IRISH ASSOCIATION FOR QUATERNARY STUDIES

Field Guide No. 1

SOUTH COUNTY DOWN

A FIELD GUIDE TO THE QUATERNARY DEPOSITS OF SOUTH CO. DOWN, NORTHERN IRELAND

by

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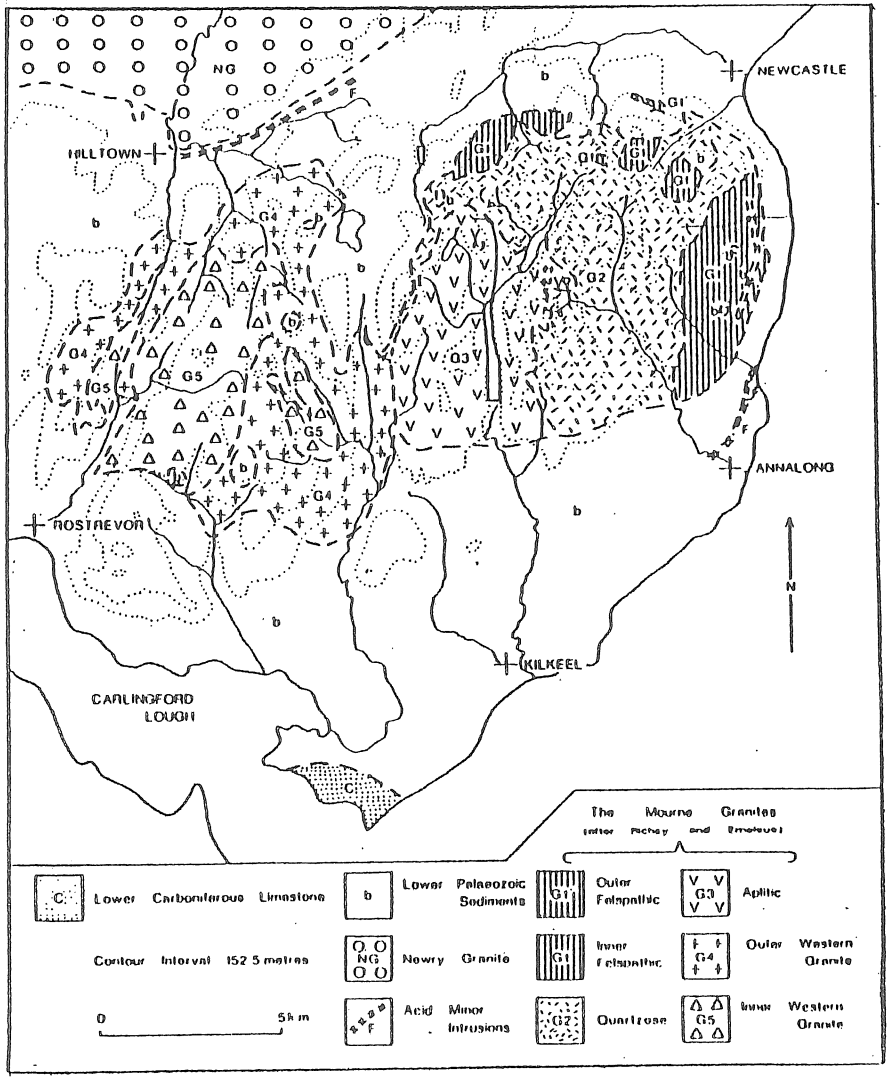

Fig. 1 Solid Geology

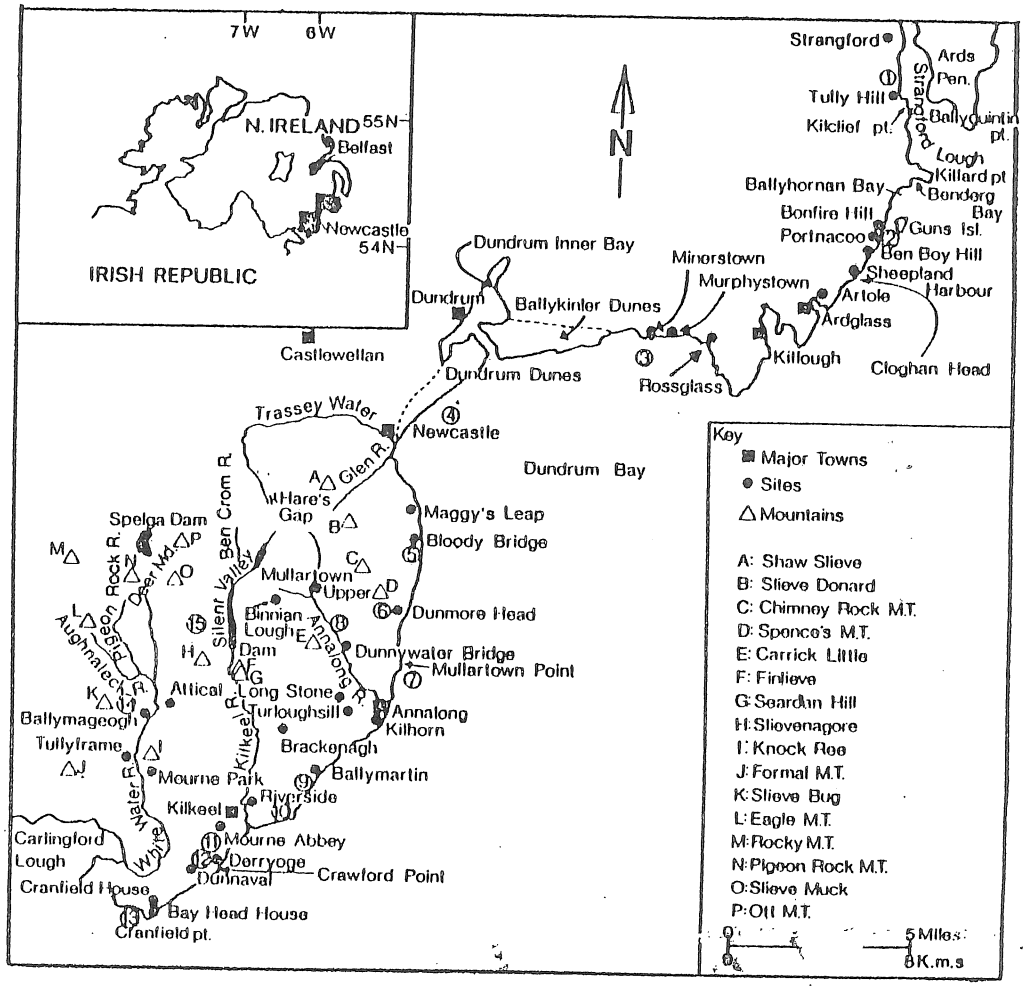

Fig. 2 Itinerary

A. INTRODUCTION

The influence of topography on glacial movements, types of ice masses and patterns of deposition can best be considered with reference to the one inch Ordnance Survey map of the area (Sheet 9; Third Series). Three major geologic-topographical units are present.

The southeastern coastlands of Co. Down from Killard Point (J605434) to Newcastle (J375310) rarely rise above 65m O.D. and are underlain by Lower Palaeozoic sediments (Fig. 1). Much of this zone is comprised of large drumlins many of which are rock cored. Extensive inter-drumlin areas are infilled with raised beach sediments and peat.

The Mourne Plain extends from Annalong (J375198) south-westwards to the mouth of the structural depression of Carlingford Lough (J242119). It is mainly below 120m. O.D and is underlain by Lower Palaeozoic sediments with an important exposure of Carboniferous Limestone at the exit of Carlingford Lough.

The Mourne Mountains are formed by two granite central complexes, the Eastern Mourne Centre with three intrusive members, and the later Western Mourne Centre with two (Fig. 1). The granites intrude and metamorphase steeply folded Lower Palaeozoic slates and grits. Tertiary dyke swarms also occur (Emeleus and Preston, 1969).

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 Mournes on the basis of rounded outlines of the highest peaks such as Slieve Donard (853m). In contrast 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 Synge and Stephens (1960, 1966) 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 and northern Ireland 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 obsèrvations on Late-Midlandian ice limits have been discussed by Stephens and McCabe (1978) and will be outlined in section E.

