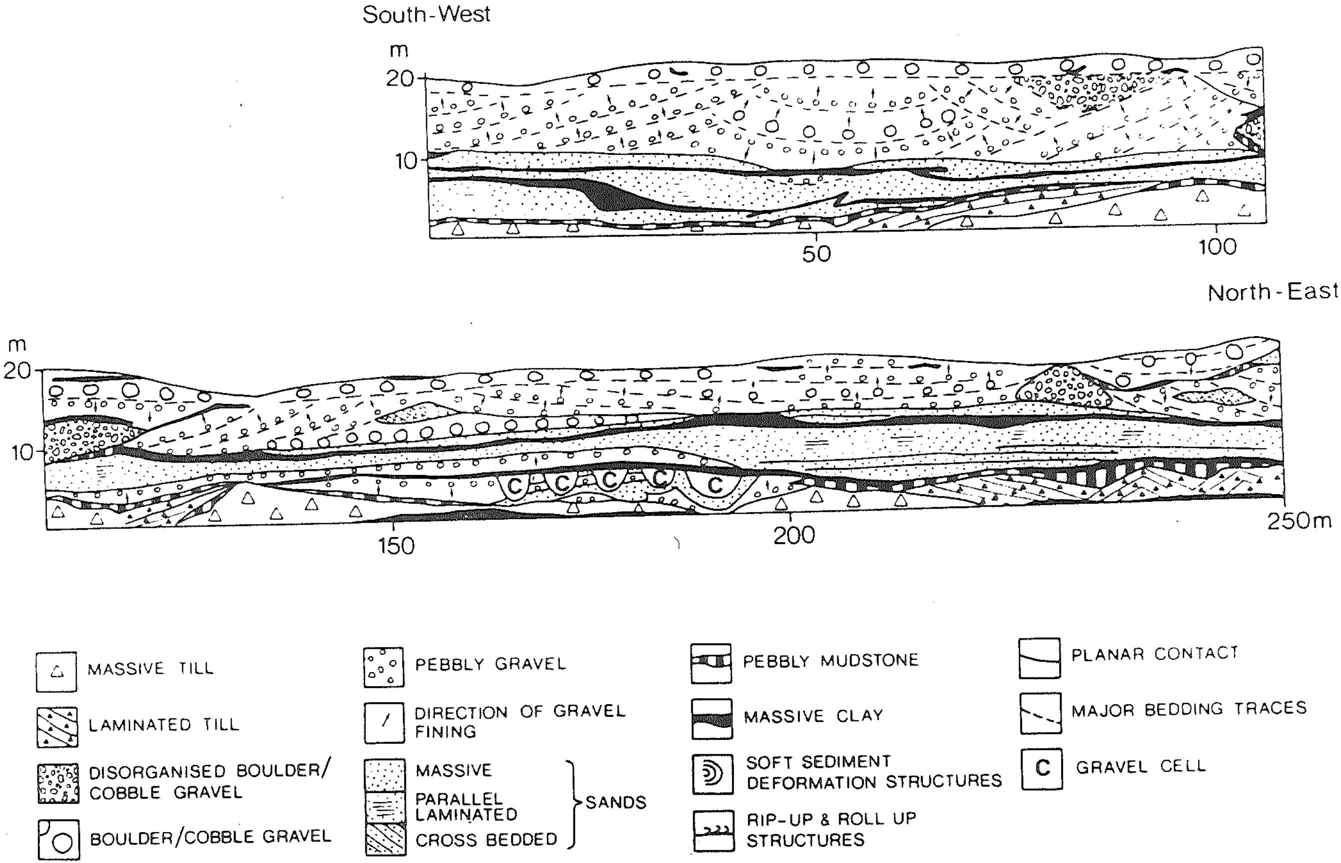

Fig. 26 Ballyhornan Bay section.

pellets (Ovenshine, 1970) occur throughout. Red clay beds occur at all levels.

3. Gravel association. The jucntion with the underlying sands is planar, channelled or marked by soft-sediment deformation gravel dykes/sills. The gravel occurs as a nested set of fourteen major channel infills on the basis of well-defined margins, erosional junctions and sedimentary contrasts. In normal section, channels range from 10-80m in width by 5-11m in depth. The sequence is characterised by:

(i) Channels occur as a nested, prograding sequence. Margins are dish shaped or erosional.

(ii) Clasts are subrounded. Bullet-shaped modes are uncommon.

(iii) Where present (exc. BGmm) major bedding-planes contacts are sharply-defined and parallel channel margins in a fashion similar to catenary curves.

(iv) Channel bases may be lined with 1m of Fm or Fd. Mud drapes occur in many infills.

(v) Three main infill types occur. The lower part of the sequence is dominated by stacked beds of stratified, normally-graded cobble gravel (Bgmg(n)) and pebble gravel (Pgmg(n)). Boulder grade clasts commonly form a lag at the base of individual beds. Channel deposits in the mid-sequence consist of stacked beds of 'n' and 'i' graded boulder gravel (75%) and disorganised boulder gravel (BGmm/BGcg) (25%). The top sequence is almost entirely boulder gravel lithofacies (BGmm, BGcg, BGmg). Channel margins are poorly-developed and clast clustering is apparent.

(vi) The section shows a general coarsening-up trend. Channel cutting and filling are associated with a general palaeoflow to the south and southeast.

Interpretation. Although the diamictons are in some respects similar to some basal tills their internal structures (slumpfolds, interbedding with other lithofacies, sand stringers, crude stratification) are not truly typical of this origin.

These attributes suggest that they are resedimented glacial debris with stratification and matrix differences related to differences in type and distance of flow (Fig. 27). Lithofacies Dms reflects winnowing. The laminated pebbly mudstone drape probably reflects density underflows and bottom current reworking. Clasts within these beds show dropstone structures (cf. Powell, 1981; Thomas & Summers, 1982). The interbedded red muds are texturally distinct from fine-grained rhythmites (Ashley, 1975) and are associated with plume rain-out during phases of decreased debris flow activity.

The sand apron prograded over the diamicton association and seems to be associated with sediment gravity flows of low to intermediate viscosity (Middleton& Hampton, 1976). Lithofacies Fl contains type AB Bouma divisions suggesting turbidity currents activity. Lithofacies Sh contains roll-up and flame structures, rip-up clasts, channel traces and isolated pockets of ripple-drift, cross-lamination. This assemblage probably reflects a wide range of depositional mechanisms associated with density underflows. Lithofacies Sm suggests gravity flow of cohesionless sediment (grain flow).

The gravel association prograded generally south-eastwards as a distributary-type system subject to avulsion or changes in fluid/debris input. The coarsening-upward nature of the sequence probably reflects increase in debris input rather than a forward surge of the ice-margin. Rapid accumulation of this type probably increased local slopes which would facilitate sediment remobilisation and subaqueous sediment transport. This occurred as a series of pulses evidenced by sharp, planar junctions and clay drapes. The presence of mudstone on the channel bases/flanks indicates that phases of cut and fill are not closely related.

The coarsening-upward gravels show from base to top: normal grading and stratification→inverse grading with some

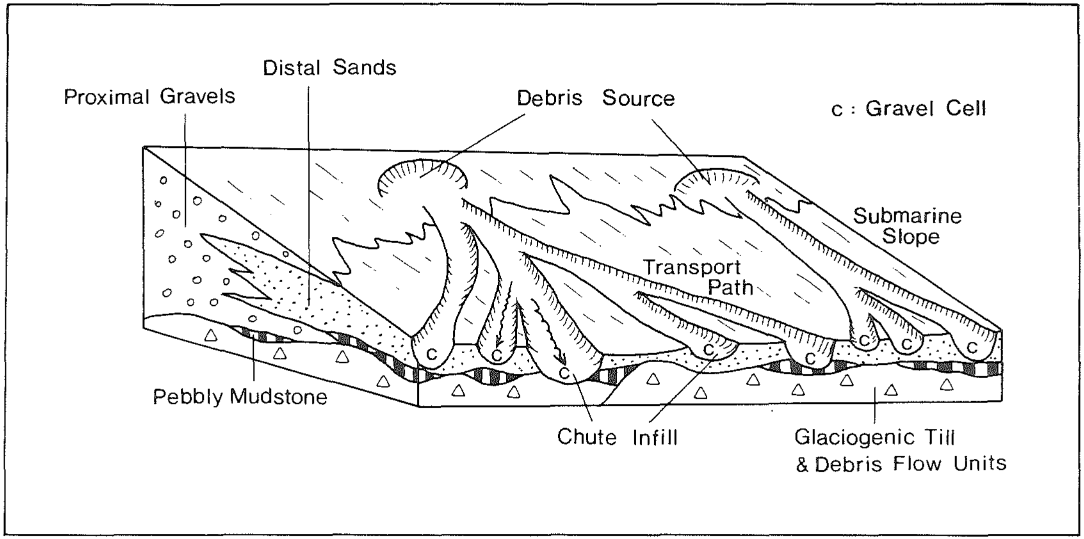

Fig. 27 Gravel cell genesis.

stratification→disorganised beds with little grading or stratification. Stacked sequences of this type are similar to resedimented, deep-water conglomerates (Walker, 1975, 1983). The gravels therefore represent the evolutionary continuum recognised in high-density sediment gravity flows (Lowe, 1982; Walker, 1975, 1983).

Depositional Model - The Killard Point Type. Regional sea level, lithofacies arrangement and interpretation of associated processes indicate a submarine origin (Fig. 28). The depositional environment suggests that:

1. The absence of melt-out/rain-out diamictons precludes deposition from overriding ice or an ice-shelf.
2. The sedimentary sequence suggests transport of Ca.1km from the grounding zone.
3. The lateral persistence of mud horizons indicates that debris flow activity was episodic.
4. The nested set of gravel infills does not represent direct meltwater input (cf. Rust & Romanelli's model, 1975). They are high-density sediment gravity flows.
5. The absence of ice-berg furrowing probably indicates moderately deep water (Ca.100m?).
6. Sequences such as this indicate that all grain sizes may be remobilised by bottom current and debris flow activity.
7. This interpretation supports Ruddiman and McIntyre's (1981) view that Late-Pleistocene, mid-latitude sea surface temperatures, coupled with rising sea levels, provided a strong deglacial mechanism which was largely independent of terrestrial deglacial mechanisms.

A wide range of glaciomarine environments occurs (Andrews & Matsch, 1983). The Killard Point model is distinct from most in that it highlights the importance of high-density sediment-gravity flows in outer proximal (1km from grounding zone) glaciomarine environments.

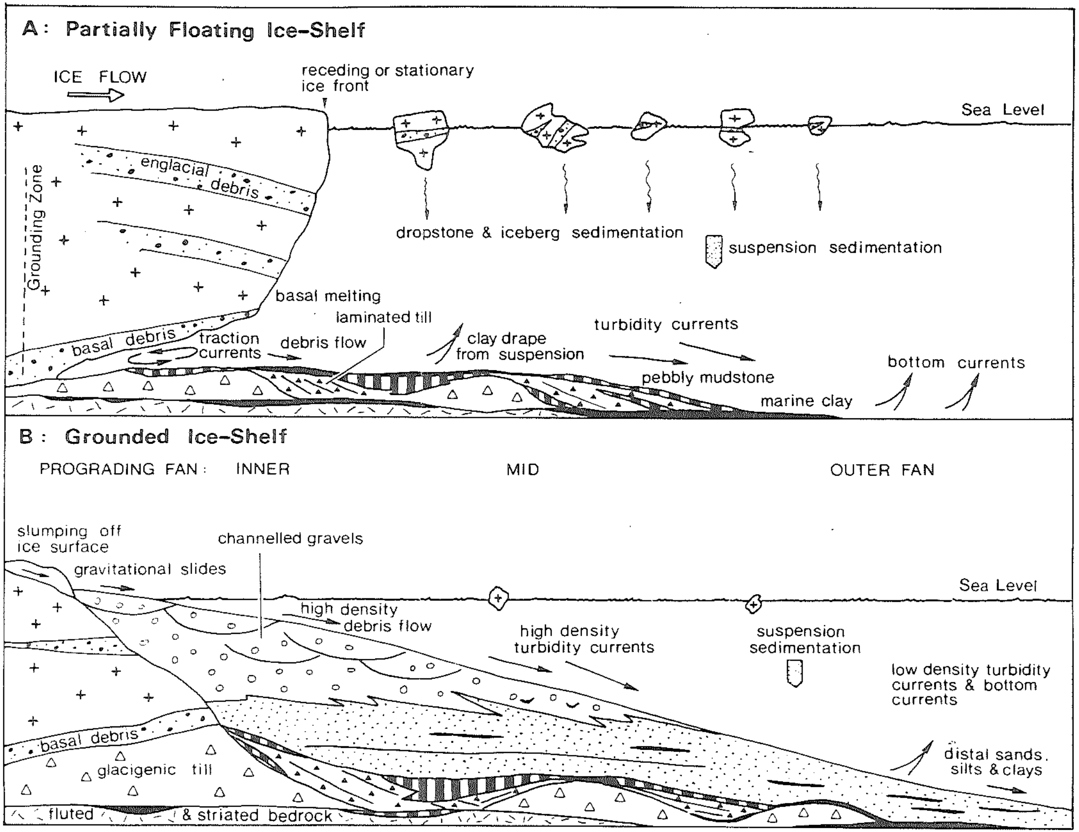

Fig. 28 Composite model of the depositional environment, Killard Point, Co. Down.

MURLOUGH 'SPIT', DUNDRUM BAY (Site 18, J404347; J.D.O.)

Introduction. Murlough 'spit' in association with Ballykinler 'spit' represents the largest area (10.3km) of sand dunes on the eastern seaboard of Ulster (Fig. 29). The area is of sufficient size and importance in both geomorphological and botanical terms, that over 60% of Murlough spit now forms a Nature Reserve under the jurisdiction of the N.I. National Trust (started 1967). Despite its potential as a site of continuous postglacial deposition, it is unfortunate that research on Murlough offers only a limited understanding of depositional history and environmental conditions. Given a resurgence of interest in models of coastal response to sea-level change, it is appropriate to consider what problems the site presents and what answers, if any, can be obtained from these deposits. As access to Ballykinler is prohibited due to MOD ranges, most field evidence is derived from the Murlough side of the sink.

Description. The use of spit terminology to describe Murlough coastal deposition, is one that both Whittow (1974) and Davies and Stephens (1978) make, yet it is far from clear that Dundrum littoral sedimentation can be considered as a spit in terms of its genetic implications. In a descriptive sense, the 12km of near continuous dune and sand beach morphology between Newcastle and Tyrella appear to show two spit-like macro-features. The near perfect planview refraction arc of these features is broken by a tidal-dominated channel (The Channel) that separates Murlough from Ballykinler and connects a tidal lagoon (The Inner Bay) with Dundrum Bay. On either side of the Channel are smaller accumulation spit forms. The largest is on the Murlough side and is vegetated (trees and buckthorn) and on map evidence is a late-19th century feature. Modern net erosion of the Ballykinler beach face is providing sand for marginal Channel ridge. The longshore continuity of Dundrum is further disturbed east of Ballykinler by a series of igneous dykes trending at

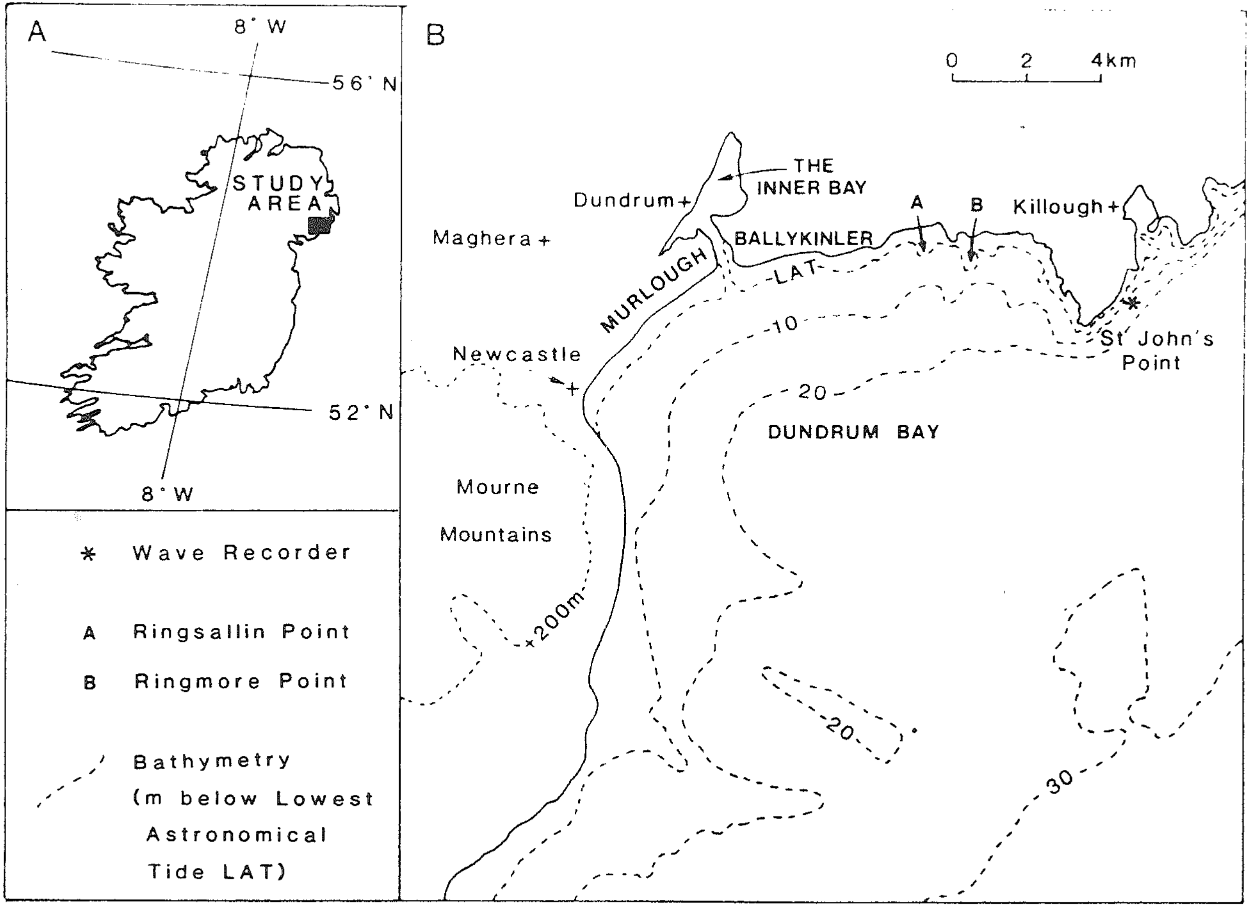

Fig. 29 Location of Dundrum Bay and Murlough spit.