B. STRATIGRAPHICAL NOMENCLATURE

At present no sub-till organic horizons have been described from south Co. Down. It is therefore difficult to relate the older drift units to specific cold stages of the Quaternary. Thus the drift sub-division must be based on litho-stratigraphy using a system of formations resembling that recommended by the American Commission on Stratigraphical Nomenclature (1961) (See also McCabe and Hoare, 1978). Such an approach is important because, if exposures permit, identification of new units can then be introduced into the established framework.

The term formation is applied to the basic mapping unit and includes the deposits associated with a phase of glaciation, marine action or periglacial activity. The scale of glacial phases (formations) may range from major ice sheet glaciations or mountain glaciations to major readvances.

Seven glacial formations, one periglacial formation and at least two complex marine formations have been identified from the stratigraphic record (Table 1).

Phase	Comments	Type Sites/Areas
10. Glassdrumman : Severe periglacial climate with permafrost and scree formation.	Ice-wedge pseudomorphs, cryoturbation structures and erected stones in many gravel/sand pits.	Glassdrumman
9. Silent Valley. Valley glaciers and corries existed in the mountains during and after phase 7.	End moraines occur at the exit of the Silent Valley (Scardan Hill) at Attical (45) and at Mullartown Upper in the Annalong river valley.	Silent Valley, Ballymageogh.
8. Dunnaval : Late-glacial rise of sea level closely associated with the retreating ice margin.	Formation of late-glacial notches, beach ridges and red marine clay.	Dunnaval plain
7. Cranfield : After phase 6 the ice withdrew in the west and either stabilized or readvanced to Cranfield Point at the entrance to Carlingford Lough. In the east it probably lay between Dundrum and Killard Point.	Large NW/SE gravel ridges at Cranfield PT. Killard PT./Killough gravel/glacio-marine complex.	Cranfield Point Killard Point
6. Ballykeel : A major readvance of ice in the east and west following the Derryoge marine phase. Ice limits at Ballykeel and Glassdrumman.	High level benches, probably of marine origin, occur only in the ice free area between Ballykeel and Glassdrumman/ Dunmore Head.	Ballykeel push marine Glassdrumman ridge and outwash.
5. Derryoge : An ice free episode in the south Mourne Plain with erosion of pre-existing drift followed by deposition of laminated silts and sands.	Laminated silts and sands in 'channel like' depressions.	Derryoge
4. Mourne : An advance of inland based ice into the Mourne area.	Lateral moraines in the north Mournes Ice decay moraines on the Mourne plain.	Kilkeel area
3. Ballymartin : A south-westward expansion of Irish Sea ice onto the Mourne Plain.	Clay-rich till, with shells, Irish Sea type erratics.	Ballymartin coast.
2. Moneydorragh : A major expansion of local ice from centres of ice dispersion within the Mourne mountains especially in the Kilkeel river and Deer's Meadow catchments. This ice moved radially in all directions, covered the Mourne plain and passed off-shore between Annalong and Cranfield point.	Granite rich-till with subordinate lower Palaeozoic rocks.	Ballymartin coast.
1. Annalong : Irish sea based ice advanced S.W. across the Mourne plain and reached the eastern facing valleys and the flanks of the N.E. Mournes.	Clay-rich till with shells, Irish Sea type erratics including Ailsa Craig microgranite. The upper mountain summits were probably unglaciated.	Ballymartin coast Annalong river valley.

Table 1. A summary of the glacial stratigraphy and patterns of ice movements in south County Down, Northern Ireland (Modified after Hannon (1974) and Stephens and McCabe (1977).

C. SEQUENCE OF EVENTS

1. Annalong Phase

The oldest known glacial deposit in the area is the till of Irish Sea provenance which occurs along the base of the cliff section south-west of Ballymartin village (J. 341163). It is overlain by tills of phases 2 and 3. The till has a silt-clay rich matrix, contains shell fragments and erratics of Ailsa Craig microgranite, chalk and flint. Clearly the till has not been derived directly from the Local Lower Palaeozoic sediments but is associated with an on-shore movement of Irish Sea based ice. Similar till facies occur at various sites on the Mourne Plain at Annalong (J 371 199) Glassdrummon (J 378 223), Brackenagh (J 314 197) and possibly in the western Mournes at Trainor's Bridge (J 213 274) (Hannon, 1974).

The overall pattern of ice sheet movement during this phase is difficult to reconstruct because of subsequent erosion and redistribution of drift by inland, mountain and Irish Sea sources. However it is probable that the ice breached some of the cols along the northern rim of the mountains such as the Hare's Gap (J 323 288) and certainly encircled the mountains since Irish Sea type erratics occur up to about 500m but seem to be absent from the highest summits such as Shan Slieve (J 347 293) and Slieve Donard (J 358 278). The erratic evidence indicates that ice streams breached the lowest cols and moved generally southward along the Whitewater, Kilkeel and Annalong river valleys (Hannon, 1974).

2. Moneydorragh Phase

At Ballymartin the granite-rich till which directly overlies the Annalong till is associated with an expansion of ice from the mountains some 6-7km to the north. The main areas of ice dispersion were located in the Deer's Meadow, the Silent Valley catchment and minor valley and corrie centres such as the Glen river valley. The two major ice centres were contiguous with a radial dispersion of ice which covered most of the western Mournes and certainly all of the Mourne Plain. It extended an unknown distance off-shore.

Granite erratics were transported north at least to Rathfriland (J2033) and south into the Irish Sea basin (Hannon, 1974). The southern extent of ice at this time is unknown but McCabe (1973) has recorded Mourne granite boulders within the Tullyallen Formation in Counties Louth and Meath. It is therefore possible that mountain ice was confluent with ice based in the Irish Sea basin at this time.

3. Ballymartin Phase

At Ballymartin the Moneydorragh Till is overlain by an Irish Sea till termed the Ballymartin Till (Hannon, 1974). Lithologically it is similar to the Annalong Till and is therefore impossible to separate from it except in multi-till sequences. It relates to an onshore movement of Irish Sea ice across the Mourne plain for about 4km. up to 120m.

It is difficult to determine the extent of mountain ice at this time but the large fluvio-glacial fan at the exit of the Annalong valley at Dunnywater Bridge (J 355 223) may be of this general age.

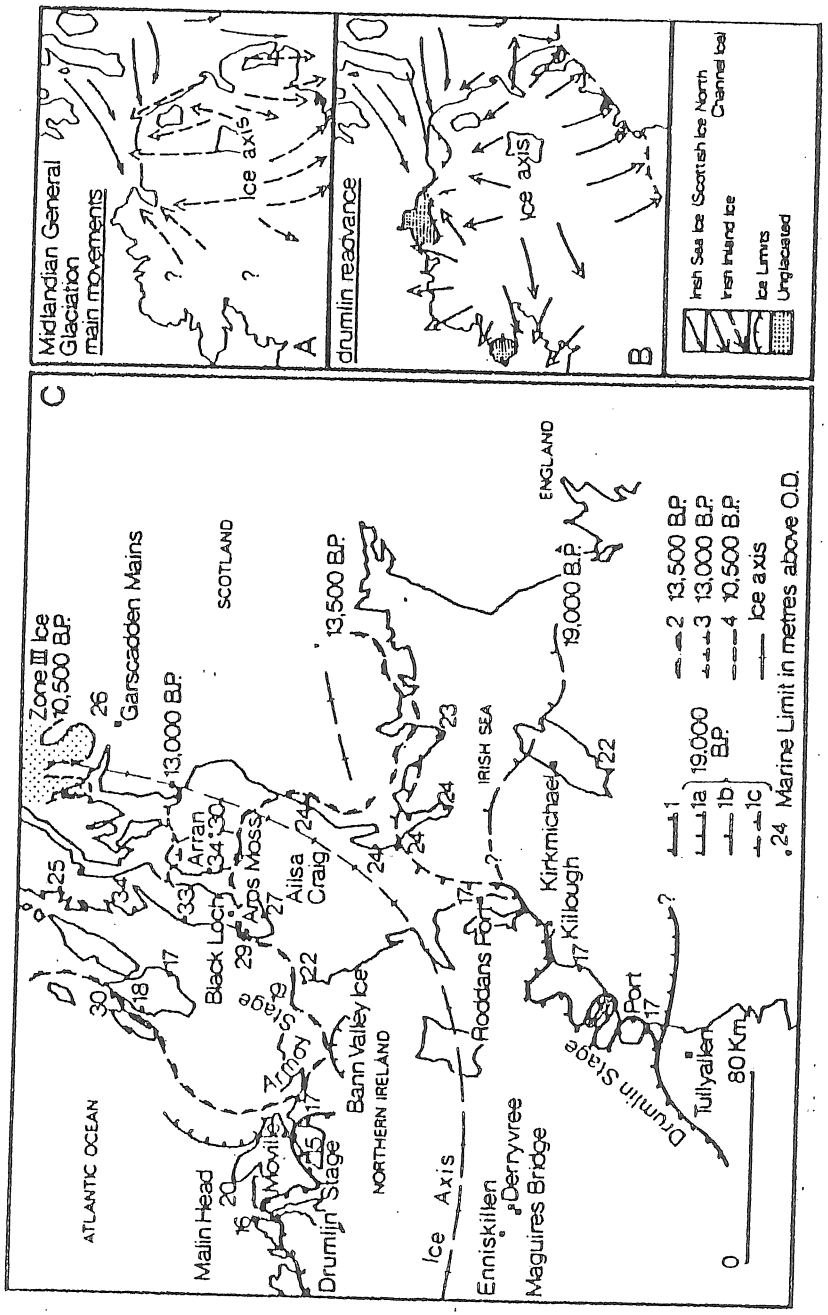

Fig. 3 General directions of ice movement during the late-Midlandian glaciation in Ulster (A and B). The approximate extent of ice during the Drumlin Readvance is shown in C. With acknowledgment to G.F. Mitchell and F.M. Synge. (See also Stephens et. al. 1975; Stephens and McCabe, 1978.)

4. Mourne Phase

During this phase ice from extraneous centres of dispersion in central Ulster and Lough Neagh moved south-eastward and almost encircled the mountains (Figs. 3 and 4). Some authorities (Hannon, 1974; Stephens et al 1975) have suggested that part of the Mourne plain between Kilkeel and Annalong were ice free at this time but conclusive evidence is lacking. However, since this episode equates with the maximum expansion of Late-Midlandian ice it is unlikely that the Mourne massif deflected the ice sufficiently to leave an ice free zone to the lee of the mountains. Furthermore this ice sheet is known to have been at least 400m. in thickness on the northern slopes of the Dublin mountains 100km. farther south (Hoare, 1976).

Evidence for this phase is based on:

i. the well-defined drift limits composed of granite debris along the northern rim of the Mournes. Lateral type moraines occur at about 400m. on Craigdoo (J 272 298) and at 427m. on Ott mountain (J 283 270). Widespread slope deposits occur above these levels (Hannon, 1974).

ii. the presence of meltwater channels at similar levels to the lateral granite moraines.

iii. the presence of Tyrone igneous erratics within the mountain mass at Attical (J 275 193). This indicates that extraneous ice from the north-west penetrated the mountain rim and entered the Deer's meadow catchment (Hannon, 1974).

iv. ice decay features on the Mourne plain such as the Long Stone - Turloughsill moraine (J 355 199) 2km. west of Annalong. It is likely that this feature is an interlobate deposit formed, during initial deglacierization, when the ice split on the lee side of the mountains.

v. till deposits derived from the Lower Palaeozoics east of Kilkeel which rest on Irish Sea till.

5. Derryoge Phase

After the retreat of the Mourne ice to the west of Derryoge Harbour (J 303 127) fluvio-glacial erosion cut a series of channels in till which may be seen in the Derryoge cliff sections. Subsequently the channels were infilled with laminated clays, silts and sands which contain remains of marine foraminifera and ostracods (D. Huddard, personal communication). The channel infills were later disturbed by an eastward ice advance.

6. Ballykeel Phase

A major readvance of inland based ice occurred on both sides of the Mournes following the Derryoge marine phase. In the east the ice reached Glasdrumman (J 379 238) and Dunmore Head (J 385 245). To the west ice moving out of Carlingford Lough reached Ballykeel (J 338 159). It is only in the ice free area between these ice limits that high level benches (+20m.*) of probable marine origin occur.

* All heights of raised beaches are given in Mean Sea level (M.S.L.) which is 2.44m. below Irish Datum.

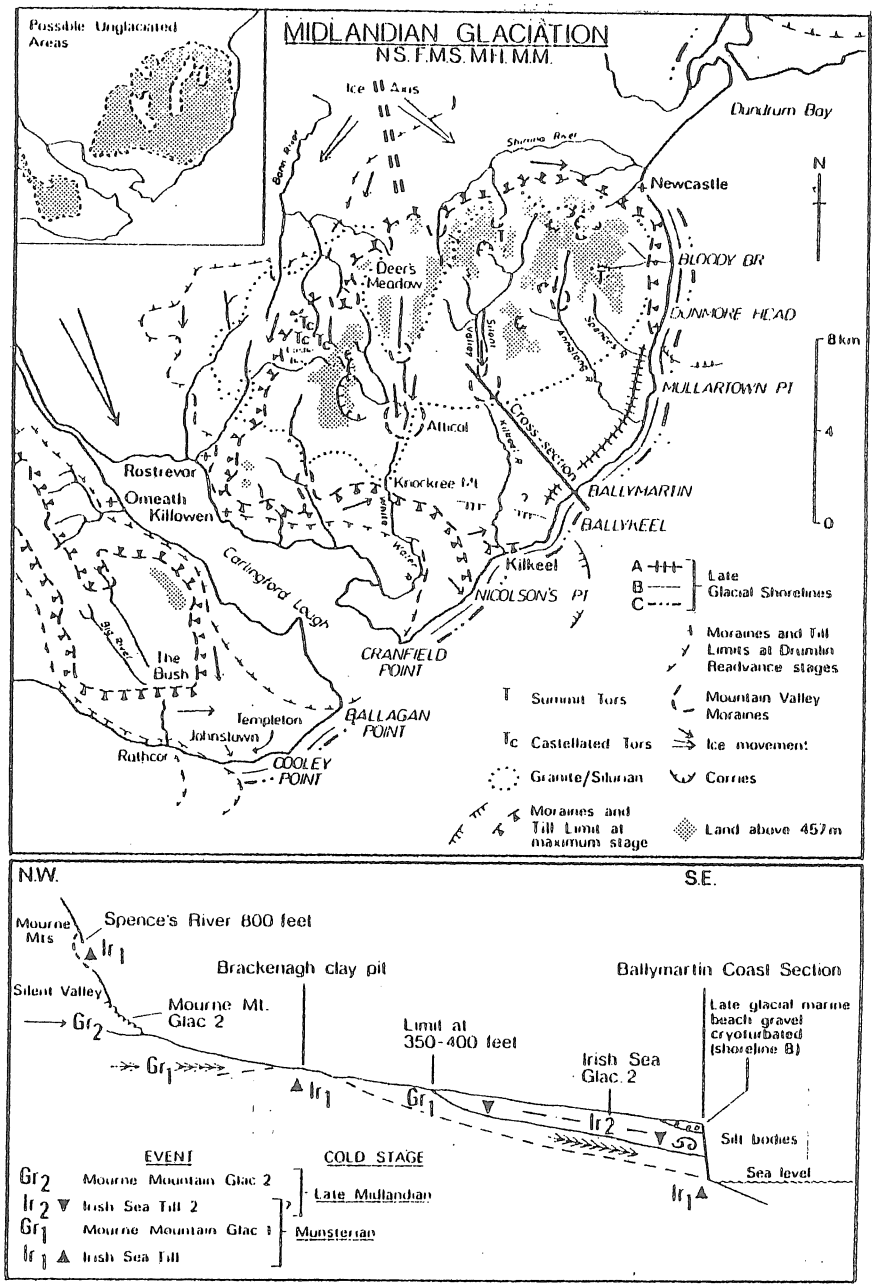

Fig. 4 Late-Midlandian ice limits in S.E. Co Down and the Carlingford Peninsula. Superimposed on this map is the alternative possibility for different ice limits of the Drumlin Readvance - See text, Section E. The extent of Late-glacial shorelines A, B and C are indicated in Fig. 8.

7. Cranfield Phase

A series of N.W.-S.E. trending gravel ridges on the south Mourne plain mark the phased retreat of ice from Ballykeel to Cranfield Point where the Carlingford ice lobe stablized. The large arcuate ridge complex may be traced from Cranfield north westwards to Mourne Park (J 268 154) and Formal mountain (J 243 166).. To the east of the Mournes a similar ice limit occurs between Dundrum, Ardglass and Killard Point. In the ice free area between these limits raised marine features occur at 18-19m.