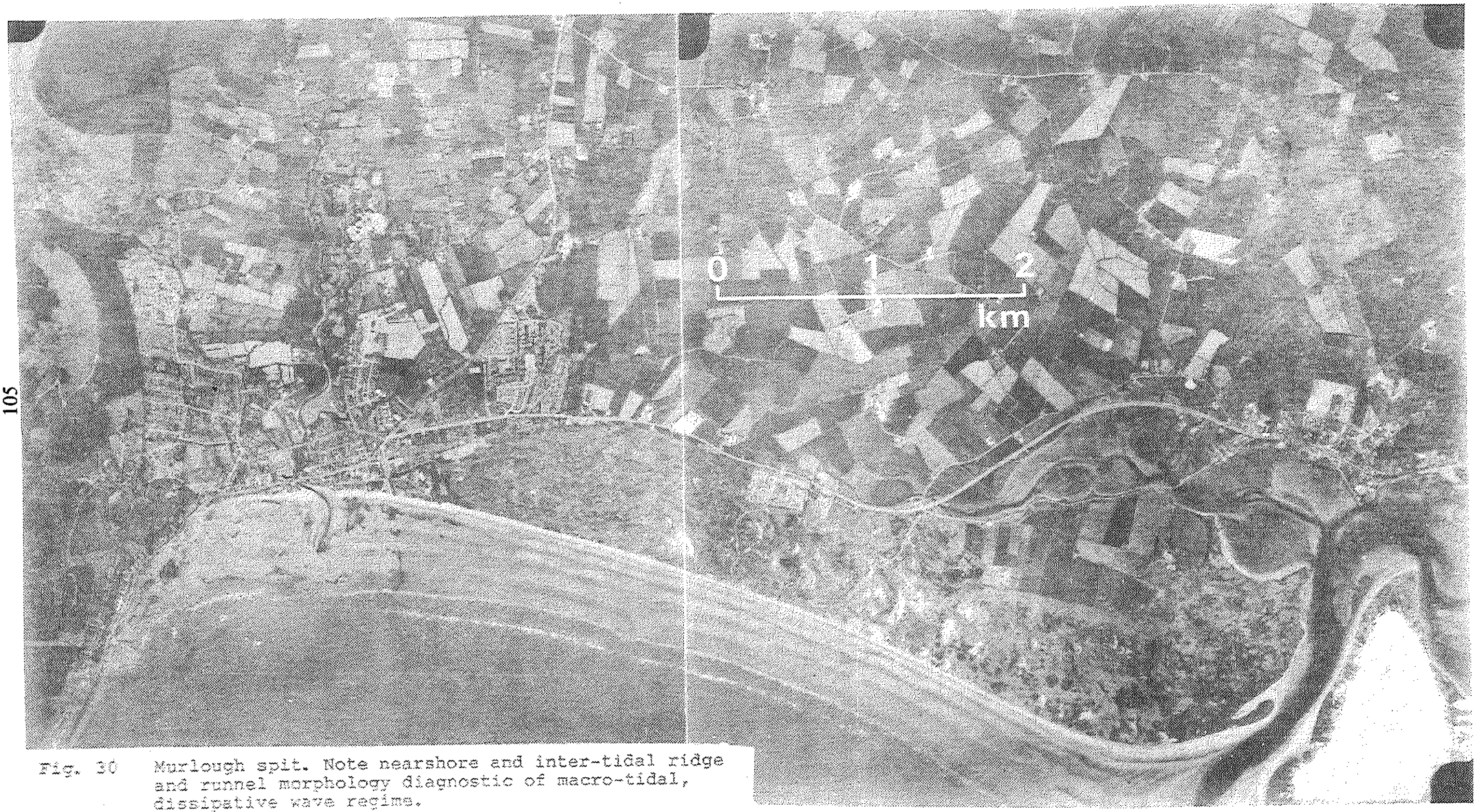

Fig. 30 Murlough spit. Note nearshore and inter-tidal ridge and runnel morphology diagnostic of macro-tidal, dissipative wave regime.

right angles to the beach strike to form major nearshore shoals. The Channel has a substantial ebb-tide dominated delta which appears to be linked on both beach sides to a series of seasonally prominent, inter-tidal, longshore-parallel sand ridges (ridge and runnel) (Fig. 30).

The dune system (vegetation and morphology) has been considerably disturbed by 18th century rabbit warrens, continuing Ministry of Defence (MOD) usage since World War I and latterly in parts by tourism. Where unstabilized blowouts still occur, and fossil-soil sequences can be seen in the dune sequence. The oldest of these paleosols is by far the most extensive, forming a low (12-15m O.D.) undulating surface which covered most of the existing Murlough dune system. The surface associated with the soil was primarily heath vegetated and, based on charcoal remnants from the 'A' horizons of the podzol profiles, dated at 3000-5000 b.p. (Cruickshank, 1980). Younger immature soil profiles show no great lateral extent. The oldest soil horizon divides the 'Older Dune' from the 'New Dune', with the latter characterized by low to steep angle cross-bedding composed of thin laminar cosets, while the former is a featureless, massive sand unit that has been bioturbated.

At the base of major blowouts the tops of gravel ridges can be found. Figure 31 shows where blowouts have exposed elements of an extensive system of parallel/sub-parallel ridges underlying the dunes. The width and spacing of dunes are now known in detail, though Mitchell and Stephens (1974) present data which they argue shows the ridge height to fall in a seawards direction (+10m O.D. to +5m O.D.) with the final ridge emerging from under the dune cover and fringing the dunes on the seaward side. The landward edge of these gravel ridges has not been plotted in detail but limited borehole and morphological evidence (Orford, 1982a) suggests that the ridges do not cover the entire width of Murlough spit, rather they finish midway across the width. The distinctive flatter agricultural land on the north side of the

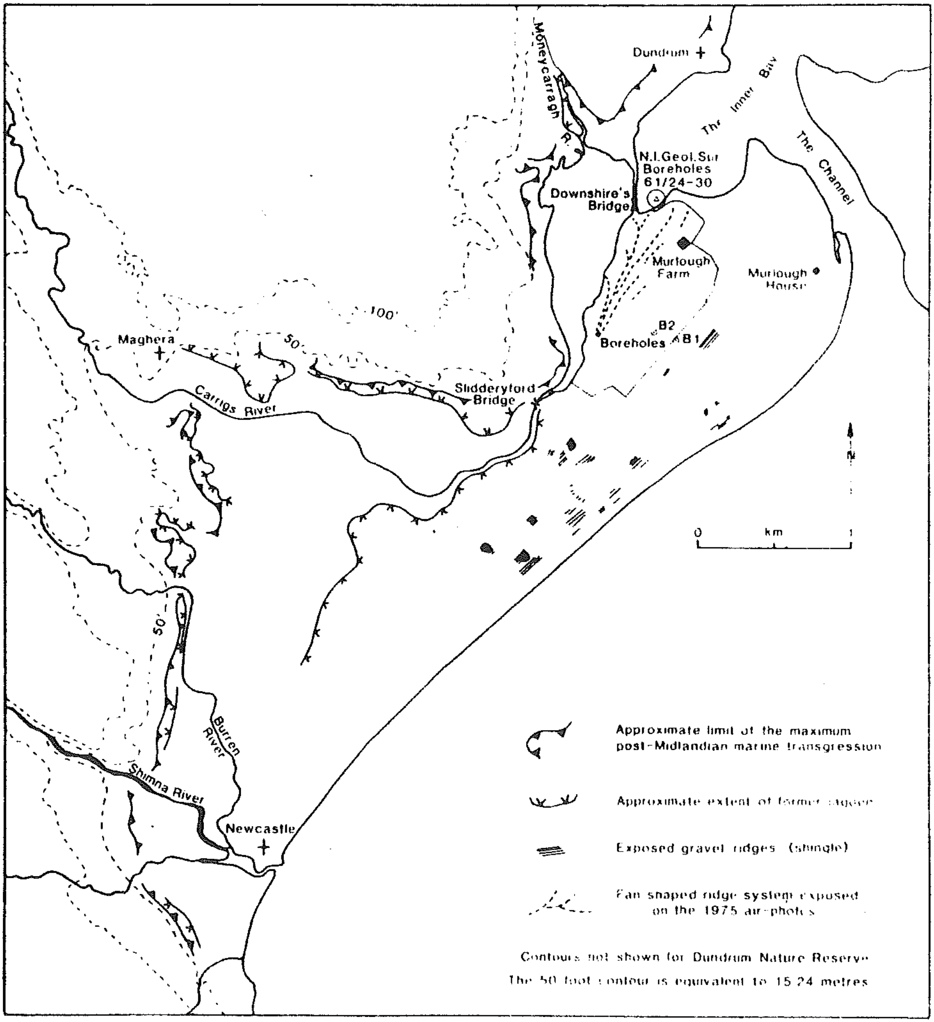

Fig. 31 Location of post-Midlandian morphology and deposits at Murlough spit.

spit appears not to be gravel ridge based. The width of gravel at the southern end of the feature is also unknown, as the morphology has been completely disturbed by Newcastle. However the sand dune width at Newcastle is significantly less than at the spit head. Between the spit, the Mournes and the Silurian basement is a triangular area (Maghera lowland) which is gently sloping seaward and has been suggested by Shepherd (1971) to be formed of peaty organic soils banked against a till-covered, rising land though recent reconnaissance augering shows this organic element to be hard to locate! Cut into the till around the Maghera lowland is notch/platform at about 14m O.D. (Fig. 31). At some points on the notch (e.g. in Dundrum village) gravel accumulations can be found (Shepherd, 1971).

In 1975, aerial photography (in a particularly dry summer) showed a series of fan-rib like ridges underlying the flatter ground on the north side of the spit. These appear to be tied to a position near the rising till-covered Silurian basement at Slidderyford. These features may have some possible spatial expression in the 'capes' or minor headlands found on the south shore of the Inner Bay near Downshire's Bridge (Fig. 31).

Figure 32 is a schematic attempt to show the stratigraphical and spatial relationships between features described and sediments/structures available from a number of shell and auger boreholes in the area. A generalized facies interpretation of key sediments from Borehold Bl (Orford, 1982b) is also included.

Wave and tidal regime. Ulster's eastern seaboard is fetch limited and sheltered from direct Altantic ocean influences. Storm waves are mainly from either southeast or northeast, with the former direction more influential for beach behaviour. Data from an inshore wave pressure recorder east of Dundrum Bay (Orford unpubl.) indicates a median significant wave height of 0.3m, and an exceedence significant wave height of 1.5m for 5% of the time. Modal wave crossing period (T_z) is 6-7 sec. Of

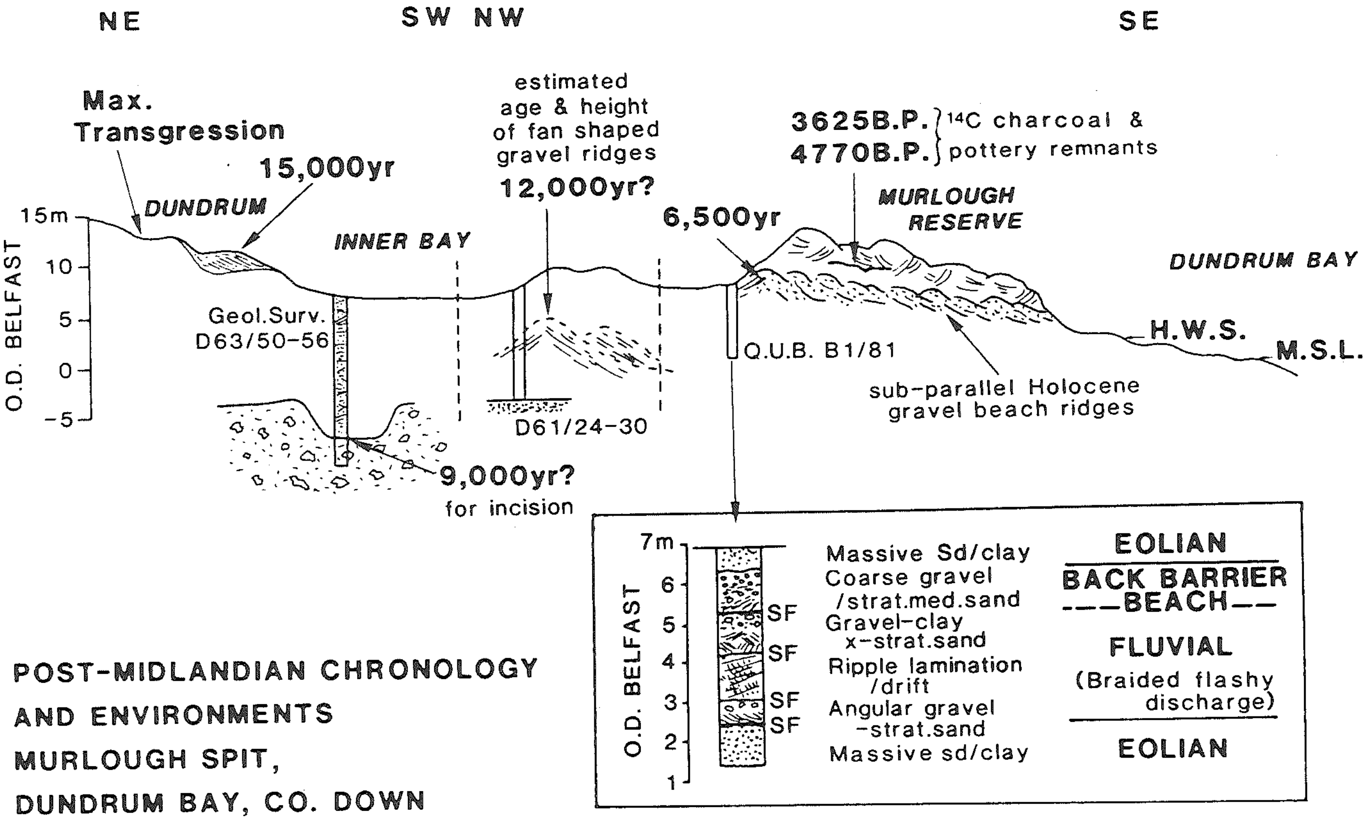

Fig. 32 Schematic stratigraphical relationships of post-Midlandian morphology and sediments at Murlough.

major interest for understanding littoral deposition in Dundrum Bay, are the movement of long period constructional swell waves into the eastern seaboard, which can be identified from off of the wave records (>14 sec.). Offset zeta-shaped or crescentic-shaped bays occur to the north of Dundrum (along the Ards Peninsula) and their northwards, offset direction implies refraction of northerly moving swell which could only emanate from the Atlantic by way of the southern Irish Sea.

Tidal range in Dundrum is 4.3m (springs). Tidal range is maximised for Ulster near Dundrum, but quickly drops to 1m (springs) at Fair Head on the north coast. Such tidal variation is clearly important for interpreting paleo-sea level morphological remnants. Macro-tidal range is considered important in the development of the highly dissipative wave regime operating now in Dundrum Bay.

Interpretation and discussion. The central question is how the bulk of Dundrum was formed relative to sea-level position. The spit supporters argue that the feature shows classic spit morphology with sediments being moved longshore from the glacial debris off of the Mourne flank as well as from the Kilkeel Plain. Mitchell & Stephens (1974) relate the step-like gravel ridge system to the falling sea level from the Flandrian transgressive peak of +2 to +3m O.D. (5000 b.p.). This fall to contemporary sea-level is reflected in the seaward decrease in the ridge height, while as a concomitant, a regressive shoreline would have exposed considerable sand (origin not mentioned) sufficient for eolian dune building. To this end, the presence of prominent inter-tidal ridges may have contributed to the movement of beach sand into the dunes. The disturbance of the dune cover some time post 3000 b.p. and the growth of the New Dune has also been attributed to this influx of fresh sediment as sea-level fell. The Maghera lowland is regarded as the remnant of a lagoon trapped by the early Holocene spit growing north-east across Dundrum Bay. The notch in the till cover, inshore of the spit, is a remnant of a late-glacial shoreline (c.15,000 b.p.) now isostatically raised.