Since the ice margin was now largely land based rapid ablation by claving was decreased and this may have facilitated stabilization of the ice margin and the build-up of the huge moraine complexes at Cranfield and Killard Point.

8. Dunnaval Phase

The Late-glacial rise of sea level seems to have been in close contact with the retreating ice margin during the Cranfield phase since red marine clays are intercalated with the Killard Point gravels. All of the raised beach features which show evidence of disturbance by periglacial activity are grouped in the Dunnaval Phase (for more detailed observations see Stephens and McCabe, 1978).

9. Silent Valley Phase

It is likely that mountain ice masses developed at much the same time as the ice sheets on the surrounding lowlands though they seem to have been out of phase (cp. Dublin Mountains, McCabe 1979). The outer limits of the last major valley glaciation in the Mournes have been identified by large arcuate ridges in the Annalong (Moneydorragh More, J 355 223), Kilkeel (Seardan Hill, J 305 210) and the White Water (Ballymageogh, J 272 193) river valleys The maximum extent of the valley glaciers post-dates the Ballykeel phase and is probably penecontemporaneous with the Cranfield phase.

10. Classdrumman Phase

Many gravel pits indicate that severe periglacial conditions occurred in the area after the final dissolution of the ice. Periglacial structures including well-developed ice-wedge pseudomorphs occur in all surface fluvio-glacial gravel formations and in Late-glacial beach gravels. It is also certain that most of the scree slopes in the area were active at this time. In Ireland it is not yet certain whether periglacial structures in the Late-Midlandian deposits relate solely to the period up to the end of Zone I or whether some may relate to Zone III of the Late-glacial.

D. ITINERARY

1. Cloghy

On the main Ardglass road, 2km. due south of Strangford town an extensive area of raised beach plain occurs in Cloghy townland (J 595 481). It's surface is flat and occurs between 7 and 8m. with beach gravels exposed in coastal sections. Inland the beach fades out and is replaced by a break of slope in solid rock which may be a fossil cliff.

Immediately to the south the road skirts a raised shingle ridge (6m.) along the base of Tully Hill near Kilclief Point (J 595 467). The Tully Hill drumlin shows evidence of marine notching at 17m. Adjacent drumlins are notched up to 18m. and below this level a thick layer of red marine clay may be found in drain and temporary sections.

2. Killard Point/Killough Coast

A complex of ridges separated by irregular depressions some 0.5km. in width trends N.E.-S.W. from Killard Point (J 608 435) to Ardglass. The feature was formed in an ice marginal environment when the north-westerly retreating ice became land based. This reduced rapid rates of ice loss by calving into the deeper parts of the Irish Sea basin. Drumlin fields (N.W.-S.E.) begin a few hundred metres to the N.W. of the moraine and are best viewed from the gravel hill of Ardtole (J 563 381) on the main road immediately to the north of Ardglass.

The structure of the complex may be studied from the excellent exposures on the north and south side of Killard Point and in Ballyhornan Bay (J 595 425). On the north side of Killard Point the deposits range from fine, well-bedded sand to poorly-sorted gravels which have been 'caught-up' with units of massive till and lenses of red marine clay. Large dropstones also occur in various sand beds. Clearly this suite of deposits has been disturbed by glaci-tectonics in an ice-proximal environment. The presence of red marine clay throughout the section indicates that the sequence is glacio-marine in nature and probably accumulated near an ice-shelf.

No massive till units or well-developed glaci-tectonic structures occur on the distal side of the feature on the southern side of Killard Point (Benderg Bay) or in the Ballyhornan Bay sections. Instead, layers of red clay are intercalated with units of flat-bedded, fluvio-glacial sands and gravels. As a whole these sections indicate deposition in a glacio-marine environment some distance from the ice margin. In Benderg Bay large erratic boulders of Carboniferous limestone (2m. in diameter) as well as N.W.-S.E. streamlined bedrock knobs occur on the foreshore. The Carboniferous limestone is derived from a restricted outcrop near Comber 30km. to the N.W.

Farther south the ice marginal deposits rest directly on Lower Palaeozoic bedrock at Ben Boy Hill (J 588 401). Washing limits and swash gullies occur at Ben Boy Hill and Portnacoo (J 590 406). Around Sheepland Harbour (J 579 392) areas of washed rock with drapes of red marine clay over rocky knobs are widespread. Fluvio-glacial gravels and lenses of red clay are exposed at Cloghan Head (J 580 390).

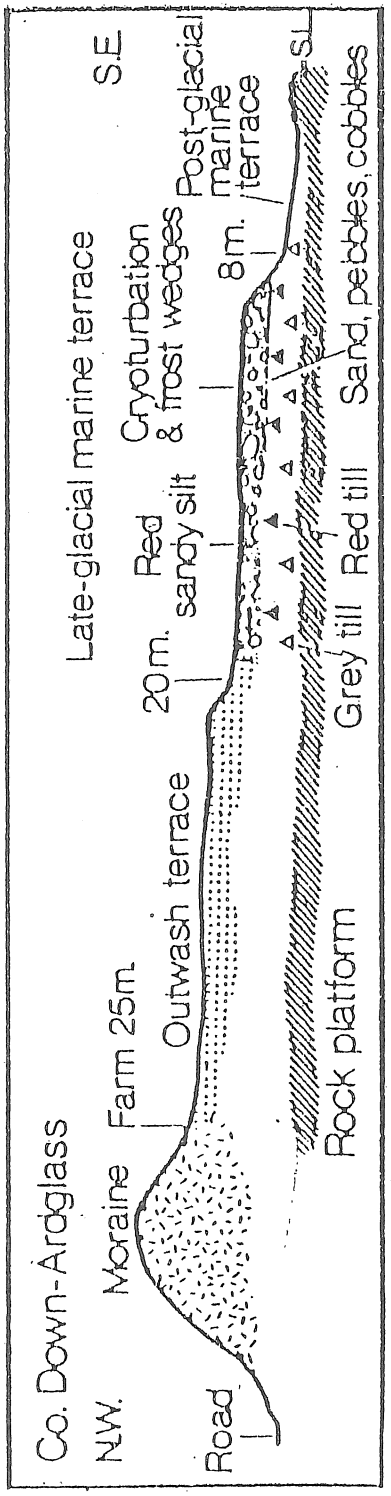

Fig. 5 Ardglass

An excellent coastal section occurs on the north side of Ardglass Harbour (J 563 375) (Fig. 5). A low level marine-cut, rock platform of unknown age (for discussion see Synge, 1979) has been striated by south-eastward moving ice. It is overlain by grey and red tills which are composed predominantly of local rock types. This section is sealed by fluvio-glacial gravels in ridge and plain form. Various raised marine features have been cut into these deposits (Fig. 5).

A higher rock-cut bench occurs on the side of the road leading to the coastguard station at Killough (J 539 356). No till is present but up to 6m. of poorly-sorted, fluvio-glacial gravels are exposed.

3. Minerstown Coast

Various drift notches occur where the main Killough-Dundrum road meets the coast at Rossglass (J 503 358). The lowest post-glacial notch occurs at 5m. and higher late glacial notches at 10-11m. and possibly 21m. Farther west, at Murphystown (J 498 361) and Minerstown (J 488 362), a series of large beach ridges straddle the main road with heights of 13-14m. and 16-17m.

Well-bedded beach gravels occur in artificial sections excavated during the construction of the caravan park at Minerstown. In this section shelly post-glacial beach gravels with evidence of human activity are seen to overlie and truncate cryoturbated, low-level late-glacial beach gravels

4. Murlough Nature Reserve (by I. Shepherd and J. Watmough)

A complex shingle spit, 5km. long and over 0.8km. wide, has developed north-eastwards from Newcastle, and behind this barrier formed a tidal lagoon of which only Dundrum Inner Bay remains (Shepherd, 1970). Blown sand from the beach has covered most of this spit and built up an extensive area of dunes which reach a maximum height of 28m, in itself one of the remarkable features of the Dundrum dunes.

The shingle ridges which form the spit are exposed throughout the dune system in blow outs which have a dry shingle floor. These sites have been surveyed to establish their height above sea level. Elsewhere, further information about the buried ridges has been obtained by drilling to determine their exact location. Where this has proved impractical, because of the depth of covering sand, a restivity meter has been used to locate and survey the shingle ridges. It has been established that the spit is composed of at least twelve sub-parallel shingle ridges the highest of which reaches a height of 9m. Examination of the shingle reveals pebbles of Silurian strata, dyke rocks, Mourne granites and glacial erratics. Measurements of shingle size and shape show that the pebbles decrease in size from south-west to north-east along the spit - no doubt due in part to longshore movement of beach material by dominant waves from the south-east.

This spit formed in post-glacial times (after 10,000 B.P.) when, with the interaction of isostatic and eustatic forces, there were complex readjustments of land and sea levels Thus the variation in height of the shingle ridges may reflect both subsequent isostatic recovery of the land as well as storm wave effects. These ridges were covered subsequently by sand blown from the beach. Sand traps have been set up to collect wind blown sand for analysis in conjunction with measurements of the rate of erosion and deposition of sand in the inter-tidal zone, and this is providing information on the grain sizes of the sand reaching the dunes.

A humus soil horizon may be traced across parts of the dunes, and overlies a strongly developed podsol profile which has been revealed by blow-outs. In places the podzol is repeated in a double profile. The main humus horizon may represent a lengthy period of soil stability and plant growth. Preliminary investigations suggest one main humus surface, and possibly two less humic surfaces on the repeated profiles.

The Dundrum dunes became a Nature Reserve of the National Trust in 1966 (Resident Warden is Mrs J. Watmough), and parts are protected from recreational use. Plant communities include the dune succession from Marram to heath, as well as extensive and expanding Hippophaë and Rosa pimpinellifolia scrub. The vegetation of the dune system is well developed and shows the succession from the newly developed foredunes to an old acid dune heath (Watmough, 1970).

The strand line carries a varied vegetation in the summer months when such plants as Sea Sandwort (Honkenya peploides) and Sea beet (Beta maritima) are abundant on the shingle beach. On the sandy beach at the north-eastern end of the spit, plants of Sea rocket (Cakile maritima), Oraches (Atriplex sp.) and others form embryo dunes during the summer months. Sea couch grass (Agropyron junceiforme) and Marram grass (Ammophila arenaria) also occur, and become responsible for the formation of the fore-dune ridges by their accumulation of wind blown sand. On the lee slopes of the fore-dunes, the first colonisers of the dunes to appear are Thistles (Cirsium arvense) together with more specialised dune plants such as Sea holly (Eryngium maritimum), Perennial spurge (Euphorbia paralias) and Portland spurge (Euphorbia portlandica).

The sand surface itself is covered primarily by two mosses, Tortula ruraliformis, the major dune colonising moss in Britain, and Rhacomitrium canescens which is here exceptional in living on dunes.

In the partially covered fixed dune areas, can be found a variety of plants, many of which are winter annuals (small plants with shallow roots). These grow during the damper winter months and flower in the late spring. The deeper rooted perennials flower during the dry summer months. Rest harrow (Ononis repens) and Birds foots trefoil (Lotus corniculatus) are the most important nitrogen fixing plants. They help to enrich the sand and encourage a wider range of plants to grow.

The fixed yellow dunes are the most fertile areas, with an alkaline/neutral soil reaction. A rich variety of plants can be found in the continuous cover of vegetation. Several of these are rare Irish plants such as Bee orchid (Ophrys apifer), Pyramidal orchid (Anacamptis pyrimidalis) and Blue fleabane (Erigeron acre).

With the increasing age of the dunes and leaching of calcium salts from the surface sand, acid soil conditions develop. The vegetation reflects this change in the appearance of Bracken (Pteridium aquilinum) over large areas with an undergrowth of Brambles (Rubus sps.). In the spring, Primroses (Primula vulgaris) and Bluebells (Endymion nonscriptus) are widespread. They flower before the Bracken emerges, as only a few plants such as Twayblade (Listera ovata) can tolerate its dense shade. Burnet rose (Rosa pimpinellifolia) also occurs on the acid dunes, where it may predominate over extensive areas. Dense scrub areas of Gorse (Ulex europea) and Blackthorn (Prunus spinosa) are also found.

On the oldest dunes, very acid conditions occur on which a Heath type of vegetation has developed. Ling (Calluna vulgaris) and Bell heather (Erica cinerea) are predominant though Mosses and Lichens are abundant.

Sea Buckthorn (Hippophae rhamnoides) was planted originally in the vicinity of Murlough House to stabilise blowing sand. It is now spreading extensively over the dunes, where it forms impenetrable thickets.

5. Bloody Bridge

An interesting drift exposure occurs adjacent to the Bloody Bridge carpark (J 389 271). Up to 2m. of compact, greyish till, largely derived from the local shales and sandstones, occurs at the base of the section. This till contains large boulders some of which are pink Mourne granites set in a sandy matrix with thin streaks of washed sand. The lower unit grades upward into a deposit (1m.) which lacks a matrix and consists mostly of glacially-faceted pebbles and boulders. Both units contain the same rock lithologies and are related to deposition by a single ice mass. However the lower till is undoubtedly a basal, matrix-rich till (lodgement or melt-out) which has undergone shearing and pressure melting during deposition. The upper unit resembles an ablation type deposit from which the fines have been removed by meltwater. This unit occurs as a distinct till facies along the steep, narrow coastal strip from Maggy's Leap (J 388 283) south to Dunmore Head (J 384 246). It is probably the ground moraine of the southerly ice advance marked by the gravel ridges at Dunmore Head and Glassdrumman.

6. Glassdrumman/Dunmore Head

The deposits in this area illustrate the classical model of ice-contact and pro-glacial gravel deposition. At Glassdrumman (J 379 238) a N.W. - S.E. trending ridge, at right angles to the contours, rises to about 70m. and records ice contact gravel deposition at the limit of glacial phase 6. A flat spread of outwash sands and gravels grades south from the distal side of the ridge. In contrast the steep northern slopes of the ridge are ice-contact in origin.

The large pit along the core of the ridge has exposed a wide variety of washed sediments which show rapid lateral and vertical variations in grain size and sorting. Large boulders up to 3m. in diameter are common on the pit floor and the sediments are faulted. Clearly the ridge formed close to the ice margin in an environment of extreme fluctuations in meltwater discharge. The dominant lithologies present are derived from the underlying Lower Palaeozoic sediments with subordinate amounts of Mourne granites.

North of Glassdrumman hummocky gravel topography occurs up to a well-defined drift limit at 150m. Fossil felsenmeer occur above this level. At lower levels the present form of the Dunmore Hill gravel complex is the direct result of fluvio-glacial erosion as the ice withdrew north.

Periglacial structures including ice-wedge pseudomorphs and cryoturbation nodes occur in most of the gravel pits in the area but are especially well-preserved in the pits immediately to the east of the main road (J 380 236).

7. Mullartown/Annalong

The coastal zone between Glassdrumman and Annalong consists of a spread of fluvio-glacial gravels associated with the Glassdrumman ice limit. High level notches (25-26m.) have been cut into these gravels immediately to the west of the main road around Mullartown House (J 372 206). Lower late-glacial raised notches occur at Mullartown point (19m.) and, on the northern outskirts of Annalong, this notch crosses the main road, To the east this late glacial terrace has been truncated by post-glacial marine erosion at 7m. and 4m.

A similar suite of raised beach notches occur on either side of the main road south of Annalong at Kilhorn church (J 366 185). In this area the lower late-glacial notches (13m.) tend to cut out the 18m. notch which is well developed north of Annalong. The highest notch and terrace features (20-22m.) continue along the western side of the main road but 'pinch out' north of Ballymartin village. The absence of such high level features farther south indicates that the ice limit marked by the Ballykeel ridge (J 336 158) is important and is similar to the ice limit at Glassdrumman because high level benches only occur in the area between these ice limits. The area between Ballykeel and Glassdrumman must therefore have been ice free during the initial stages of the late-glacial transgression (Stephens and McCabe, 1977).

8. Annalong River Valley

At Dunnywater bridge (J 355 223), where the Annalong river valley opens out on to the Mourne plain, a large fan slopes south-eastwards from the depression between Carrick Little (259m.) and Round Seefin (232m.). The deposit consists of a wide variety of sediment types in close juxtaposition indicating a high energy fluvio-glacial environment. Fluvio-glacial erosion has breached the centre of the fan leaving a large, steep-sided meltwater channel. The fan may represent the limit of the last valley glacier to occupy the Annalong river valley.