Difficulties with this interpretation are:

1. No origin is attributed to the flat 'agricultural' ground to the rear of Murlough spit. Its origin is central to the development of the gravel ridge system which overrides it, or banks against it.

2. Evidence of longshore gradients in pebble size on the modern gravel beach may reflect longshore sediment reworking during sea-level stationarity over the past 4000 years rather than necessarily infering transport response to spit development.

3. The fan-rib like spit at the rear of Murlough is difficult to fit into this general model. When did it develop, and what was the sea level at the time of its development?

4. How are two opposing spits, Murlough and Ballykinler, created by longshore supply from the one major sediment source off of the Mournes?

5. The gravel ridges show a high degree of linearity and lack of bifurcation (though this may reflect limited exposure through the dune cover). This does not seem feasible given a single points sediment source which would probably be prey to intermittent erosion. Pulses of sediment (from episodic storms) entering the beach system would lead to branching and merging of longshore ridges. Only the ridge features at the back of Murlough show these classic signs of spit-based bifurcation. Falling sea-level could be cited as the cause of longshore ridge coherence, with a new ridge dominating the shoreline the length of the spit as sea-level progressively declines. However, as Carter (1982) points out the ridge top elevation range is not more than gravel ridge top elevation range associated with contemporary sea-level. As this is the only site which shows the falling ridge heights, it is circular to use the site as supporting evidence of a falling sea-level, which is then used to justify the origin of the ridge series. Furthermore, Carter (1983) indicates that there is no unequivocal evidence to show this Flandrian regression took place at all, such that an alternative

explanation should not require sea-level fall as a contributory mechanism.

A partial alternative chronology is suggested (Fig. 32):
1. The notch in the till-covered Silurian basement is the post-glacial maximum transgressive limit. It was wave cut and some gravel ridge accumulation took place.
2. Late-glacial and post-glacial isostatic uplift led to regressive shoreline positions. At some point in this regression Slidderyford Headland (J393345) was the attachment point for a small mixed sand/gravel spit trailing northeast. With continuing falling sea-level this was left abandoned (c.12,000 b.p.?) and lies now at the rear of Murlough.
3. As the shoreline receded eastwards, reworking of the till cover by fluvial processes took place. Borehold B1 shows that under Murlough Spit lies at least 5m of sediment interpreted as braided stream deposition (Orford, 1982b) associated with discharge from off of the Mournes. The limit of this fluvial deposition was somewhere out in Dundrum Bay commensurate with the regressive shoreline minimum position. The borehole sediments rest on a well-sorted fine sand unit (= eolian element of the post-glacial regression?). The incised fluvial channel picked up at the top of the boulder clay (-5m O.D.) in the N.I. Geol. Survey borehole on the landward side of the Inner Bay (Fig. 31) appears related to a low base level position of the post-glacial regression.
4. During the rapid Holocene transgression (10,000-6,000 b.p.) the rising sea-level rolled onshore, around the full length of Dundrum Bay, a 'barrier' of reworked fluvial sediment. This was probably breached by the seepage from the lagoon trapped behind the landward encroaching barrier at an early stage, and subsequently kept open by tidal action.

At this stage the sequence of events becomes debatable as the origin of the multiple gravel ridge unit is contentious. If sea-level did fall back from its transgressive maximum (post-

Flandrian) then the ridges could be associated with the reworking of a nearshore equilibrium as the effective wave base moved seawards. This view is not so different from that of Mitchell and Stephens (1974). Any alternative is difficult to realise. The nearest analogue is that provided by Roy et al (1980) who show that Holocene prograded beach ridges in eastern New South Wales are a result of reworking of inner shelf material as the shoreface profile of equilibrium is reasserted during the still stand following a transgression. Although the wave energy and wave type for these two sites is markedly different this could be the mechanism for multiple ridge emplacement that would not require a regression as a driving mechanisms for ridge building.

A number of further questions remain to be answered:

1. Barrier or spit genesis are unlikely to be mutually exclusive categories. The presence of northeast longshore sediment transport associated with southeast storms means that some point source feeding from the Mourne glacial debris would have occurred, regardless of other sediment sources, during any barrier formation. To what extent was the relative sediment supply either longshore or onshore favoured?
2. How was the dune field formed? Was it regressive in structure, keeping station with the prograding beach ridges, or was it transgressive once the ridge system was built? If the latter, what process allowed for the switch in sediment type so that the transgressive dune cover would start to develop?
3. When did the present nearshore dissipative wave regime develop and to what extent did its development act as a trigger for dune sedimentation?

Conclusion. Dundrum Bay's littoral sedimentation affords a rare opportunity for studying the depositional process by which a gravel ridge system is emplaced in a low wave-energy environment. The traditional idea of spit deposition is not sufficient to explain the morphology observed at Murlough. An alternative view of a regressive barrier system is suggested.

DAY 3 ; MONDAY, 14 APRIL, 1986

ITINERARY

a.m. DRUMLINS, ARCHAEOLOGY AND CONSERVATION ISSUES, INTERGLACIAL PEAT, INTERTILL DETRITUS PEAT

Site 19 Jerrettspass: Sand cored drumlin/meltwater channel (A.M.M.)

Site 20 Navan Fort: Conservation issues (J.M.)

Site 21 Mullantur: Drumlin lee-side deposit (A.M.M.)

Site 22 Benburb: Interglacial peat (D.G.)

p.m. DRUMLINS, TILLS AND INTERSTADIAL PEAT

Site 23 Derrylard: Drumlin lee-side deposits (A.M.M.)

Site 24 Aghnadarragh: Glacitectonised lignite, tills, intertill organic horizons, mammoth remains (A.M.M., D.G., R.C., P.D.)

<u>JERRETTSPASS</u> (Site 19, 0071322; A.M.M.)

Introduction. Literature on the composition of Late-Pleistocene drumlins indicates that they are generally composed of basal tills, with stratified sediment occurring as a minor constituent (Menzies, 1979). Recently, a series of papers have considered the likely depositional environments associated with the genesis of stratified sequences within drumlins (Dardis & McCabe, 1983; Dardis <u>et al</u>., 1984; Dardis & McCabe, 1985). In most cases where a substantial sand core exists the major problem is whether the stratified sediments were deposited in a proglacial or subglacial environment.

Sand cored drumlins occur at the northern and southern parts of the Poyntz Pass channel system which is approximately 30km in length and varies from 3 to 6km in width (Figs. 33, 35). This channel system was used during the last deglacial phase and shows many similarities to tunnel valley systems (Ehlers, 1981). Sand cored drumlins only occur along and within the channel system. Large rock drumlins occur in areas west and east of the main channel (Fig. 35).

At Jerrettspass, drumlins average 500m in length by 200m in width and are oriented north-south. Summits are at 50m O.D., 50m below the shoulder of the channel (Dardis & McCabe, 1983).

Stratigraphy and sedimentology. In 1981 the Jerrettspass exposure showed a basal prograding coarse-clastic deltaic sequence (units 1 - 3), varying in thickness from 4 to 9m, unconformably overlain by a discontinuous layer of horizontally-bedded gravel (unit 4) (Fig. 34). These units constitute the sand-core which is overlain by a series of glacigenic tills (units 5 - 8). The orientation of large-scale cross-stratified beds indicate a general southward current flow during development of the sand core. Lithological analyses indicate that the tills are derived from northerly sources.

Unit 1 (Bottomset beds). These are predominantly fine-grained

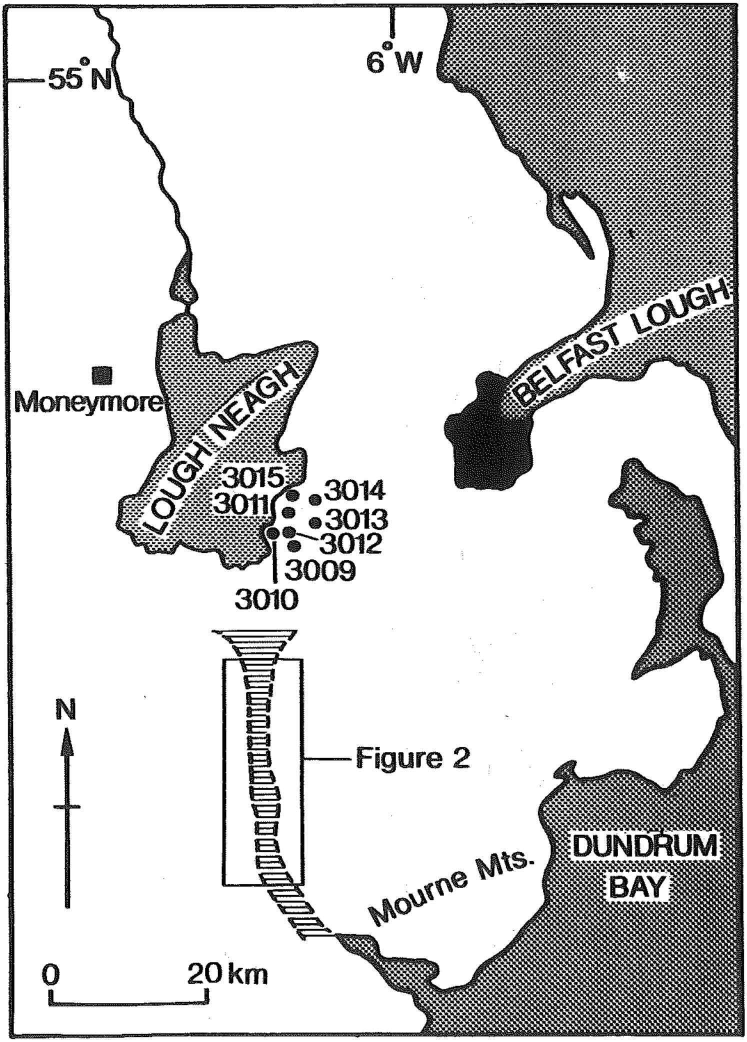

Fig. 33 Location of Fig.35 and the Poyntz Pass glacial drainage channel. Numbers refer to borehole records of some sand-cored drumlins in central Ulster.

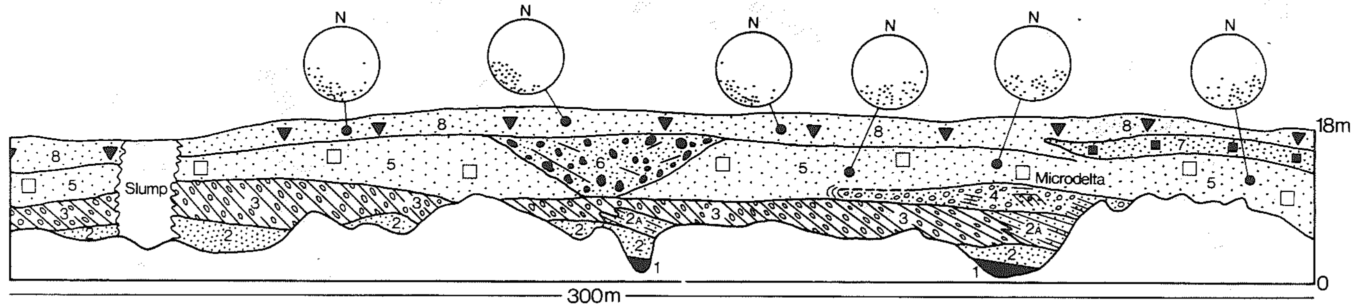

Fig. 34 Sedimentary facies of the Jerrettspass Drumlin.

1. Bottomset beds 2. Toeset beds 3. Foreset beds
4. Topset beds 5. Lower till 6. Sediment gravity flow facies 7. Massive till facies 8. Upper till facies.

horizontally-bedded sands, silt and clay (+1 to +9ϕ). The sediments contain a wide range of primary sedimentary structures including normally-graded sand, type'S' and drape laminations (Jopling & Walker, 1968), and occasional pebble sized clasts.

Facies relationships include transitions from suspended load to bedload sedimentation and are similar to vertical sequences generated in prograding bottomset sediments of glaciolacustrine origin (Ashley, 1975; Cohen, 1979). They reflect deposition from low density, bottom flowing turbidity currents and low energy suspension sedimentation (Gustavson, 1975).

Unit 2 (Toeset beds). The bottomsets grade upwards into toesets (Elliott, 1978) which are mainly type 'A' and 'B' ripple drift cross-lamination (Jopling & Walker, 1968), normally graded beds and parallel-laminated silt and clay. They consist largely of incomplete Bouma sequences (Bouma, 1962; Walker, 1976) with minor diamicton units. These beds are similar to rhythmite and proximal turbidite sequences deposited on foreset slopes (Cohen, 1979). The presence of interbedded dropstones, massive sand and diamictons indicates grain flow, slurry flow and sedimentation from floating ice operating in conjunction with turbidity current activity.

Unit 3 (Foreset beds). These avalanche-front cross-stratified beds consist largely (70%) of pebble and cobble gravel. Dips range from 30° to 15°. The cross-strata are similar to coarse-clastic delta foresets (Clemmensen & Houmark-Nielsen, 1981) and to foresets of pipe-flow dunes (McDonald & Vincent, 1972).

Unit 4 (Topset beds). These subhorizontal, parallel bedded gravels are fragmentary and are up to 1.5m in thickness. Their lateral discontinuity may indicate partial incorporation into the overlying till or erosion prior to till deposition.

Unit 5 (Lower till facies). The topset beds grade into a

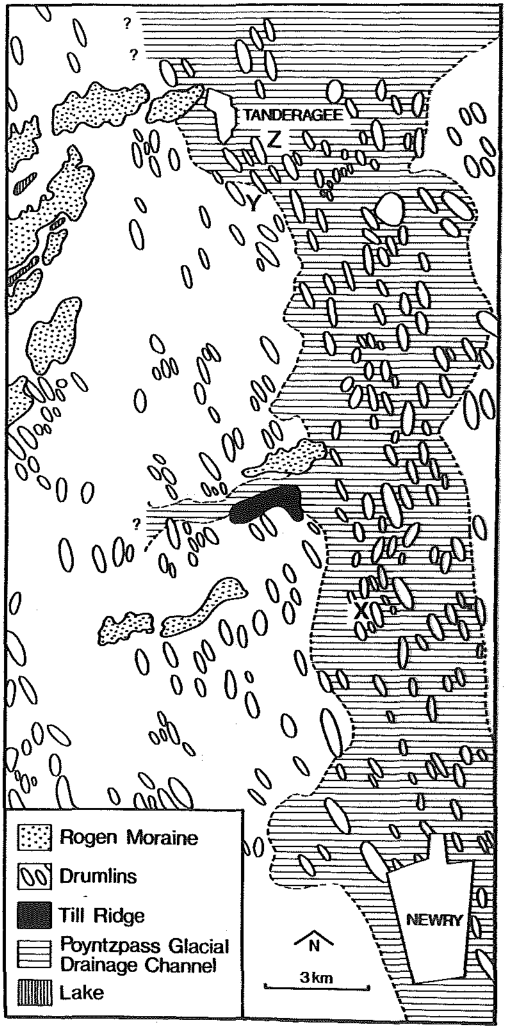

Fig. 35 Glacial morphology of the Poyntz Pass channel. The location of the Jerrettspass, Glebe Hill and Tandragee drumlins is indicated by x, y and z respectively.

glacigenic till facies (2-5m) which forms a distinct carapace along the entire length of the exposure. There is no evidence of glacitectonic deformation of the underlying sediments or widespread erosion of the sand core. The till is matrix-supported, contains glacially bevelled and rounded clasts, boulderlags and evidence of crude foliation.

A basal melt-out origin is suggested by gradational contacts with underlying sediments, the absence of deformation structures, the vertical transition from foliated to massive till, uniaxial fabrics and the presence of far travelled erratics (cf. Shaw, 1980).

Unit 6 (Sediment gravity flow facies). A trough infill 28m by 7m has been excavated in unit 5 and forms an erosional contact with unit 3. It is truncated by the basal part of unit 8. The diamicton fill is crudely stratified, contains boulder lags, and flow structures which suggest an origin by channelled sediment gravity flow.

Unit 7 (Massive till facies). A thin layer of massive till (56m x 2-3m) occurs at the boundary between units 5 and 8. Detailed examination was not possible due to the unstable nature of the face.

Unit 8 (Upper till facies). The drumlin surface consists of a continuous layer (4m) of till containing a relatively high proportion of clasts in comparison with the underlying tills. It is massive with a few poorly-developed traction layers (lags). Till macrofabrics indicate a close correspondence with drumlin long axes (N/S).

Genesis of the sand core. The sand core shows a bottomset-foreset-topset transition sequence which was controlled largely by the geometry of the bedrock channel. Sediment facies arrangements of this type are commonly attributed to supra aquatic, Gilbert-type coarse-clastic deltas (Elliott, 1978). However, a number of characteristics are more typical of subaqueous dunes. For example, the facies arrangements (units 3, 4) are identical to foreset and stoss beds generated in closed pipe flume experiments (McDonald & Vincent, 1972). In these cases the stoss beds (topsets) are only generated over a relatively small part of the dune. This may explain the lateral discontinuity of unit 4 at Jerrettspass. Foresets within the sand-core indicate unimodal flow. Reactivation surfaces are conspicuously absent which may indicate that the sand-core represents a single bedform or megadune. Finally, outsized clasts could indicate expulsion from ice and there is little evidence to suggest a major hiatus in deposition between the stratified sediments and the overlying melt-out tills. A model of sedimentation within a subglacial valley system is suggested (Fig. 36). Melt-out deposition of till commenced after subglacial channel sedimentation was completed and drumlin streamlining occurred after sedimentation was complete.