Farther up valley arcuate moraines occur at the Hare's Castle (J 340 250) and small corrie moraines may be seen at Binnian Lough (J 324 243). These morainic forms must relate to the phased withdrawal of the ice during the Late-Midlandian. The precise relationships to glacial events on the lowlands are at present unknown.

9. Ballymartin Coast

This section occurs on the coast, immediately to the south of Ballymartin village (J 341 162) and provides a unique record of the earliest known glacial events in this area. The critical section is about 250m. in length and 5 to 6m. in height but this varies due to marine erosion and slumping (Fig. 6).

Three distinct till units occur along the section. The lowest till, termed the Annalong Till is up to 2m. in thickness and consists predominantly of silt and clay with an admixture of Lower Palaeozoic sediments and a few granites. Pebbles of flint, chalk and granites foreign to the Mourne area (Ailsa Craig) along with comminuted shell fragments have been recovered from the section. Tills with such characteristics are associated with onshore movements of ice which passed along the Irish Sea basin. Similar tills have been found elsewhere on the Moune Plain (Brackenagh Clay pit, J 331 187) (Hannon, 1974).

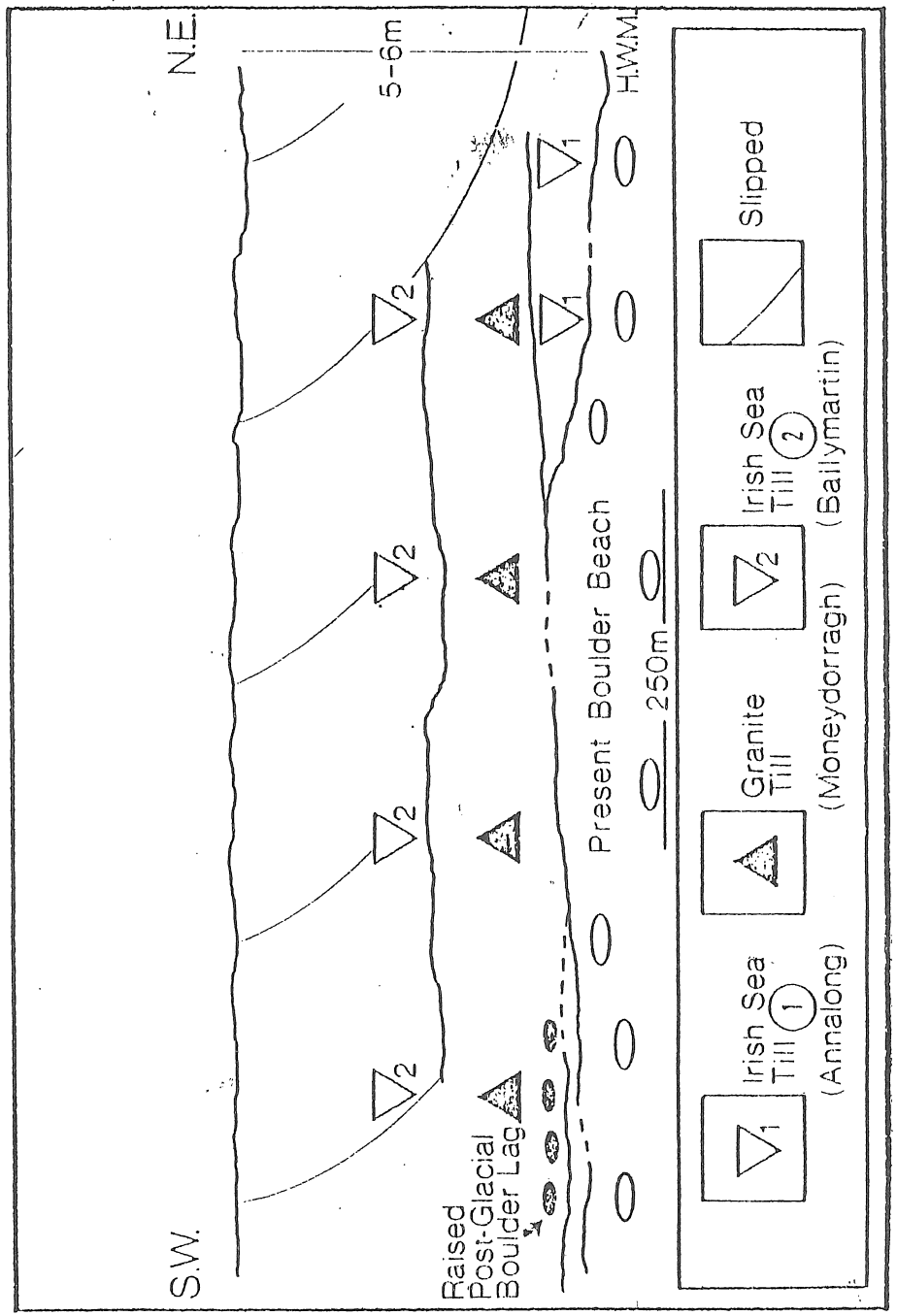

Fig. 6 Ballymartin

The Annalong Till is overlain by the Moneydarragh Till which has been derived from the granites of the eastern Mourne complex. The till matrix reacts weakly with N-acid in contrast to the tills above and below. The lithological characteristics of the till indicate deposition from an ice mass which developed within the high Mournes, some 6-8km. to the north.

The section is capped by the Ballymartin Till which is identical lithologically to the Annalong Till. It is related to an ice sheet of Irish Sea provenance moving across the southern Mourne plain. Such tills seem to fade out inland at about 120m.

This tripartite sequence may represent the changing strengths of ice based in the mountains and in the Irish Sea basin. Time intervals between the three units is unknown due to the lack of suitable intraformational evidence but it is likely that this was within the same cold stage.

10. Ballykeel Bay

Thedeposits exposed in the cliff section at the southern end of Ballykeel Bay occur immediately to the north of the exit of the Mullagh river (J 338 157). These deposits are distinct from those at Ballymartin for several reasons:

i. They consist of overcompacted laminated silts and sands, overlain and intruded by a tectonically-structured, sandy till which is capped by a layer of poorly-sorted gravels

ii. There are only small amounts of Mourne granites present and most of the pebbles can be readily matched with the Local Palaeozoic sediments. Chalk and flint fragments can occasionally be found.

iii. Morphologically the deposits are associated with a large ridge which may be traced north and then north-west across the Mourne Plain. In contrast, the Ballymartin till sequence cannot be related directly to any ridge on the adjacent Mourne Plain.

The stratigraphical and morphological features of these deposits indicate that they are related to an ice lobe which moved from Carlingford Lough across the Mourne Plain east as far as Ballykeel Bay. No high level late-glacial beaches (+20m) occur within this ice limit but pinch-out immediately to the north-east around Ballymartin.

11. Kilkeel Area

Much of the topography on either side of Kilkeel - Cranfield Point road is composed of broad N.W. - S.E. trending gravel ridges separated by spreads of fluvio-glacial sands and gravels. The ridges are ice-marginal in origin and relate to successive positions of the ice front during its phased retreat from Ballykeel west to Carlingford Lough. Good examples occur east of the Kilkeel river at Riverside (J 315 152) and to the west at Mourne Abbey (J 302 143) and Derryoge (J 296 129). A large kettled gravel moraine occurs at the junction (J 296 132) of the main road and the minor road leading to Derryoge Harbour.

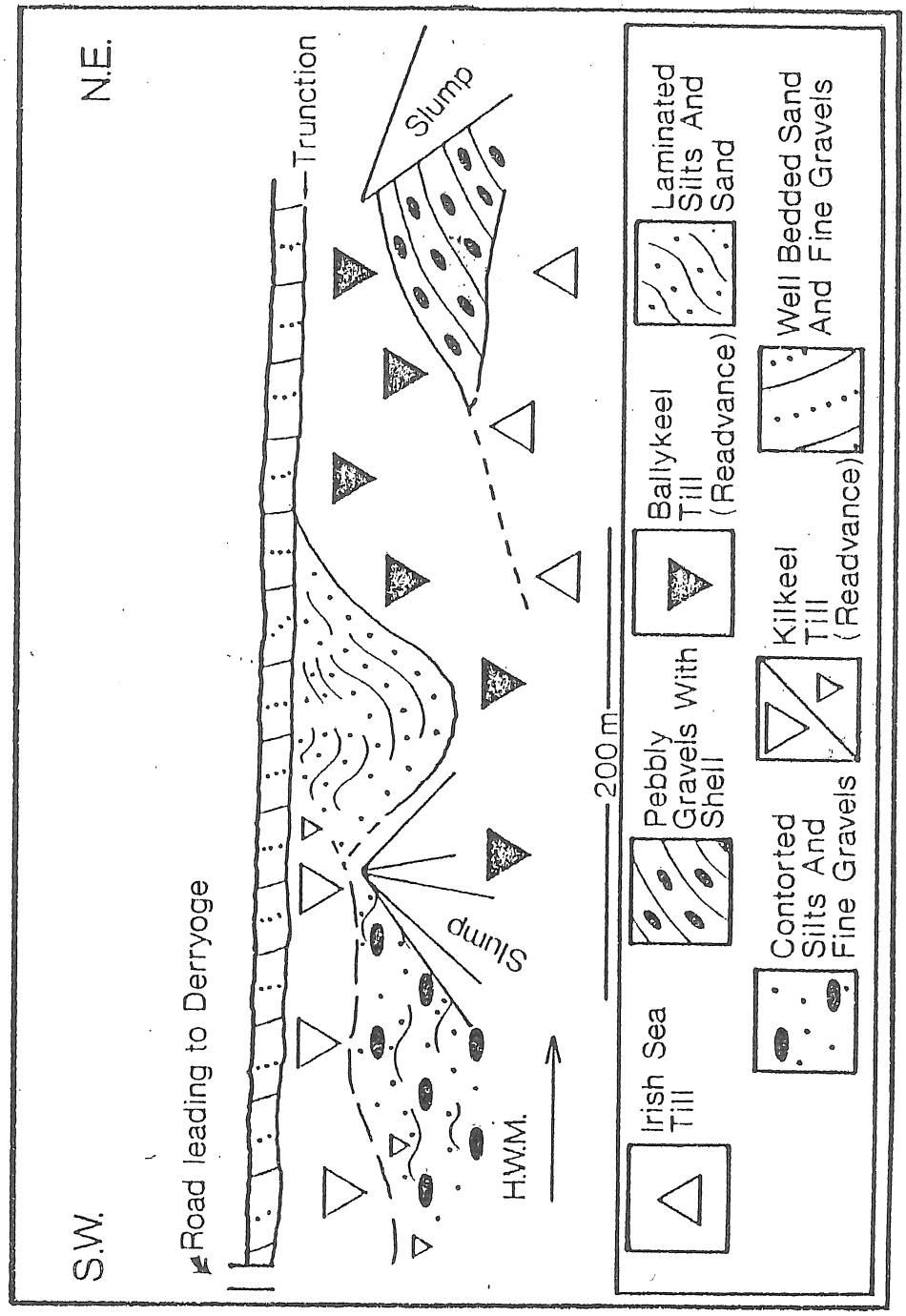

Fig. 7 Derryoge

On the eastern side of Kilkeel harbour (J 318 143) a series of well developed fluvio-glacial terrace-toe fragments associated with deposition down the Kilkeel river, occur at 16-17m, 14-15m, 12m. and 7m. It is possible that these relate to former sea levels but detailed work has not been completed.

On the Kilkeel Plain several large commercial gravel pits have been excavated in fluvio-glacial gravels. Immediately to the east of the Riverside - Kilkeel Point road, ice Wedge pseudomorphs and cryoturbation structures have been recorded from these expsoures (J 322 144).

12. Derryoge Harbour

An extremely complex and variable suite of Pleistocene sediments occurs for about 250m. along the coast at Derryoge Harbour (J 303 127). The cliff is subject to periodic slumping which often obscures the sequence summarised in figure 7.

At beach level, 150m. north of the exit road a shelly, silt-rich till crops out and is overlain by pebbly gravels which contain a well-preserved suite of marine molluscs. Both deposits have been disturbed by glaci-tectonics and date originally from an onshore movement of Irish Sea ice.

The Irish Sea deposits are overlain by a thick, brown till composed largely of local Palaeozoics. This till is related to ice which moved eastward to the Ballykeel limit since it contains erratics of Carboniferous limestones derived from outcrops at the mouth of Carlingford Lough.

A large 'channel-like' feature has been cut into the till immediately to the north of the exit road. It has been infilled with contorted, over-consolidated, greyish laminated silts and sands which contain a sparce marine fauna (D. Huddard, pers. comm.) and occasional dropstones. In places the upper part of the sequence has been sheared by over-riding ice and small till bodies have been mixed with the silts. The entire sequence has been truncated and is overlain by well-bedded sands and fine gravels.

The sequence may be interpreted as follows:

i. The till and shelly gravels of Irish Sea provenance were contorted and disturbed by ice which deposited the lower local till during the easterly ice advance to Ballykeel.

ii. The ice withdrew to the west or vacated this area and erosion of the till occurred.

iii. Desposition of the grey silts and sands in the eroded channels may relate to a glacio-marine episode. A similar situation occurred in north Co. Lough when rising sea levels were in close association with the retreating ice margin at this time (McCabe and Hoare, 1978).

iv. The ice margin oscillated in this area, deposited a till, and deformed the laminated silts and sands. The eastern limit of this oscillation may be marked by one of the large gravel ridges around Kilkeel.

v. Truncation of the drift sequence by fluvio-glacial meltwater and marine action.

13. Cranfield Point Area

A large arcuate moraine ridge composed of sands and gravels may be traced from Cranfield point (J 102 273) north along the east bank of the White Water through Ballyardel (J 278 142) and then north-west by Mourne park (J 266 155) to the lower slopes of Formal mountain (J 235 164). It represents the limiting deposits of a large ice lobe centred in Carlingford Lough after ice withdrawal from the Mourne Plain. The Cranfield limit can be matched with a similar deposit on the opposite side of Carlingford Lough at Ballagan Point (J 203 006). Large commercial sand and gravel pits are common along the feature (J 278 115).

The lodgement till associated with this phase has been derived from local Carboniferous limestones and crops out at Cranfield point (J 271 100).

At Tullyfram (J 262 170), to the west of Mourne Park, the moraine ridge has been breached by a large meltwater channel related to ice wastage within the mountains. A large gravel pit occurs near the point where the main road crosses the moraine at right angles.

A large spread of gravels grades east from the Cranfield ridge along the coastal fringe for 2.5km. Its northern limit is well-marked at Dunnaval (J290 123) and Ballyhattan at about 19m. where a series of large N.N.W - S.S.E. trending ridge moraines have been truncated abruptly. This line of truncation occurs between Cranfield and Crawford's Point (J 301 122). Although the gravels of the Dunnaval plain are mostly outwash its present surface is the result of marine erosion as is the truncation of the moraines. Other evidence of marine activity is the narrow beach ridge (15m.) which may be traced parallel to the present coast for 1.5km, from Bay View House (J 275 104) to Slatemill (J 272 101). Small gully sections in the ridge show well-bedded beach gravels resting on a boulder lag derived by washing of the underlying till.

Large gravel pits occur immediately to the east of Cranfield House (J 275 108). The exposures are mainly in medium grade fluvio-glacial gravels and sands. Cryoturbation structures are fairly common in the top meter of gravels.

All of the raised beach features on the Dunnaval Plain are late-glacial in age because of the presence of cryoturbation structures and their height range. No such raised beaches are known to occur within the Cranfield limit. However, lower post-glacial raised beaches with shells are common within Carlingford Lough (Stephens and McCabe, 1977). For example the highest post-glacial notch at 7m. may be seen immediately behind the caravan park at Cranfield on the ice-proximal slope of the moraine (J 270 104).

14. The Upper White Water and Pigeon Rock River Valleys

The limits and deposits of the last major mountain glaciation in the Mournes may be examined along the upper reaches of the White Water river. During the Silent Valley phase a composite valley glacier developed in the Pigeon Rock (J 2523) and Deer's Meadow (J 2626) catchments and extended down the White Water to Ballymageogh (J270 192). The lateral ice limits are marked by a series of moraines on the eastern slopes of Slieve Bug (J 2519). The major cross valley moraine may be traced as a large arcuate ridge between Ballymageogh and Attical (J 279 199). The large pits at Ballymageogh indicate that it is composed of poorly-sorted gravels and sands derived principally from Mourne granite.