NAVAN FORT (Site 20, H847452; J.M.)

Introduction. The Iron Age enclosure of Navan (Emain Macha) is the centre of a former ritual complex situated 2km west of Armagh city. The site was the late-prehistoric capital of Ulster and the legendary seat of the Kings of Ulster commemorated widely in Early Irish literature. Although there is some evidence for farming activity at Navan extending to c.3000 b.c., the main evidence for occupation comes from the period c.600-100 b.c. This is the time of transition between the Bronze and Iron Ages and, as such, Navan offers unique evidence for the continuity of settlement and change of culture at the time of the first appearance of the Celts in Ireland.

The major identifiable features at Navan are shown on Figure 37 and comprise: the main circular enclosure of c.16 acres delimited by an earthern bank 12m wide and up to 3m high; Loughnashade, a now partially drained lake of past ritual

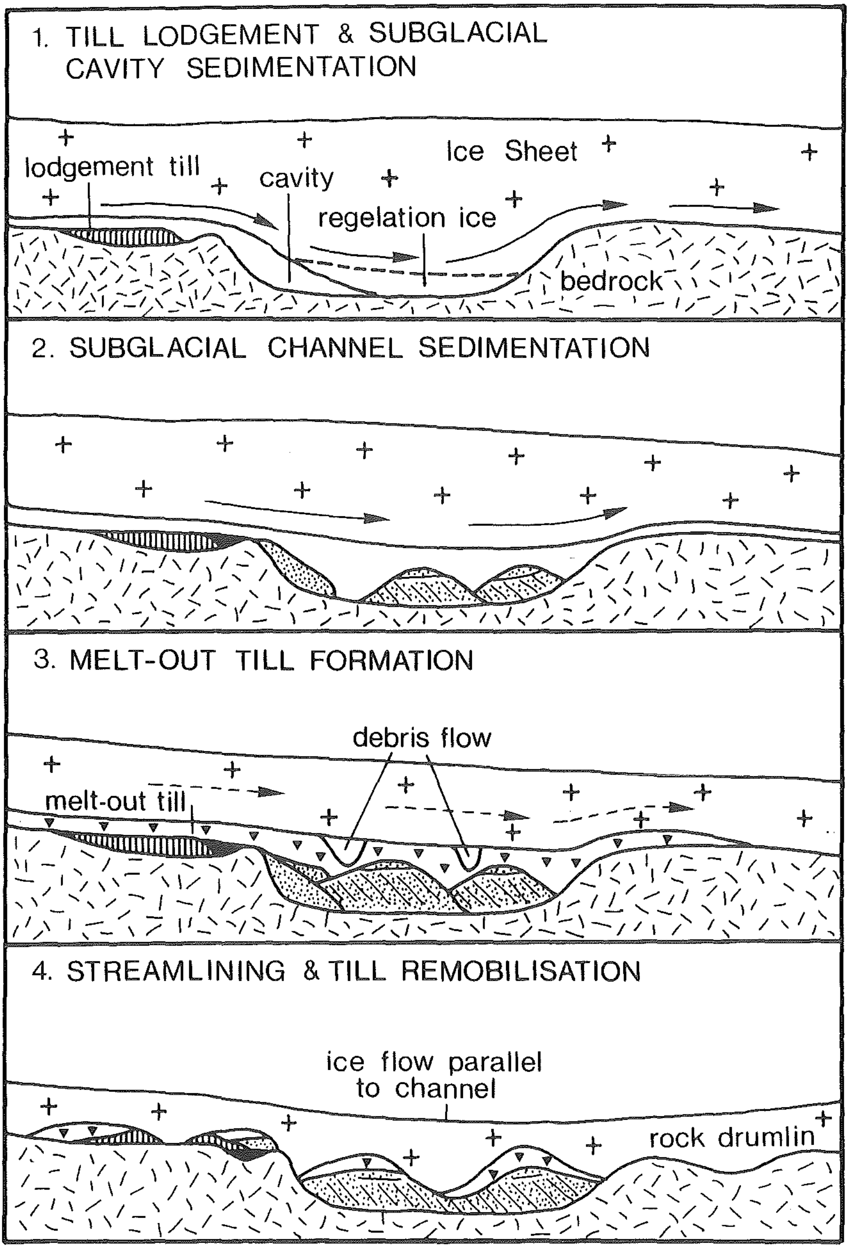

Fig. 36 Simplified depositional model of sand-cored drumlins, Poyntz Pass channel.

significance; an artifically constructed hollow known as the King's Stables; a second hill fort known as Haughey's Fort; and two passage tombs both of which have been destroyed. The enclosure at Navan includes two mounds; one near the centre is a low ring-barrow of c.20m diameter, and, offset to the west, a larger mound 100m in diameter and 6m in height. Both were the subject of excavations in the 1960's and early 1970's by the late Dudley Waterman of the Archaeological Survey (Selkirk & Waterman, 1970) and await full publication. A small, partial excavation was undertaken at the King's Stables in 1975 by Mr. Chris Lynn of the Archaeological Survey (Lynn, 1977).

Navan Fort. The earliest evidence of occupation includes some traces of Neolithic settlement (pits, pots) found below the large mound. The major period of occupation began c.1000 b.c. with the erection of a sequence of figure-of-eight structures which comprised a small circular residence and an adjoining,larger circular enclosure. These structures were built, one on top of another, over a period of centuries spanning the Late Bronze Age and into the Early Iron Age. Evidence in the form of finds of imported items on the site, most notably the skull of a Barbary ape from either southern Spain or North Africa, suggest that the settlement was associated with individuals of high social status.

Around 100 b.c. the area of the round houses at Navan was cleared and a vast circular structure built of concentric rows of oak posts was erected. It measured c.40m in diameter and there is some debate as to whether such a large structure might have been roofed or not. Remains of the large central post, believed to have served as a free-standing (totem) pole rather than a structural support, were used to date the structure by dendrochronology. The post not only provided a maximum date very close to 100 b.c. for the construction, but also helped to complete the Belfast tree-ring chronology. The Great Post at Navan was found to bridge the last gap between the Belfast floating'long chronology' based on 5000 years of prehistoric bog

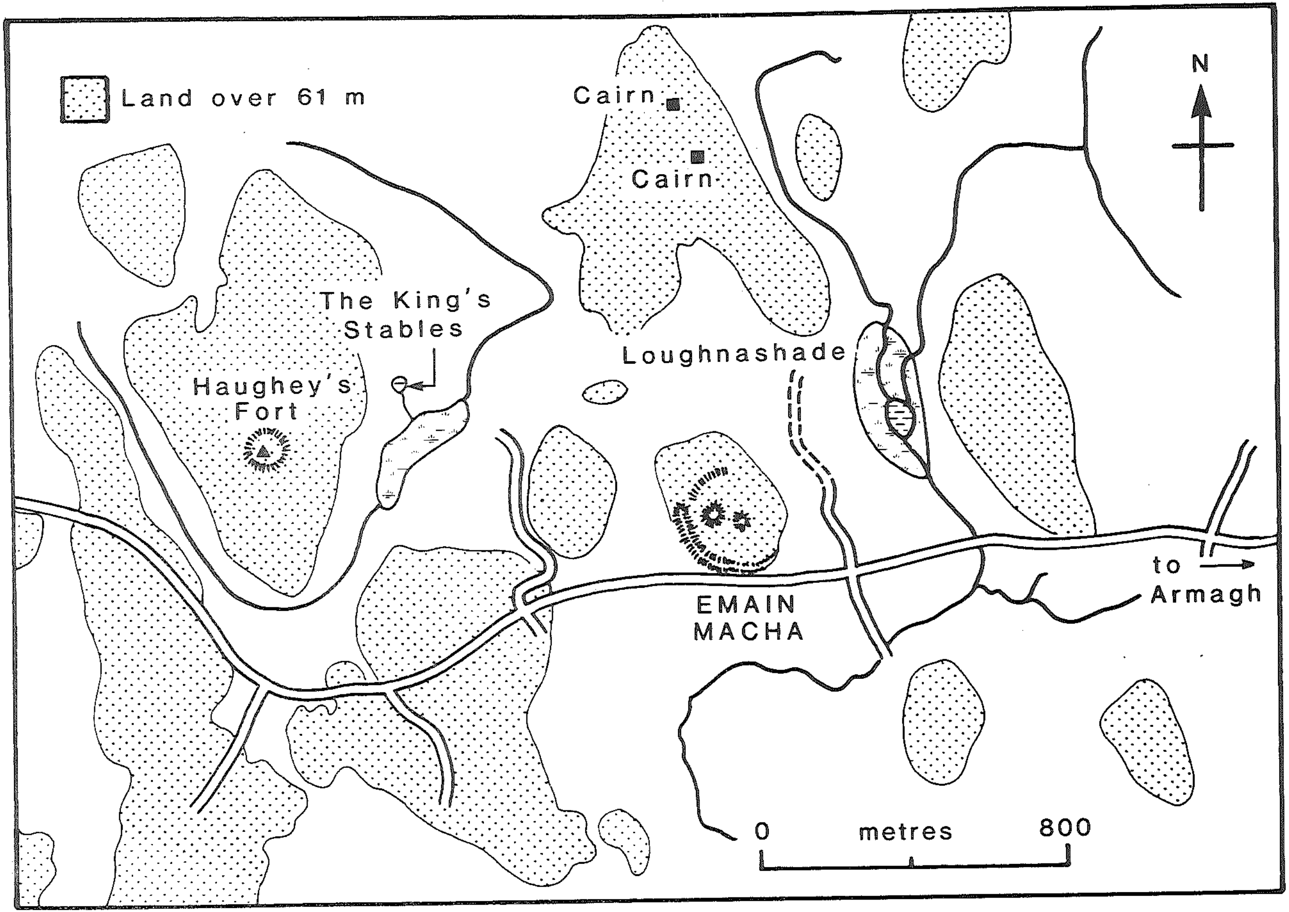

Fig. 37 Plan of Navan Fort.

oaks and the recent, absolute chronology based on modern and archaeological material (Baillie & Pilcher, 1985). Now completed, the Belfast chronology is the second longest tree-ring series in the world.

The excavations within the Navan enclosure showed that the large circular structure was ritually destroyed in three acts. The first involved filling the interior of the structure with limestone cobbles up to a height of c.2-3m. Then, the upper part of the structure was fired and finally sods were heaped onto the stone cairn to form the mound seen (in reconstructed form) today.

The Ritual Landscape. During the period of Late Bronze Age occupation, contemporary with the figure-of-eight structures, the inhabitants of the area also excavated the large artificial pond known as the King's Stables. The site was a roughly circular hollow, c.25m across and c.4m deep. In the small test excavation, Mr. Chris Lynn of the Archaeological Survey (Lynn, 1977) found the remains of red deer, cattle, dog, pig, and a very small amount of sheep. The configuration of anatomical parts, including the articulated skeletons of two dogs, the absence of extremities of the cattle (although they would have been the commonest food debris), and the finding of the severed facial portion of the skull of a young male all suggests a ritual purpose for the pool. Some industrial activity would also have been likely nearby as clay sword moulds were also found in the pond. A pollen core from the pond indicated that it was established in an area of dense forest c.2700 b.p. which was then subsequently cleared and used for pasture up to c.900 b.p. The trees present at the time of excavation were mostly Corylus, Alnus and some Quercus (larmour, 1977).

Haughey's Fort, although not excavated, is typologically similar to other Irish hill forts with a Late Bronze Age date and may have served as a centre for secular occupation while Navan was the ritual/ceremonial centre.

At about the time of erection of the circular structure, Loughnashade ('lake of the treasures') was being employed for Celtic ritual offerings. At the end of the 18th century, items compatible with a religious offering were found here including four large bronze trumpets plus animal bones and human skulls.

The Threat to Navan. A small limestone quarry was begun near Navan Fort in the last century. Since that time it has expanded towards the very edge of the Monument and devastated much of the area between it and Loughnashade. The quarry's attempt to expand from its present limits had recently been the subject of the longest local planning inquiry in Northern Ireland and at the time of writing the results are not yet known.

MULLANTUR (Site 21, H816486; A.M.M.)
Introduction. Spindle-and parabolic-shaped drumlins in northern Ireland possess stratification sequences on their lee-side flanks (Fig. 38). These forms lack the distinctive steep stoss - and tapering lee-ends of classical drumlins and tend to occur in linear zones transverse to Late Pleistocene ice flow. (Fig. 38). Stratified deposits may occur either as infills in embayments excavated in the lee-side of barkhanoid forms or be superimposed on the lee-side of whaleback forms. The stratification sequences developed as a result of sedimentation in interconnected subglacial water filled cavities and are unlike remanié proglacial sediments moulded by ice into drumlin form (Dardis et al., 1984; Dardis, 1985; McCabe, 1985). Stratigraphic evidence suggests that the lee-side sequences developed during drumlin streamlining, which supports the view that subglacial hydraulic processes played an important role in drumlin formation.

Sedimentology. The Mullantur drumlin is located south of the main late Pleistocene ice divide. It is oriented NNE-SSW, is

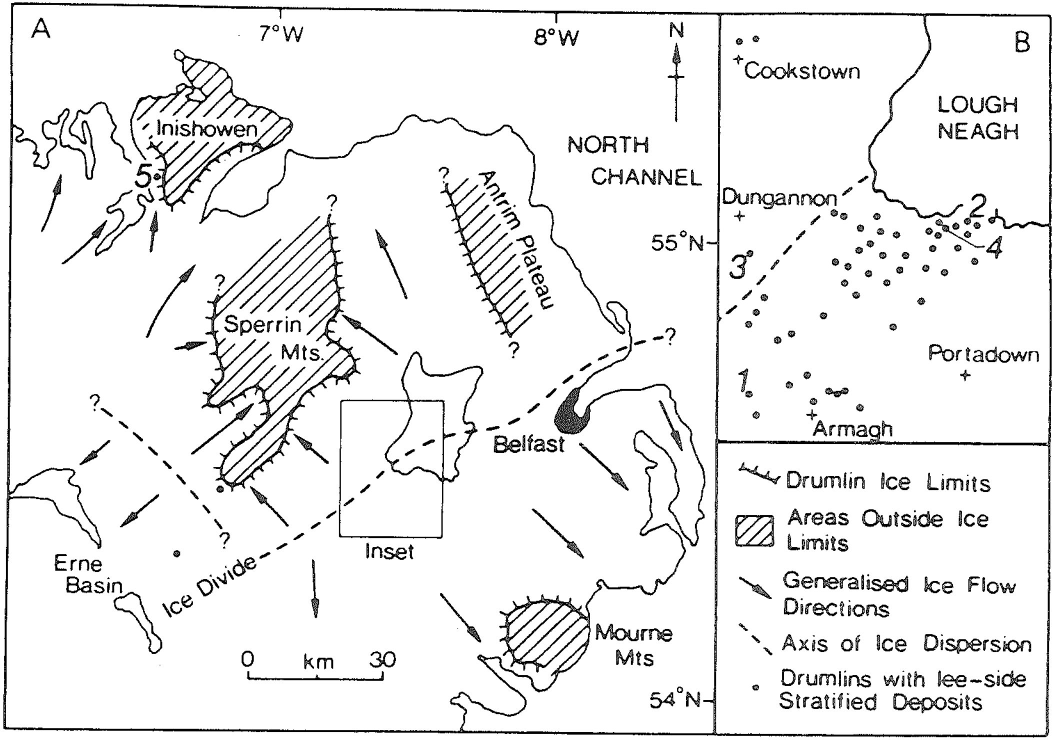

Fig. 38 Location map and known distribution of drumlins with lee-side stratification sequences in NE Ireland.
1-Mullantur 4-Derrylard

600m long, 530m wide and attains a height of 85m O. D. Stratified deposits are exposed in a disused gravel pit on its southwestern flank (Fig. 39). The lee-side stratified deposits are underlain and partly draped by glacigenic till which forms the main component of the drumlin. The lee-side deposit occurs as a wedge-shaped unit which thickens towards the southern end of the drumlin. Borehole data indicates that the stratified deposits do not continue north beyond the drumlin apex or leading edge. At the junction with the underlying stratified sediments the till is crudely-bedded. Dardis (1982) and Dardis et al., (1984) have shown that this till is identical to the surface drumlin tills of south central Ulster which have been interpreted as subglacial melt-out in origin. This is, in part, substantiated by the non-erosional, planar bed contact at the junction between the lee-side deposits and the overlying till carapace and the absence of glacitectonic deformation structures.

The lee-side deposits are composed predominantly of steeply dipping (15-30^{o}) cross-bedded sediments (gravel 80%, sand 20%). Beds vary from 20-120cm in thickness though there is a tendency for thickness to increase downslope. Variations in sediments type are shown in Table 7. The main proximal-to-distal facies changes are:

1. A downslope decrease in the proportion of unstratified boulder gravel and inversely graded pebbly gravel.
2. A downslope increase in the proportion of inversely and normally-to-inversely graded boulder gravel and normal-to-inversely graded pebbly gravel
3. A downslope increase in the proportion of boulder and pebbly gravel with fine-grained matrices.

Discussion. Lee-side sedimentation represents one of the final stages in the process of drumlinsation since lee-side deposits developed before subglacial till sedimentation was complete (Fig. 43). The lack of glaciotectonic features and the proximal to distal sediment transformations indicate that lee-side sequences

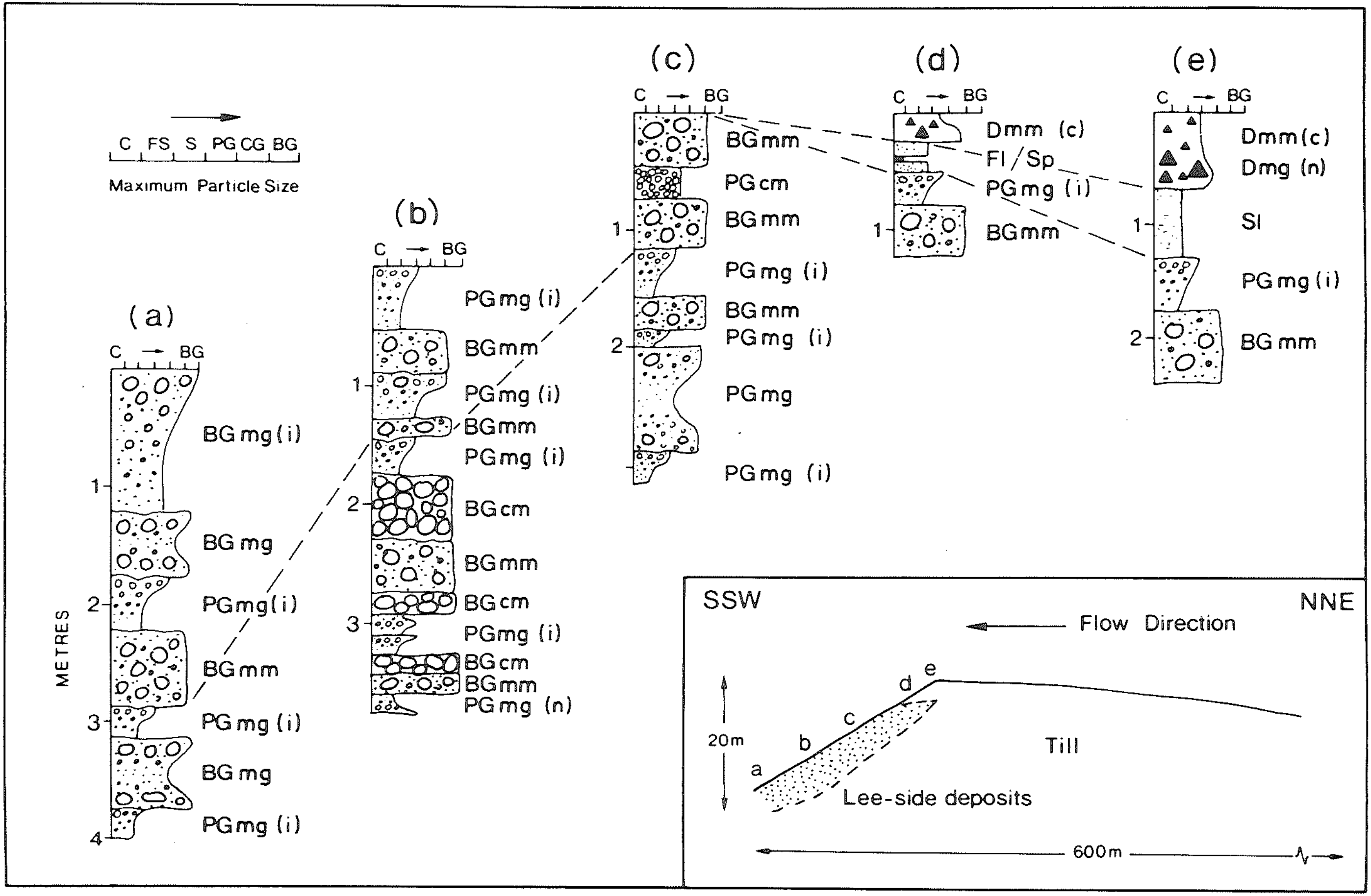

Fig. 39 Proximal-distal relationships in the Mullantur drumlin (see Table 7 for lithofacies code).

Table 7: Lithofacies and sedimentary structures of drumlin lee-side stratification sequences. (Coding is based on criteria outlined by Miall (1977), Eyles *et al.* (1983), Walker (1975a), and Martin (1980))

Code	Facies	Description
Diamicton facies		
Dmm	Diamicton	Matrix-supported; massive; unstratified; cobble/gravel/pebble/sand/silt/clay admixture; boulders rare.
Dmm (c)	Diamicton	As with Dmm, but showing occasional cobble or gravel lags.
Dms	Stratified diamicton	Matrix-supported; winnowed; interbedded with Fl or Fm facies.
Gravel facies		
BGmm	Boulder gravel–disorganized	Matrix-supported; unstratified; massive; boulder/cobble/pebble/sand admixture.
BGcm	As above	As above except clast-to-matrix supported.
BGmg (n)	Boulder gravel–normally graded	Matrix-supported; stratified; normally-graded; admixture of boulders/cobbles/sand; muds uncommon in matrix.
BGmg (i)	Boulder gravel–inversely graded	As with BGmg (n) except inverse grading.
PGmm	Pebbly gravel	Matrix-supported; unstratified; pebble/sand admixture.
PGmg (n)	Pebbly gravel–normally graded	Matrix-supported; normally-graded; pebble/sand admixture.
PGmg (i)	Pebbly gravel–inversely graded	Matrix-supported; inverse grading; pebble/sand admixture.
PGcm	Pebbly gravel	Clast-supported and massive
PGcg (i or n)	Pebbly gravel	As with PGmm except clast-to-matrix supported.
Sand facies		
St	Dunes	Sands; may be pebbly; solitary or grouped cross-beds.
Sp	Planar stratification	As with St, though grouped cross-beds are more common; cross-beds are generally low-angle.
Sr	Ripple-bedded sands	All varieties of rippled beds present, including climbing ripples; find-to-coarse sand.
Sl	Horizontal lamination	Fine-to-coarse sand, may be pebbly.
Mud facies		
Fl	Flaser	Interbedded sand, silt and clay; may show ripple marks, drape laminae or wavy bedding; commonly fining-up.
Fm	Drape laminae	Mud, silt.

cannot be readily attributed to glacial overriding. The lee-side deposits are in situ formed only on the protected lee-side face of till protuberances and represent nodes of subglacial meltwater deposition within water-filled cavities. The grading characteristics of the gravel have been compared with proximal/distal relationships in coarse-grained, submarine conglomerates (cf. Davis & Walker, 1974; Walker, 1975; 1984). It has been shown that lee-side cavities formed contemporaneously with drumlin streamlining. It is therefore tentatively suggested that lee-side cavity development, associated with final drumlin development, may provide a trigger mechanism to account for 'surge-type' glaciological conditions associated with drumlin stream lining. (Dardis et al., 1984; Dardis, 1985).

BENBURB (Site 22, H80985202; D.G.)

Introduction. In 1977 a compressed peat and late-mud deposit was recorded at Benburb, Co. Tyrone (Boulter & Mitchell, 1977). In 1982, with the assistance of a Praeger Committee Grant from the Royal Irish Academy, an entire profile was extracted using a percussion drill (Gennard, 1984). The deposit, which is exposed in the side of a tributary of the River Blackwater, extends north to south for 13m and has been traced for 6m east of the stream section into the side of a drumlin (Fig. 40). Coring revealed boulder clay covering a compacted peat deposit (1.2m) which rested on plastic grey clay (Table 8). It was not possible to continue coring beneath this clay as the core liners became firmly embedded in the deposit. The position of the compacted peat deposit below the local drumlin field suggests that the deposit may have been more extensive prior to erosion during drumlin formation.

Pollen Analysis. The pollen analysis of the deposit revealed a sequence in which all 4 stages of an interglacial were found (Fig. 41). Objective zones were assigned to the results using a computer program for zonation (Gordon & Birks, 1972).

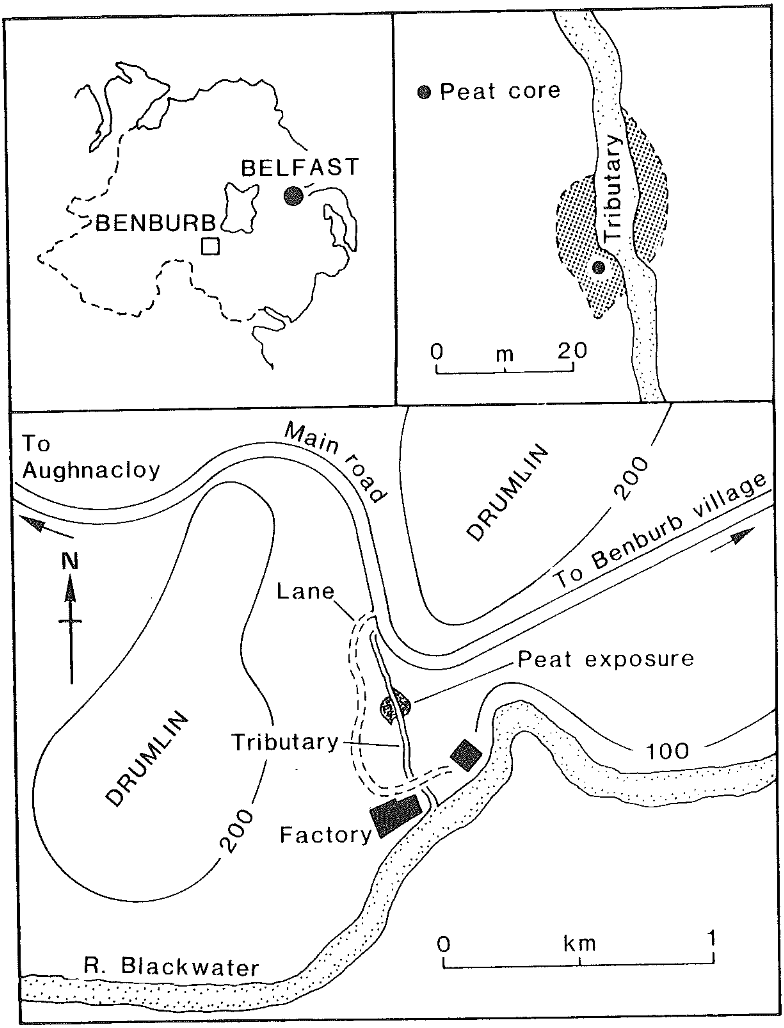

Fig. 40 Location of Benburb interglacial site. Note position and extent of peat in minor tributary stream.

Table 8 : Lithology of the core obtained by percussion drilling at Benburb.

Depth (m)	Lithology	Colour
0.00-0.75	Dark brown top soil	7.5YR/3/4
0.75-1.52	Dark brown sandy, gravelly clay	7.5YR/3/4
1.52-2.1	Dull reddish-brown clay with sand and gravel	5YR/4/4
2.12-2.25	Dark greyish-yellow plastic clay	2.5Y/4/2
2.45-2.74	Firm brownish-grey plastic clay	7.5YR/5/1
2.74-4.00	Compressed black peat and lake mud	7.5YR/1.7/1
4.00"	Grey plastic clay	5Y/5/1

Colour was determined in the laboratory using the Standard Colour Chart after the frozen, stored cores had been defrosted.

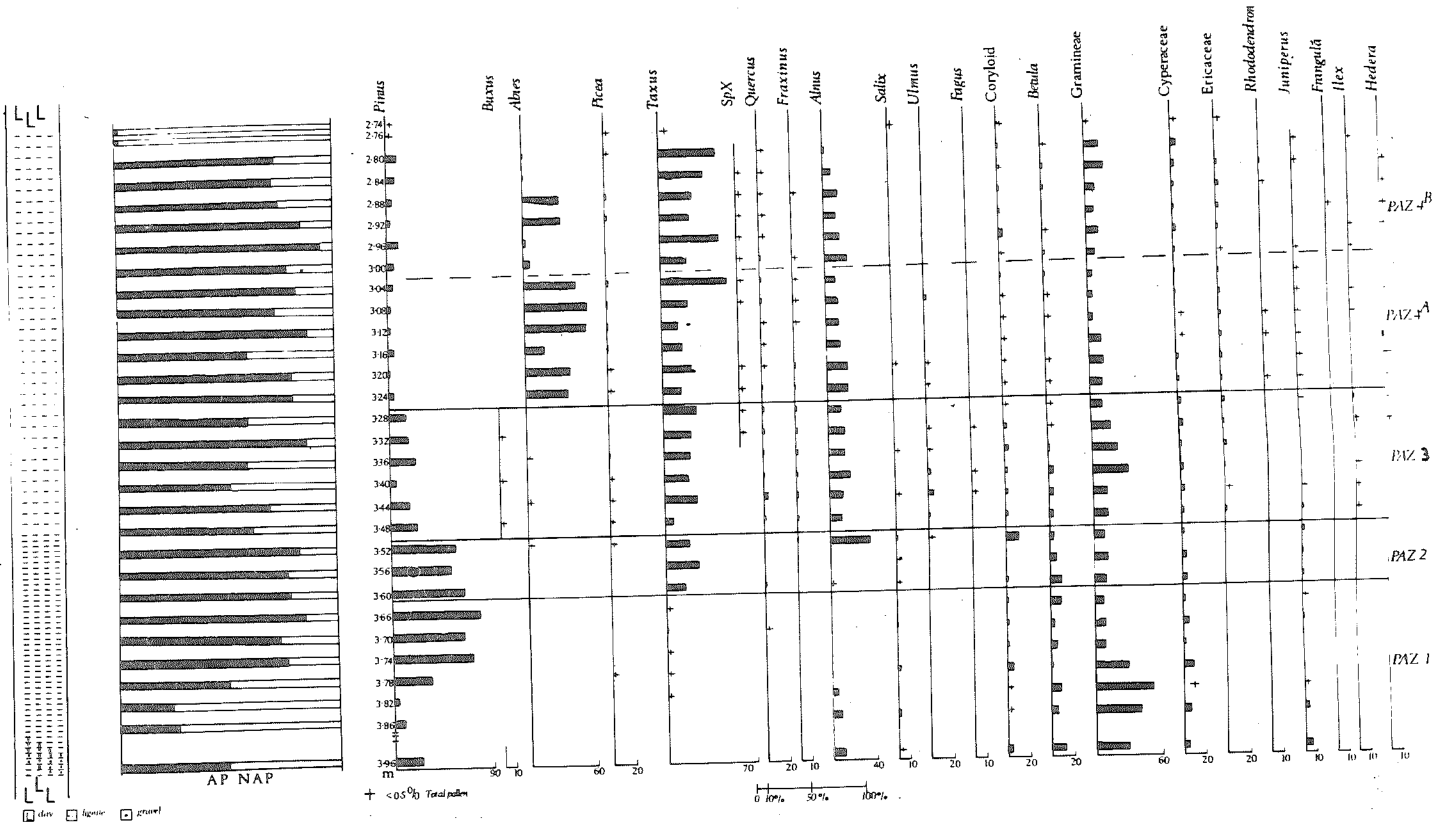

Fig. 41 Relative percent pollen diagram showing the major contributors to the interglacial cycle at Benburb.

Zone 1. Pinus (80%) and Betula (up to 10%) dominate. Alnus, Salix, Juniperus and Coryloid pollen are also present.

Zone 2. Alnus pollen increases to 36% of the pollen rain at the expense of Gramineae which falls to 10%. Coryloid pollen also rises to a peak of 10% in this zone whilst Betula falls to 5%. Pinus and Taxus are the main contributors to the pollen rain, but Fraxinus and Ulmus are present in small quantities.

Zone 3. This reflects the mesocratic zone of the interglacial. Levels of Pinus pollen fall to between 25% and 15% leaving a mixed deciduous forest dominated by Quercus, Fraxinus and Ulmus. Fagus is present as single grains in 3 spectra of this zone together with Buxus pollen.

Zone 4. The Late temperate stage in which Abies enters for the first time together with Rhododendron, a species characterising the 'only known' Irish interglacial. A third pollen type indicative of Gortian sites is the unknown species X. At Benburb this is confined to the Late temperate stage whereas at Gort and at Marks Tey (Turner, 1970) it is present in the Mesocratic stage. In the latter part of this zone, Abies pollen falls away despite a renewed peak at spectra 2.88m and 2.92m as does Alnus and Coryloid pollen levels. Taxus remains the dominant arboreal species although Picea reaches its maximum in this zone.

The top of the deposit is truncated and only the final spectrum can be tentatively regarded as the terminal stage of the interglacial. In this spectrum Pinus and Betula dominate, thereby reflecting the change in vegetation as the temperate climate gave way to glacial conditions. Although only a single spectrum it is important to consider this pollen assemblage in the light of the deposit found at Aghnadarragh (Site 24).

Discussion. Species which are classically regarded as indicative of a Gortian deposit are present in the Benburb deposit. These are the association of *Abies*, *Taxus*, species X and *Rhododendron* in the late temperate stages. However, certain differences exist between the assemblage at Benburb and other interglacial deposits in Ireland. The levels of *Hippophae* pollen are extremely small; only 4 grains which could be ascribed to *Hippophae* were found. This is of the order of contribution usually ascribed to the Last interglacial in Britain and not of the magnitude usually associated with Gortian sites in the south and west of Ireland (Jessen *et al.*, 1959). Coryloid pollen is found early in the diagram in association with *Pinus* and *Betula* in zone 1. This contrasts with the Gort and Baggotstown sites where Corylus enters the diagram in association with *Quercus* and *Hedera* in the Mesocratic stage (Jessen *et al.*, 1959; Watts, 1959). *Buxus* pollen is found exclusively in the mixed deciduous forest assemblage at Benburb, and not in association with the zone dominated by *Abies* as is typical of other Gortian sites.

These differences can be considered to reflect natural geographical and climatic differences between Gortian deposits in the north-east of Ireland as compared to the west and south. However, when these differences are considered alongside the stratigraphic position of the Benburb peat, beneath a Midlandian till and the absence of penultimate interglacial indicators such as *Azolla filliculoides* L from the deposit, the predictable question of the age of the deposit and the age of Gortian deposits is raised.

The stratigraphic position of Gortian deposits and the case for a last interglacial age, based on an 'objective' stratigraphic approach has been reviewed by Warren (1980, 1985). Watts (1985) restated the floristic similarity between Gortian sites and those of the Hoxnian in England. He emphasized the correlation of Gortian and Hoxnian (penultimate interglacial) sites as being the current state of the palynological art. Cox (1980) pointed out that recognition of Hoxnian and Ipswichian deposits in East

Anglia is based solely upon their pollen profiles. Turner (1970) underlined the difficulties of drawing broad generalizations about the till sequences of East Anglia, thereby raising the difficulty of distinguishing between Hoxnian and Ipswichian sites on stratigraphic grounds alone. Warren (1980) expanded much the same criticism and suggested that the palynological interpretation of Gortian deposits as equivalent to those of the Hoxnian, bedevilled attempts at stratigraphic correlation and dating. Many stratigraphic problems would be resolved if the Gortian was considered as Last interglacial in age and distinct from the British interglacial Hoxnian sequences.

Resolution of these problems must not simply increase the number of Gortian-style sequences recognised but, involve a close examination of each new deposit without recourse to the idea that they are all representatives of the penultimate interglacial (Falsification theory may be applied). If this approach is adopted then differences in assemblage may be interpreted as geographical variations rather than separate interglacials or the penultimate interglacial. The value of seeking for expected indicator species such as Carpinus to define Last interglacial deposits in Ireland and the need for standardization of palynological approaches to allow meaningful comparisons must also be considered and the validity of each hypothesis tested.

DERRYLARD (Site 23, H958615; A.M.M.)
The drumlin at Derrylard is parabolic in outline, trends NNW-SSE, is 700m long by 370m in width and is associated with ice flow from the north (Fig. 38). The lee-side deposit was composed largely of boulder gravels but most have now been removed. This site is important since it illustrates:

1. The nature of the transition from drumlin tills into lee-side deposits (Fig. 42, logs c-f).
2. The texture and internal structure of distal lee-side stratified deposits (Fig. 42, logs a-b).

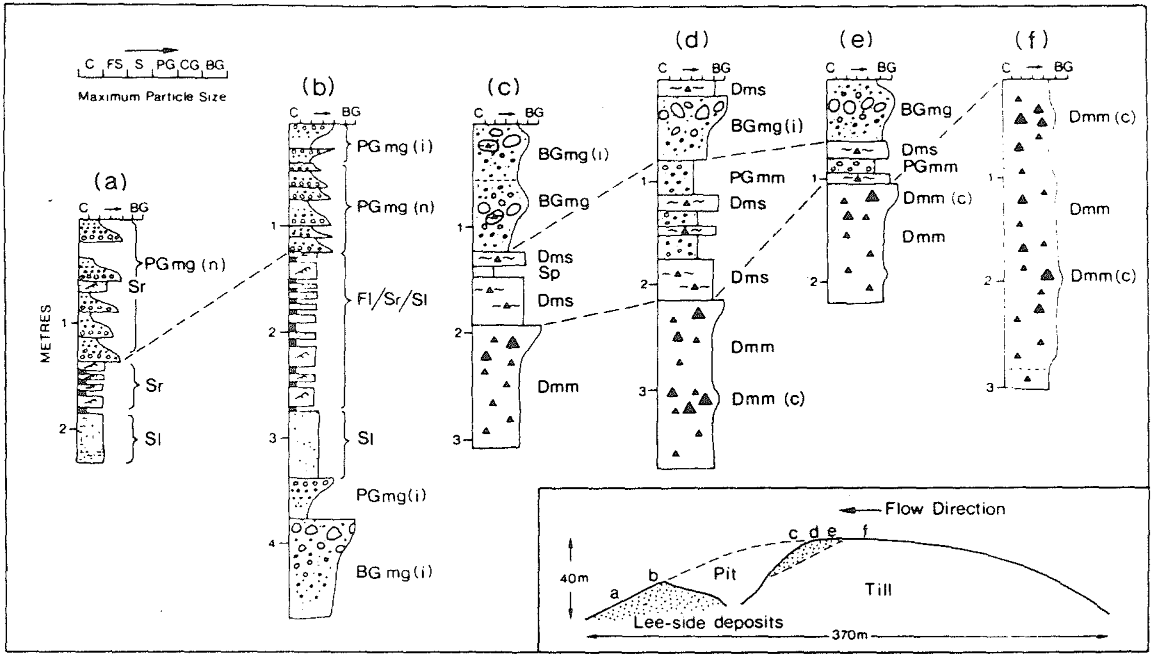

Fig. 42 Proximal-distal lithofacies relationships in the Derrylard drumlin.

The lee-side deposits are underlain by two till units which are derived from local Carboniferous limestones and Tertiary basalts. Bed contacts between the tills is gradational or marked by boulder lags. The upper till is typically coarser in texture and exhibits a greater clast size range and boulders lags than the lower till lithofacies. Both till lithofacies are known from other drumlin exposures in south central Ulster (Dardis, 1982).

The transition from till to lee-side deposits is marked by stratified diamictons (Dms) interbedded with gravel. The junction between this interbedded unit and the underlying till lithofacies is marked by a well-developed traction layer which indicates partial erosion of the drumlin till. The main proximal to distal sedimentary trends in the interbedded units are:

1. A downslope increase in bed thickness and sorting.
2. A downslope increase in the proportion of pebble gravel lithofacies with a corresponding reduction in cohesive matrix.
3. A downslope decrease in the preservation of traction layers.

These beds show several characteristics of sediment gravity flow deposits (cf. Middleton & Hampton, 1976). Their pattern probably indicates a lateral facies transition downslope from debris flows in which the larger clasts were supported by buoyancy and cohesiveness of clay-water mixes, to stratified, fine-grained cohesive flow deposits formed by suspension sedimentation of sand and pebble-sized debris (cf. Lowe, 1982).

The distal, lee-side deposits show a prograded (coarsening-up) sequence from parallel laminated, coarse-to-medium sand interbedded with silt and clay into cross-bedded, pebbly gravel (Fig. 42). Sand beds are laterally discontinuous and exhibit multiple reactivation surfaces similar to flaser or lenticular bedding, (cf. Reineck & Wunderlich, 1968) or rhythmic sand/mud

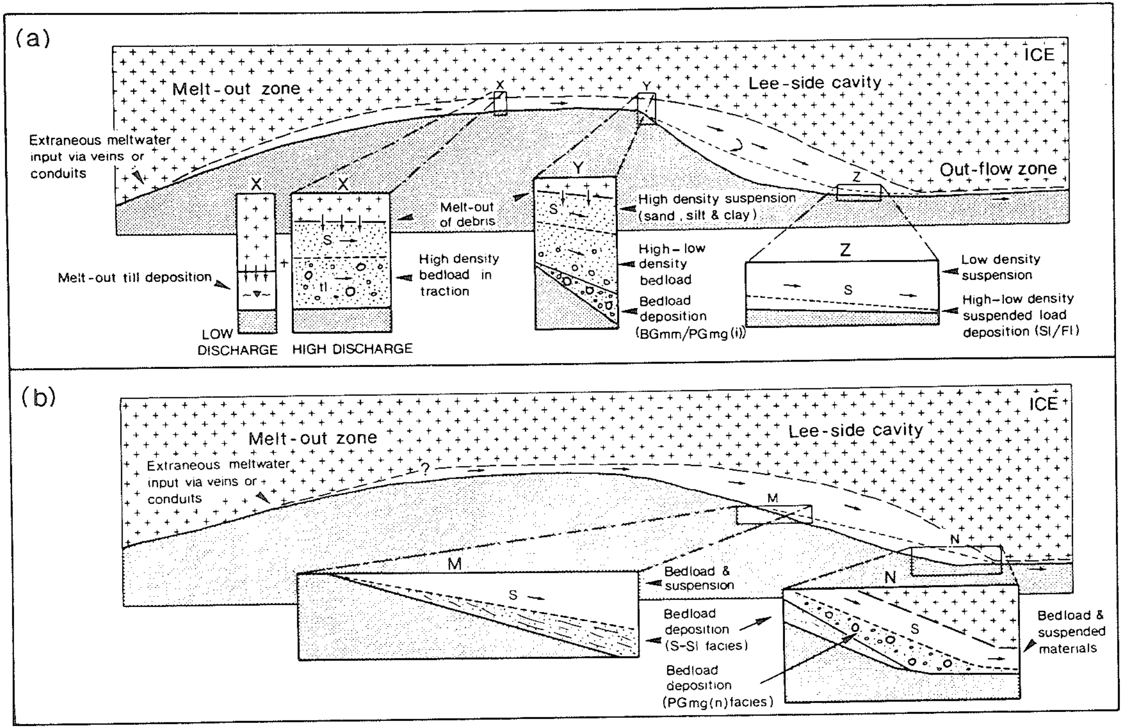

Fig. 43 Depositional palaeoenvironments of lee-side stratification sequences (a) Barkhanoid drumlins (b) Whaleback drumlins.

bedding (Reineck & Singh, 1973). These may originate by rapid temporal or spatial changes in flow conditions. Unsteady flow conditions of this type occur in different environments characterized by ephemeral flow conditions (Tunbridge, 1981; Scott et al., 1969). They also occur in subglacial or proglacial environments where fluctuations in melt-water discharge, direction or velocity are common (Collins, 1979; Liestøl, 1967; Ostrem, 1975 ; Rothlisberger, 1972). The deposits are typical of low density turbidity current sedimentation (Middleton & Hampton, 1973, 1976) under upper-to-lower flow regime conditions (Simmons et al., 1965). It is possible that the sand lithofacies represents the lee-side, end member component of the flow continuum across the drumlin (Fig. 43).

AGHNADARRAGH(Site 24, J735127; A.M.M., D.G., R.C., P.D.)
Introduction. A trial pit has been excavated during lignite exploration near the shores of Lough Neagh at Aghnadarragh, Glenavy, Co. Antrim (Fig. 1). The exposed pit face consists of a thick sequence of Pleistocene deposits which lie directly on woody lignite of Oligocene age. The site is excavated in a flat, terrace-like feature (30m O.D.) which is up to 1.5km in width and parallels the lake shore as far north as Antrim town. To the east the terrace is replaced abruptly by drumlin swarms which dominate the landscape around Glenavy. At present, the geomorphological or sedimentological significance of this marked topographic change is unknown. The flat 'terrace' topography may either be a constructional feature associated with deposition at the ice/substrate interface or be the result of an erosional event associated with a former high lake level.

The Pleistocene deposits consist of lower and upper tills which are separated by undisturbed, stratified sediments which contain two distinct organic rich horizons (Fig. 44). The sequences occur within two basins which are separated by a prominent ridge

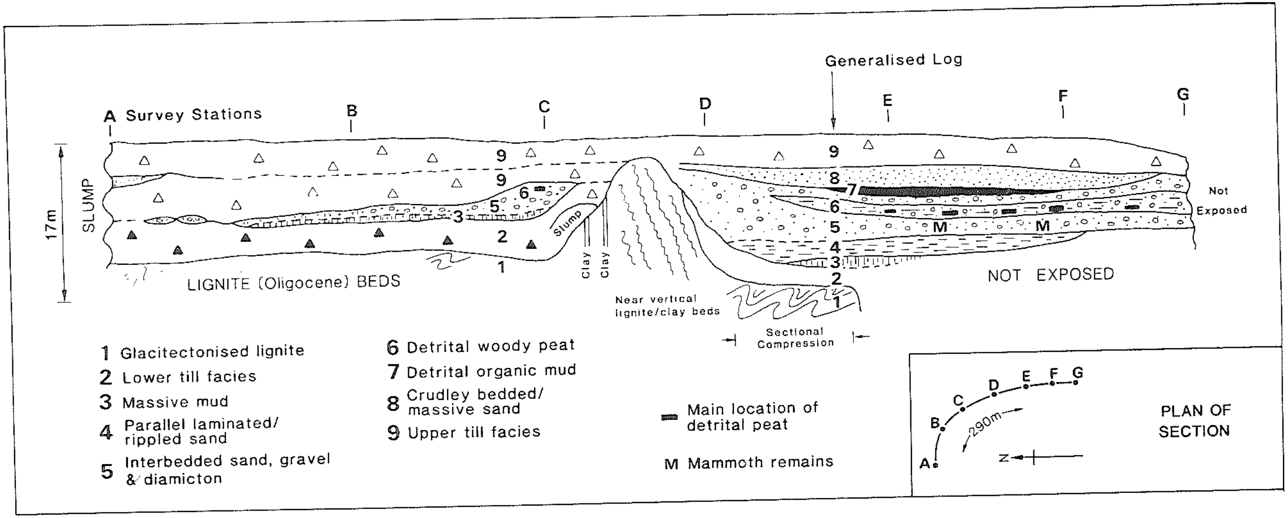

Fig. 44 Aghnadarragh section, Glenavy, Co. Antrim.

of lignite. Master bedding planes within the stratified sediments are similar to shallow catenary curves which suggest that they represent the infill of a shallow channel. Five samples have been submitted for 14C dating but no results are available at present. The observations and interpretations presented below are the result of preliminary investigations.

Lithostratigraphy and biostratigraphy. Nine major lithological units have been recognised (Fig. 45) though all of these are not present in the western basin:

Unit 1. Glacitectonised Lignite. The woody lignite and clay beds exposed at the base of the pit are known collectively as the Lough Neagh Clays. On pollen evidence they are generally considered to be of Late-Eocene to Middle Oligocene in age (Watts, 1970). They formed as the Lough Neagh depression downwarped and received detritus from the Tertiary basalts and other lithologies. At a maximum they are thought to be at least 350m in thickness and underlie some 500km^2 around the southern and southeastern margins of Lough Neagh.

In this pit the 'Lough Neagh Clays' are mainly lignite with occasional interbeds of grey clay. The present exposures and those during excavation show that a 10m ridge of lignite occurred above the lignite beds which are exposed in the bottom of the pit. The feature strikes at 40°. The sides of the ridge are steep, the top is planed and its flanks are draped by the lower till (unit 2). The planed top of the ridge is overlain by the upper till (unit 9). Almost all of the beds within the ridge strike at about 10° and dip steeply eastwards (75-90°). They show evidence of intense sectional compression in the form of isoclinal folds and small-scale shear structures which are in some ways similar to certain types of soft-sediment deformation.

Unit 2. Lower Till Facies. This lithofacies directly overlies the lignite beds at the base of the pit and almost buries the ridge of lignite (Fig. 44). It is up to 5m in thickness,

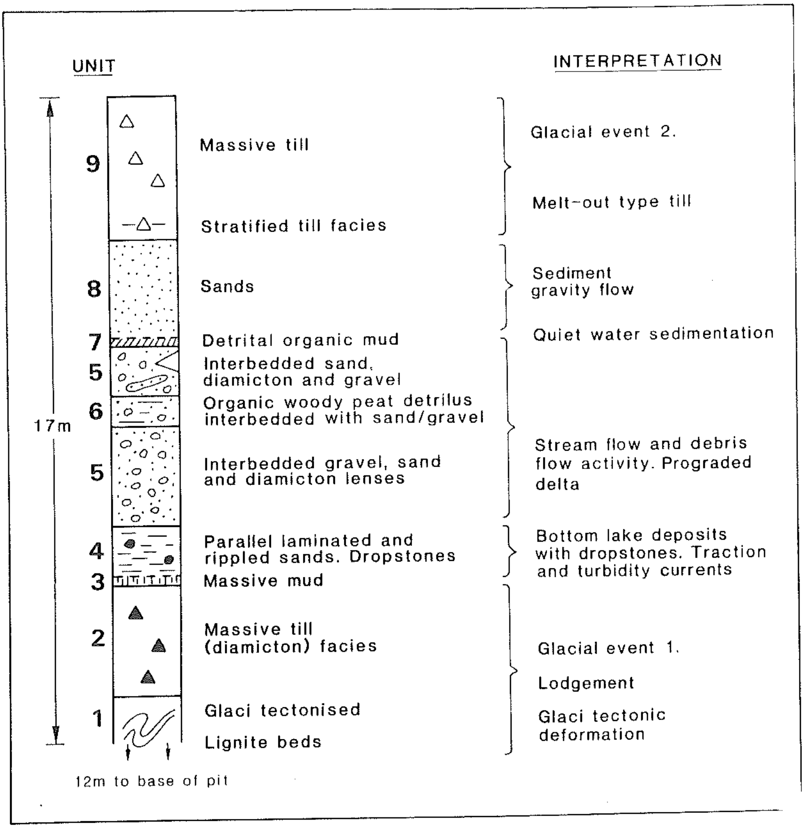

Fig. 45 Generalised log, Aghnadarragh.

overcompacted, brownish-black (10YR 3/1) in colour and has a silt/clay rich (60%) matrix. Certain parts of the till are characterised by abundant armoured mudballs which seem to be derived from debris identical to the till itself. Although the bulk of this lithofacies is massive it is strongly foliated towards the base of the section and adjacent to the central ridge of lignite. The foliation consists of thin (<40cm), subhorizontal stacked beds of till, sand and pebbly gravel which dip gently east. Shear structures are common between individual beds and slickensides commonly occur within till units.

Clast fabrics range from 290 to 320^{o} and have low dip angles. Pebble sized clasts are mainly derived from local Tertiary basalts with small amounts of chalk, flint and Carboniferous limestone. The till contains a varied suite of igneous rocks which are derived from the Central Tyrone Igneous Complex 20km due west.

Unit 3. Massive mud. Where exposed, the junction between the masive mud and the lower till facies is gradational and no weathering horizons were observed. This contact is gradational over 0.5-1m and is marked by a decrease in clast content, a decrease in matrix sand (42 to 18%) and an increase in matrix silt/clay (58 to 82%). Towards the top of the mud lithofacies is a pebbly mudstone with dispersed clasts (<5cm). The mud is always friable and is not overcompacted.

Unit 4. Parallel Laminated and Rippled Sand. The pebbly mudstone grades up over about 1m into 2-3m of parallel laminated and rippled sand beds. The sands are well sorted and of medium grade. Isolated clasts up to 15cm in length occur sporadically within this unit. Towards the top of the sand unit (1m x 30cm) lenses of sandy diamict interbed with parallel laminated sand. In some cases the diamictons occur as small, channel like infills. Soft-sediment deformation structures are occasionally present along channel margins or within the main body of sand.

Unit 5. Interbedded Sand, Gravel and Diamicton. This composite unit is generally crudely-bedded and 4-5m in thickness. The deposits are the infills of wide, shallow channel-like features which occur on either side of the lignite ridge (Fig. 44). Major bedding planes approximate to shallow catenary curves. The sequence consists of rapidly alternating beds of poorly-sorted pebble gravel with cobbles, poorly-sorted pebbly sand, some parallel laminated sand an a range of sandy or silty diamictons. The latter are best seen towards the base of this unit.

All of the remains of Mammuthus primigenius Blumenbach (thirteen teeth, five tusks and one partial limb bone) have been recovered from the lower 2m of unit 5. The teeth are up to 22cm in length and are not abraided since many of their roots are still present. Remains of tusks are common though in a decomposed state. One tusk fragment measured about 1m but it was difficult to excavate because of its delicate condition. In all cases the Mammoth remains were entombed either within diamicton lenses or in beds of very poorly-sorted, matrix rich pebbly gravel. No organic material was recovered in association with the molars.

Unit 6. Woody Detritus Peat. The woody peat is clearly interbedded with unit 5 but will be considered as a separate unit from descriptive purposes only. The peat occurs as flattened sheets (2-15cm) of woody detritus. The dominant feature is abundant smoothed, compressed twigs and wood pebbles within compressed sheets of black (2.5Y 2/1), lignitic and herbaceous detritus. Typically, the massive sheets contain thin wisps and laminae of sand with occasional small clasts (<1.5cm). The detrital mats thin laterally into parallel laminated sand with interbeds and laminae of disseminated peat and wood.

The woody detritus peat is exposed in two distinct basins. The main exposure occurs between survey stations D and G with a more

Table 9: Selected pollen taxa from organic mud, interbedded gravels and peats, and woody detritus peat at Aghnadarragh, Co. Antrim.

Species		% Pollen from			
	Organic Mud	Woody Detritus Peat C	Interbedded sand & gravel some woody peat at E	Woody Detritus E top	Peat base
Pinus	•	•	11.6	12	19
Picea	+	+	4·6	5	2
Betula	4.3	+	6·5	11	18
Taxus	•	•	1·0	•	+
Alnus	•	•	5·6	1	+
Salix	•	•	•	•	+
Coryloid	4.3	•	9·3	9	14
Gramineae	20	3.4	24	7	4
Cyperaceae	55	86.7	9·3	7	6
Ericaceae	3.4	•	1·3	1	3
Empetrum	•	•	•	+	•
Calluna vulgaris	+	•		2	+
Caryophyllaceae	+	•	•	•	•
Compositae	•	•	•	•	•
Liguliflorae	+	•	•	•	•
Artemisia	1	•	•	•	•
Thalictrum	+	•	•	•	•
Myriophyllum	•	•	•	+	•
Potamogeton	+	•	+	+	+
Callitriche	•	•	•	+	•
Sphagnum	•	+	4·5	+	3
Selaginella Selenoides	+	5.9	•	•	•
Filicales	•	•	8·5	3·5	+
Crumpled Indet	•	7.6	8	4	+
Damaged Indet	•	•	9	•	8
Total Pollen Counted	525	143	215	230	230

+ indicates present
i.e. less than 1%
to a total pollen (for spores % total is based on spores + pollen)

restricted exposure below suvey point C (Fig. 44). At this locality the organic detritus is thoroughly mixed with poorly-sorted pebbly gravel or a green sand/granule admixture. These sites will be considered separately since they have somewhat differing palaeobotanical contents. All stratigraphic units were sampled for pollen analysis and 1kg bulk samples were taken from horizons rich in organic detritus. Samples were prepared by standard palynological techniques and the preliminary results are given as a percentage of total pollen (Table 9). No attempt was made to separate the pollen of Corylus from that of Myrica since comparison between samples could reflect not only different concentrations of pollen but also differing chemical treatments since hydrofluoric acid is used only where the removal of silica is required. However the results of macrofossil extraction confirms that Corylus avellana is present at some point since Corylus shells were recovered.

1. Woody detritus peat. (Below survey stations E and G) Samples for pollen analysis were taken from 2cm from the top of the exposure at E and 5cm above the base of the deposit below Survey Station G. The two deposits differ marginally in their pollen composition. Levels of Pinus pollen fall away between the base (19%) and the top (12%), levels of Coryloid pollen fall from 14% to 9% and Sphagnum falls from 3% to 1% whilst Picea rises marginally from 2% to 4.5% between the base and top of the deposit. The basal sample differs from the top of the deposit since Salix and Taxus pollen are present only in the basal samples. The results of the pollen analysis from the top of the woody peat reinforce the succession of Pinus to Picea and an increasingly more open grassland (7% Gramineae rises to 24%) in which and levels of Betula pollen have fallen from 11% to 6.5% but Alnus has risen from 1% to 5.5%.

Depositionand build-up of the organic peat layer through water action is indicated by the presence of rolled and rounded twigs and wood in the section. This is confirmed by the presence of pollen of aquatic species such as Myriophyllum verticillatum, Potamogeton and Callitriche. The presence of moving water is further confirmed by the degree of crumpled and damaged indeterminate pollen which could be considered to reflect the effects of water movement on the grains (8% crumpled indeterminate grains were recorded from the basal sample).

Macrofossil remains. The woody component of the deposit (identification and confirmations by Dr. J. R. Pilcher) comprised a large quantity of compressed wood with no surviving cellular structure which could be identified together with evidence of Pinus, Picea and an unidentified hard wood.

Macrofossil evidence of tree species was limited. Two cones of Pinus sylvestris were recovered and both were of a small size. The unwinged fruits of Betula species were also present. Accurate identification of Betula fruit to species depends upon the presence of winged fruits. Tentatively, from the shape of the fruits it was concluded that both tree and dwarf birch were present (i.e. Betula pendula, Betula pubescens and Betula nana).

Megaspores of Selaginella selaginoides were also found within the woody organic detritus. Selaginella, an open grassland indicator, is not specifically excluded from wooded environments and has been recovered from the mesocratic stages of interglacials. It is presently confined to dune slacks in Ulster at such places as Magilligan Point, Co. Londonderry.

Remains of water plants are more conspicious in this assemblage than in the organic mud (unit 7). Potamogeton sp. including P.natans which is usually characteristic of still water, is present. Given the interpretation of the prograded nature of the deposit, pools of still water or even damp marshy conditions are not precluded within this environment since Callitriche sp. (22 drupletes) a stream indicator and Carex rostrata an indicator of wet, marshy conditions are also present. The existence of

Table 10A : Macrofossil remains extracted from woody detritus peat, Aghnadarragh, Co. Down.

Species	Type of remains	Number
BETULACEAE		
Betula sp.	fr	9
Betula cf nana L.	fr	8
Betula cf pubescens Ehrh.	fr	8
Betula cf pendula Roth.	fr	3
CRUCIFERAE		
Crucifer indet	s	1
MENYANTHACEAE		
Menyanthes trifoliata L.	s	9 +24*
CALLITRICHACEAE		
Callitriche sp.	dr	22
RANUNCULACEAE		
Ranunculus lingua L.	ach	1 + 1*
Ranunculus flammula L.	ach	1*
LABIATAE		
Mentha sp.	n	1
CYPERACEAE		
Carex sp. (flattened)	n	5
Carex trigonous	n	10
Carex cf vesicaria L	n	2
Carex rostrata Stokes	n	18
Eleocharis sp.	n	3
POTAMOGETONACEAE		
Potamogeton sp.	ach	4 +3*
Potamogeton natans L	ach	1
Selaginella selaginoides (L.) Link.	m	28 12 immature
Sphagnum sp.	operculi	53
Cenococcum graniforme (Sow) Ferde & Winge	scl.	92
Indet seeds		9
WOOD		
Picea sp.	present	
Pinus cf sylvestris L.	abundant	
indet wood	abundant	

Key to terminology for tables 10A,B,C.

s = seed
fr = fruit
n = nutlet
ca = calyx
l = leaf
m = megaspores
o = oospores
scl = sclerotia
dr = drupelet
c = cone
* = fragments

this deposit as part of a prograded river deposit is further supported by the presence of such marsh plants such as Eleocharis sp, Carex cf vesicaria, Mentha sp. too badly corroded to identify further, Menyanthes trifoliata and the species of Ranunculus, R.flammula and R.lingua which are found in damp conditions.

2. Woody detritus peat (below survey station C). At this site the woody detritus is disseminated within poorly-sorted pebbly gravel and/or sand, contrasts with the large sheets of matted peat in the basin east of the lignite ridge. Duplicate samples were taken for pollen analysis. The first was sterile except for 1 Picea grain. The second revealed that the deposit had a very low pollen concentration; 10 slides were required in order to achieve a pollen total of 143. Of this 85% was Cyperaceae, 3.5% Gramineae and 5.9% (Pollen and spores) Selaginella selaginoides microspores. Pollen of Betula and Picea were present as single grains although Picea wood and cones were common (Table 10B). This evidence suggests waterbourne transport of at least some of the pollen.

Macrofossil remains. The macrofossil assemblage and the pollen assemblage are dissimilar. Macrofossils are low in number and dominated by rolled, compressed wood. Picea wood, cones, seeds and 1 needle fragment were present. Comparison with type material did not allow refinement of the species beyond Picea abies. However, cone size was in the range (6-11cm) is usually accorded to Picea abies. ssp obovata. The subspecies obovata was present in a similar Betula-Pinus-Picea assemblage at Chelford (Simpson & West, 1957).

Whole and fragments of Corylus avellana nuts and Taxus baccata seeds were recovered. This was unexpected since Taxus pollen had been found only at the base of the woody detritus peat to the east of the tectonised lignite and the pollen of both species was absent from the other pollen profiles. Taxus is a species indicative of a mild oceanic climate and is intolerant of frost

Table 10B: Macrofossil remains extracted from sandy organic woody detritus

Species	Type of remains	Number
PINACEAE		
Pinus	l	3*
Picea	c	3
	l	1*
	s	34+5*
	atypical s	2
CORYLACEAE		
Corylus avellana L.	n	4+4*
TAXACEAE		
Taxus baccata L	s	2+6*
ROSACEAE		
Rubus fruticosus agg	fr	1/2
VIOLACEAE		
Viola sp.	fr	1*
MENYANTHACEAE		
Menyanthes trifoliata L	s	2
CHENOPODIACEAE		
Chenopodium sp.	s	1*
LABIATAE		
Mentha	n	2
Bryophytes indet	l	1
Cenococcum graniforme (Sow) Ferde & Winge	scl	30
indet seeds		3
WOOD		
indet		abundant
Picea sp.		frequent

and limited in its distribution by the degree of winter cold.

Other species not recorded from the previous exposure of woody detritus peat are Rubus fruticosus agg, a member of the Chenopodiaceae and a very badly damaged seed of Viola species. Menyanthes trifoliata and Mentha Species were common to both deposits suggesting that the environment was essentially similar to that represented by the organic mud (unit 7) which also had a dominant Cyperaceae component and that the macroremains include an element (Picea and Taxus) which were redeposited.

Conclusions on flora. The organic remains represent two distinct depositional and climatic phases. The older is represented by a Betula-Pinus-Picea assemblage which shows a sequential change to a more open environment. The assemblage represents an interstadial in which the climate was sufficiently warm for a period long enough to allow migration of tree species eliminated by earlier glacial conditions (i.e. lower till). The emigration of tree species which must have been a characteristic component of the latter stages of the previous interglacial suggests that the age of the woody detritus peat is Early Midlandian. A similar interglacial assemblage is noted from Chelford in Cheshire (Simpson & West, 1957) from which macrofossils of Carex rostrata, Menyanthes trifoliata, Empetrum species nigrum and tree species of Betula (B.pubescens and B.verrucosa) together with evidence of Betula nana were found. These species are all represented in the woody detritus peat of Aghnadarragh.

Unit 7. Organic Mud. The organic mud reflects a regional treeless environment in which Cyperaceae (55%) and Gramineae (20%) predominate. The other important taxon in the regional vegetation is Ericaceae (3.5%). Although the pollen percentage is low, the Ericaceae are insect-pollinated and hence low pollen producers. Amongst the Ericaceae Calluna vulgaris was recognised.

The presence of Coryloid (4%) and *Betula* (4%) pollen does not preclude local, tree-less conditions since the levels of pollen are comparatively low and half of the *Betula* pollen counted resembled that of *Betula nana*. (Although in this judgement the same criticism regarding distinction between *Myrica* and *Corylus* applies to distinguishing between the *Betula* species). The nature of the organic mud, throughout which sand is uniformly distributed, suggests that the *Picea* grains present are redistributed, possible from the action of seasonal flooding and snow melt.

Macrofossil remains from the organic mud. The condition of the macrofossil remains is poor (Table 10C). Megaspores of *Selaginella selaginoides* (L) Link are the dominant remains (564) in the organic mud. These are small (approx. average 0.4mm diameter) and had ill-developed spinules. Watts (1959) noted a similar dominance of immature *Selaginella* megaspores at Kilbeg. Few microspores of *Selaginella* were recorded (less than 1%) from the pollen analysis in comparison with the levels of megaspores. However, this is to be expected with a predominance of immature megaspores in which the microspores may be ill-developed or the percentage of recogniseable microspores reduced by chemicals during pollen preparation.

Sufficient depth of water to support the growth of colonizers such as the Characeae must have existed locally since 2 oospores were recovered together with remains of *Callitriche* and *Potamogeton* including a single specimen tentatively ascribed to *Potamogeton perfoliatus*. In contrast, the dominance of Cyperaceae in the pollen profile is not reflected in the quantity of *Carex* nutlets reovered. Marshy species such as *Carex rostrata* are present although the balance of aquatic species to land species in both pollen and macrofossil samples suggests that marshy, wet conditions predominated.

Table 10C: Macrofossil remains extracted from Organic Mud, Aghnadarragh, Co. Antrim.

SPECIES	Type of remains	Numbers
SALICACEAE		
Salix herbacea L	l	1
PINACEAE		
cf Pinus sylvestris L.	Bark	1
POTAMOGETONACEAE		
Potamogeton sp.	ac	2 + 2*
Potamogeton cf perfoliatus L	ac	1
CYPERACEAE		
Carex sp. trigonous	n	3
(flattened)	n	1
Carex rostrata Stokes	n	7
ERICACEAE		
Empetrum	n	1
PLUMBAGINACEAE		
Armeria cf maritima (Mill) Willd	ca	1
TYPHACEAE		
Typha sp.		1
CALLITRICHACEAE		
Callitriche	dr	2
CRUCIFERAE		
Crucifer indet	s	1
CARYOPHYLLACEAE		
Caryophyllaceae indet	s	1
Stellaria sp.	s	1
SELAGINELLACEAE		
Selaginella selaginoides (L.) Link	m	564
CHARACEAE	oos	2
Cenococcum graniforme (Sow) Ferdc & Winge	scl	73
Coleopteran remains		abundant
Indet seeds		5

An overall assessment of the climatic conditions reflected by the organic detritus is clear from combined pollen and macrofossil evidence. Arctic alpine species prefominate providing evidence of a cold, open environment dominated by Cyperaceae from the assemblage comprising Salix herbacea, Betula tentatively Betula nana, Armeria cf martima, Thalictrum species and in the immediate vicinity of the deposit Selaginella selaginoides.

Conclusions on flora. The upper organic mud assemblage does not provide evidence of any specific interstadial period within the Midlandian Cold Stage since the palaeobotany is not similar either to the Midlandian 'interstadial' deposits at Hollymount (Colhoun et al., 1972) or Derryvree (McCabe et al., 1978). Elucidation of its exact relationship to these interstadia will depend upon the results of dating and further work.

Insect Fossils (Units 6 and 7). Abundant insect remains were recovered from the two main organic horizons (Units 6 and 7) by the standard technique of wet sieving and paraffin flotation. For the most part the insect remains were in a fragmentary state though there was little sign of corrosion. In the upper organic horizon it was occasionally possible to find complete sclerites, sometimes even joined pairs or elytra were visible in the field. In the lower organic horizon, the insects were more broken up and there was a marked concentration of the more laminar fragments such as elytra and pronota, suggesting that the fossil assemblage had undergone some stream sorting prior to its deposition. This interpretation is in keeping with the lithology of this horizon which was made up of a jumble of sticks and rounded wood pebbles with interbedded layers of finer plant debris and sand. Since the insect assemblage includes species of varied ecological preferences, it provides independent support for an allochthonous origin for the organic material. The fact that the fauna as a whole provides an ecologically consistent picture, suggests that there has not been any reworking of older fossil material and that the insects represent the inhabitants of the available habitats in the neighbourhood as the deposit accumulated.

In the faunal list (Table 11) the families of coleoptera are arranged in their traditional taxonomic order. For those unfamilar with this arrangement, it should be pointed out that each family groups together species with broadly similar environmental requirements. Thus, the Carabidae are general scavaging or carnivorous ground beetles; the Dytiscidae are free swimming predatory water beetles; the Hydrophilidae are largely species of waterside accumulations of vegetation with varying amount of open water. They have carnivorous larvae but vegetarian adults; the Staphylinidae are savage predators that attack all manner of small organisms in the plant detritus layer. Both the Chrysomelidae and the Curculionidae (the familiar weevils) are made up of phytophagous species which, though often fastidious about the plant group that they attack, are rarely species specific.

The numbers opposite each species indicate the minimum numbers of individuals present in each sample. They give an approximate idea of the relative abundance of the species but must be used with caution since the fossil assemblage represents an accumulation of species gathered together from an unknown sampling area and time span. Species that are rare in the fossil assemblage may have been actually common in the area at the time or else living in distant habitats. Similarly, caution should be exercised in the comparison of species abundance between the faunas from the two horizons. The coleoptera from the two organic horizons are sufficiently different from one another that they will be treated here separately.

Woody detritus peat (Unit 6). Most of the Carabidae in this fauna are characterisic of swampy habitats where the vegetation is rich and the ground soft. In particular, the abundance of *Pterostichus diligens* should be noted since this species, though very eurytopic, becomes the dominant carabid only when the

TABLE 11 : List of fossil insects, Aghnadarragh, Co. Antrim

	Upper organic horizon	Lower organic horizon
Carabidae		
Pelophila borealis (Pk.)	1	-
Notiophilus cf aquaticus (L.)	1	1
Diacheila arctica Gyll.	1	-
Dyschirius aeneus (Dej.)	-	1
Dyschirius globosus (Hbst.)	7	-
Dyschirius septentrionum Munst.	2	-
Patrobus assimilis Chaud.	2	1
Patrobus septentrionis (Dej.)	1	-
Trechus quadristriatus (Schr.) or obtusus Er.	-	2
Trechus rivularis (Gyll.)	-	2
Bembidion doris (Pz.)	-	3
Bembidion prasinum (Dufts.)	-	1
Pterostichus anthracinus (Pz.)	-	1
Pterostichus diligens (Sturm)	-	14
Pterostichus gracilis (Dej.)	-	8
Pterostichus minor (Gyll.)	-	4
Pterostichus nigrita (pk.)	1	2
Pterostichus strenuus (Pz.)	-	2
Agonum sp?	-	2
Chlaenius tristis (Sch.)	-	1
Dytiscidae		
Dytiscus sp.	-	1
Agabus cf affinis (Pk.)	-	2
Ilybius sp.	1	1
Hydrophilidae		
Helophorus aequalis Thom.	-	1
Helophorus cf flavipes (F.)	-	1
Coelostoma orbiculare (F.)	-	9
Cercyon cf tristis (Ill.)	?	3
Chaetarthria seminulum (Hbst.)	-	31
Staphylinidae		
Olophrum assimile (Pk.)	1	-
Olophrum consimile (Gyll.)	-	1
Olophrum fuscum (Grav.)	3	-
Olophrum piceum (Gyll.)	-	2
Arpedium brachypterum (Grav.) type	5	-
Acidota crenata (F.)	3	1

Table 11 cont.

Staphylinidae cont'd		
Lesteva longoelytrata (Goeze)	-	9
Lesteva sp.	-	1
Stenus juno (Pk.)	1	2
Stenus spp.	-	6
Lathrobium terminatum Grav.	-	1
Lathrobium spp.	-	4
Philonthus spp.	-	4
Tachinus sp.	1	-
Gymnusa brevicollis (Pk.)	-	6
Aleocharinae gen. et sp. indet.	-	13
Pselaphidae		
Bryaxis sp.	-	1
Scarabaeidae		
Aphodius cf fimetarius (L.)	1	-
Aphodius sp.	1	-
Byrrhidae		
Cytilus sericeus (Forst.)	3	1
Phalacridae		
Phalacrus caricis Sturm	-	1
Chrysomelidae		
Plateumaris sericea (L.) or discolor (Pz.)	-	3
Donacia versicolorea (Brd.)	-	1
Apionidae		
Apion spp.	-	5
Curculionidae		
Otiorhynchus cf nodosus (Mull.)	-	1
Rhyncolus elongatus (Gyll.)	-	2
Rhyncolus strangulatus Perris	-	1
Bagous sp.	-	1
Notaris aethiops (F.)	1	1
Notaris bimaculatus (F.)	1	-
Micrelus ericae (Gyll.)	-	4
HYMENOPTERA		
Formicidae indet	-	1
DIPTERA		
Bibionidae, Dilophus sp.	-	1
ACARINA	6	-

substrate is rather acid. The rarity of Dytiscids in this assemblage suggests that the little permanently open water was available. Only Agabus affinis is represented by more than one fragment and it lives in wet Sphagnum moss in marshes. Chaetarthria seminulum, by far the most abundant species in this fauna, is rare today and is found at the mossy edges of pools where there may be very little open water. This is also the habitat for Coelostoma orbiculare. Most of the Staphylinid species are typical of decomposing vegetable refuse. The insect fauna provides some clues as to the plant species that grew in the swamp. Notaris aethiops is a weevil that feeds on reedy splants such as Sparganium though it will almost certainly accept similar species of Carex. The smut infected inflorescences of various Cyperaceae provide the food source for Phalacrus caricisa. Plateumaris is found on a variety of marsh plants including the Cyperaceae. Finally Donacia versicolorea, here represented by the apex of one elytron, feeds on Potamogeton natans.

The fauna also provides evidence of rather drier habitats. Thus Notiophilus aquaticus (in spite of its name) hunts for Collembola in dry places with bare, vegetation free patches. Patrobus assimilis and Trechus quadristriatus-obtusus also live in drier places. The small weevil Micrelus ericae feeds on Calluna vulgaris and Erica tetralix. Two weevils are present that are entirely dependent on trees as their source of food. Rhyncolus strangulatus and Rhyncolus elongatus drill galleries into the trunks and branches of dead or dying Pinus or Abies. Since, on the whole these weevils do not stray far from their home trees, they suggest that confers must have been close by the site at this time.

The assemblage of insects from this horizon is by no means arctic, since it includes many species that reach only as far north as the southern half of Fennoscandia and there is also a complete absence of the obligate high northern species. Using the Mutual Climatic Range Method devised jointly by Tim Atkinson at the University of East Anglia and ourselves at the University of Birmingham, the thermal climate may be summarised as follows:

Mean July Temperature	+15 C to +18 C
Mean January Temperature	-11 C to +4 C

One final point concerning the relationship of the lower organic horizon and the mammoth remains is important. Although the mammoth gravels directly underlie this organic layer, the insect fauna contains none of the dung beetles that would be expected to be associated with such large mammals. It seems inescapable that, by the time the lower organic horizon (Unit 6) was deposited, the mammoths were NOT present in the area. The junction at the base of the organic deposit may therefore represent a sedimentary non-sequence.

Detrital organic mud (Unit 7). The insect fauna from this layer is not as varied as that from the woody detritus peat horizon. The Carabid beetles now indicate more open ground with a sparser vegetation cover. Diacheila arctica lives in moss tussocks round springs or trickles of water. There are, however, even fewer water beetles present in this assemblage. The Staphylinidae are here dominated by species that live under leaf or moss litter. There is a significant rise in the number of individuals of Cytilus sericeus, a species that feeds exclusively on moss. There thus seems to have been a change in the local environment towards a bryophyte dominated open habitat, but the presence of the weevils Notaris aethiops and Notaris bimaculatus show that some reedy vegetation still persisted. The absence of other phytophagous species suggest that the local flora had become impoverished.

Climatically, this fauna also contrasts with that from the woody peat horizon. Here, the relatively southern species are entirely absent and in their place are northern species such as Diacheila arctica. A summary of the thermal climate is as follows:

Average July Temperature	+11 C to +13 C
Average January Temperature	-18 C to -7 C

Possible age of the Aghnadarragh organic beds. Only the lower organic horizon has an adequte faunal diversity to permit an assessment of a possible age. At present it is emphasised that this is only a guess since faunal similarity may merely represent facies similarity. There is, nevertheless enough of a resemblance between the Lower Aghnadarragh insect fauna and that from the Chelford interstadial, to suggest a very tentative correlation.

Unit 8. Sand Facies. The organic mud is separated from the overlying sand by an erosional junction. This deposit is well-sorted and consists mainly of medium grade sand. Pebbles are generally absent though granules occur as occasional lags. Individual beds vary from massive to bundles of faintly laminated sand. Crossbeds are occasionally present. No glacitectonic structures occur.

Unit 9. Upper Till Facies. Two till lithofacies (4-7m) occur as a major drape along the entire section. The junction between the lower till unit and the underlying sand is either planar or interbedded over about 20cm. Both till lithofacies are remarkably similar in grain size distribution (40% sand; 60% silt/clay) though the lower is brownish-black (10YR 3/1) and the upper is dark-reddish brown (5YR 4/4) in colour. Till fabrics in both till lithofacies are similar (NNW-SSE). Clast types are mainly derived from Tertiary basalts with subsidiary amounts of chalk. The till lithofacies contain a wide range of igneous erratics derived from the Central Tyrone Igneous Complex. One pebble of Ailsa Craig Microgranite was recorded. The junction between both till lithofacies is gradational over 10-30cm.

Interpretation and Conclusions. The stratigraphy and fossil evidence from Aghnadarragh suggest that the following sequence of events:

1. Deformation of the lignite followed by deposition of the lower till facies (Units 1 and 2).

The style of lignite deformation at Aghnadarragh has not been reported from similar Tertiary strata in Ireland. The Tertiary earth movements in the north of Ireland normally result in various fault patterns (Wilson, 1972) many of which have been inferred from geological mapping or borehole data. It is therefore probable that the deformation of the lignite is glaciotectonic. This interpretation is supported by:

(i) Deformation patterns indicate that the intense sectional compression which occurred lies somewhere between soft-sediment deformation and fracture.

(ii) The overlying till lithofacies is heavily sheared (west to east) which indicates intense subglacial compressive flow and deposition by 'lodgement' processes. It is also evident that the strong unimodal clast fabric in the till is the result of shearing during deposition.

(iii)The lignite 'ridge' which traverses the pit is almost at right angles to the inferred direction of ice thrust.

(iv) The presence of abundant armoured 'debris-balls' in the till indicates that meltwater was freely available during deposition and is a result of intense pressure melting at the ice-substrate interface.

Two distinct phases of deformation can be recognised. The first was compression and resulted in sectional shortening. The second was thrusting of near-surface, low pre-tectonic dips into the steeply dipping strata of the lignite ridge. Deformation and thrusting of this type would be facilitated by high pore water pressures, compressive flow and an upward component of ice motion. Judging from the intensity of deformation and the orientation of the ridge of lignite almost at right angles to the direction of ice pressure it is possible that none of the exposed lignite is in situ. It has been shown elsewhere that ice sheets are capable of removing large (e.g. $4km^2$) sections of bedrock many kilometers down ice (Bluemle & Clayton, 1984). Generally, a large depression is created in the area from which the bedrock was removed. It is therefore possible that the lignite at Aghnadarragh was removed from the floor of Lough Neagh and deposited down-ice at Aghnadarragh. This idea requires further field investigation, but is supported by the presence of shallow basins (O'Sullivan et al., 1972) on the floor of the modern Lough.

The lower till facies has most of the attributes of a lodgement/sheared till complex. The amount and variety of igneous erratics present in the till indicates that it was deposited from an ice sheet which moved eastward and south-eastward from a major centre of ice depression in central and western Tyrone (Fig. 3).

2. Deposition of bottomsets (Units 3 and 4)

Lithologic evidence indicates that after ice withdrawal, mud and sand were deposited in a channel or depression on the surface of the lower till. This coarsening up sequence is similar to bottomsets described from former proglacial lakes (cf. Shaw, 1975). The mud was deposited by suspension sedimentation and the cross-bedded sand by sediment-laden, bottom currents. The presence of a pebbly mudstone horizon near the top of the mud and dispersed clasts within the sand are probably I.R.D. It is thought that this event occurred early in the deglacial phase since the top of the till shows no sign of weathering, grades imperceptibly into the overlying mud and the mud contains no pollen or macro-fossils.

3. Deposition of sand, gravel and diamicton complex (Unit 5).

This sequence has not been fully investigated and may contain a series of non-sequences. In broad terms it represents the infill of a wide, shallow river channel possibly a tributary of a former Lough Neagh. The rapid alternation in sediment type, its poorly-sorted nature and rapid changes in grain size may be attributed to repeated changes in flow regimes. The fact that diamicton units occur either as discrete lenses or as small channel infills, indicates that debris flow activity was important and may be associated with bank erosion, high sediment input, or high energy ephemeral flows.

The remains of Mammuthus primigenius generally occur in diamicton and pebbly gravel beds towards the base of Unit 5. They are not associated with either dung beetle or vegetable remains. It is therefore likely that they existed towards the end of the previous cold phase and, at a later time, their remains were reworked into their present site. However, the well-preserved molars and tusks suggest that transport was minimal and were probably freighted into position by debris flow activity rather than by rolling along a stream bed.

4. Deposition of wood peat detritus (Unit 6).
The woody peat beds were undoubtedly transported to the site judging from the rolled nature of the wood and their interbedded relationship with sand and pebble beds. However, the insect, pollen and macroremains present an ecologically consistent picture of Betula-Pinus-Picea woodlands with adjacent areas of swamp, drier ground and local pools at this time. There is a complete absence of the obligate high northern insect species. Both pollen, insect and macrofloral evidence point to interstadial conditions.

5. Deposition of the detrital organic mud (Unit 7).
The insect, pollen and plant macroremains indicate a local treeless environment during deposition of this unit. The local environment was dominated by a Cyperaceae - Gramineae assemblage with mosses, some reedy vegetation and few open pools. All of the insect remains suggest a cold, open type of environment. Although this deposit may have formed during a short interstadial

phase, the fossil assemblage does not reflect typical interstadial palaeobotanic conditions.

6. Deposition of massive/faintly-laminated sand (Unit 8).
This lens-shaped sand body is characterised by the lack of current bedding structures, and the presence of very poorly developed laminae, dish structures, good sorting and an absence of pebble-sized clasts. Deposits of this nature probably accumulate by cohesionless sediment gravity flow into a water body (Postma et al., 1983). The lack of any fossil organic remains probably indicates the proximity of the last glacial phase in this area.

7. Deposition of the upper till facies.
The junction between this lithofacies complex and the underlying sand has not been disturbed by glacitectonics. It is generally sharp and planar but at several basal exposures the sand interbeds with the till over about 20cm. These observations suggest that the bulk of the till formed by melt-out processes though the basal interbeds could be associated with minimal shearing and lodgement.

Dating the Deposits. The Aghnadarragh sequence is the most complete Midlandian sequence known in Ireland. There is no good stratigraphic or ecological argument to place any of the deposits in a stage earlier than the Midlandian. However, it is recognised that non-sequences may occur and represent substantive periods of geologic time.

The general sequence (till→stratified deposits with organic horizons→till) at Aghnadarragh has been recognised at two other sites in Northern Ireland, (Derryvree and Hollymount, Co. Fermanagh). In all cases no intraformational weathering horizons were recognised from these sequences (Colhoun et al., 1972; McCabe et al., 1978). Their absence may be the result of erosion during the climatic vicissitudes which are known to have occurred during the early and middle parts of the last cold stage in England (Coope, 1977). Nothwithstanding the probable presence of non-sequences in the stratigraphic record the three sites suggest that the Midlandian Cold Stage basically consisted of an early glaciation of short duration followed by a periglacial phase, an early interstadial, a deterioration of climate, an interstadial (Derryvree) and a Late glaciation which includes the Drumlin Substage. It is thought that the early glaciation was restricted and short-lived because of the time element necessary for Picea migration (Davis, 1976) into the deglaciated area. At present the maximum area covered by the early glaciation is largely unknown but most of Ulster was undoubtedly affected. The Late-Midlandian glaciation covered most of Ireland and post dates 30,500 year b.p. (Colhoun et al., 1972). The maximum of the Drumlin Substage is dated at 17,000 years b.p. (McCabe, unpubl.).

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