When the ice withdrew north a nested series of small gravel cross-valley moraines were formed. With farther retreat the composite White Water glacier divided into individual glaciers located in the White Water valley proper and its tributary the Pigeon Rock river. Small cross valley moraines mark successive ice marginal accumulations up valley. Complex areas of channelled moraine occur along the floor of the Pigeon Rock river, 1km. upstream from the Aughnaleck river junction. Three well-defined corries with small frontal moraines can also be seen on the eastern slopes of the Slieve Bug - Eagle Mountain range.

15. The Upper Kilkeel River Valley (Silent Valley)

The last maximum downvalley limit of mountain ice in the Silent Valley is marked by a large block moraine which extends from the south eastern slopes of Slievenagore (J 297 212) across the valley to Scardan Hill (J 309 210). Various small cross-valley moraines occur between this terminal feature and the dam wall of the Silent Valley (J 305 218). In places the cross valley features may be traced into lateral terraces along the eastern slopes of Slievenagore at about 200m. Farther ice retreat is marked by cross valley moraines at the junction (J 306 247) of the Ben Crom and Kilkeel rivers. Sections in these moraines show evidence of periglacial activity in the form of ice-cracks and erected stones (Hannon, 1974).

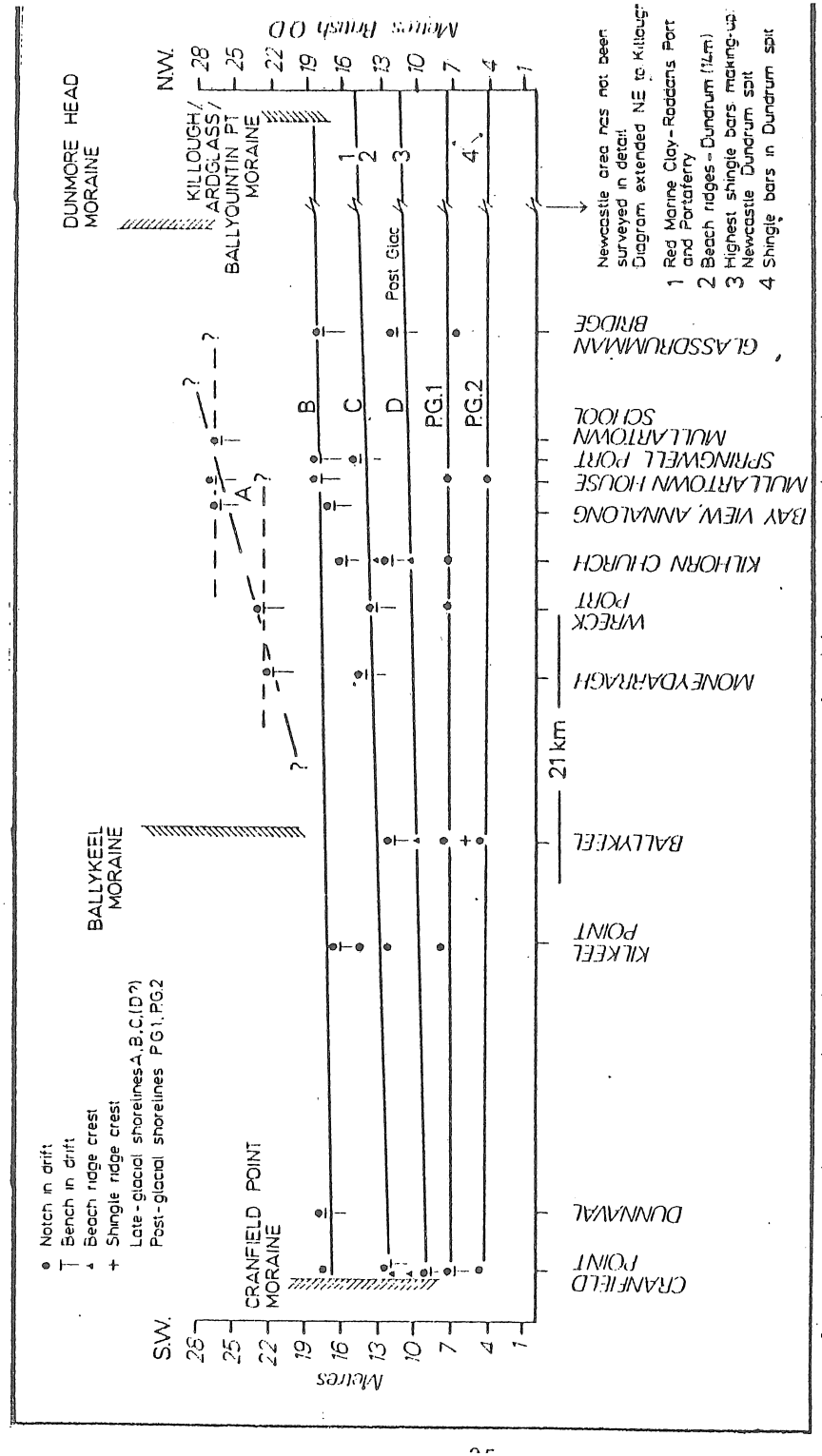

Fig. 8 The pattern of Late- and Post-glacial raised shorelines in S.E. Co Down.

E. THE DRUMLIN READVANCE

The withdrawal of the Late-Midlandian ice sheet in eastern Ireland involved the dissipation of large masses of ice in the northern Irish Sea Basin and in much of Ulster. This phase of ice retreat was generally to the north and north-west. (McCabe and Hoare, 1978). In Ulster this was followed by a widespread readvance of inland ice masses which is largely responsible for the deposition of a series of 'upper tills' involved in the construction of drumlins in lowland Co. Down (Vernon, 1966). In general the pattern of drift and ice limits indicate a westward shift in the main nodes of ice dispersion at this time.

The extent of the Drumlin Readvance ice has presented some difficulties of interpretation although it is clear that topographical constraints such as the Mourne - Carlingford massif disrupted the geographical continuity of the ice-front. Thus at least two distinct patterns of ice limits have been considered as the limiting Drumlin Readvance moraines associated with ice lobes to the east and west of the Mournes, in Carlingford lough and in Dundalk Bay.

Model A. Until recently it was believed that the Drumlin Readvance (Irish) ice extended eastwards across northern Co. Down and Belfast Lough, probably joining with ice in the North Channel; the ice also moved south-eastwards to a well-marked morainic line extending from Ballyquintin Point at the southern tip of the Ards Peninsula to Ardglass and Killough (Synge and Stephens 1966; Hill and Prior 1968). The ice probably reached Dundrum Bay, but Slieve Croob and its adjacent hill masses may have constituted a barrier, as no drumlins occur above about 160 m, or between these hills and Dundrum Bay. The ice margin appears to have looped around the hills north and west of the Mourne Mountains, while major meltwater streams carried water away towards Newcastle and Dundrum Bay from the ice-front near Castlewellan.

The ice-edge lay west of the Mourne Mountains, but at a distinctly lower level than the maximum altitude of the Main Late-midlandian ice against the mountains. It extended as a large lobe to the entrance of Carlingford Lough at the Cranfield Point and Ballagan Point moraines. A further lobe occurred to the south of the Carlingford massif in Dundalk Bay, with limiting moraines at Johnstown, Templetown and Rathcor on the northern side of the bay and at Dunany Point on the southern side (Figs. 3 and 4). Outside these various morainic limits a single late-glacial shoreline was originally mapped (Stephens 1963, 1968) and only post-glacial shorelines were observed inside Carlingford Lough and inside the Dunany Point-Johnstown moraines in Dundalk Bay. However, recent mapping has indicated that more than one late-glacial shoreline is present, the highest 'shoreline' (A in Fig. 8) perhaps being associated with a more widespread ice cover along the Mourne coast (Fig. 4). Therefore, if the age and significance of the Dunmore Head-Ballykeel ice limits are reconsidered this will necessarily alter the possible sequence of events during the withdrawal of Midlandian ice, and the subsequent Drumlin Readvance. While absolute dates are not yet available it is necessary to consider a possible alternative explanation of the moraine and shoreline sequences described above.

Model B. The Drumlin Readvance ice may have extended southeastwards across Dundrum Bay to Dunmore Head with a giant lobe moving east from Carlingford Lough to Ballykeel and south to Clogher Head (Fig. 4). At the southeastern end of the Carlingford Mountains the fluvio-glacial gravel complex in the Bush area of the Big River Valley may represent not the maximum extent of Midlandian ice but an inter-lobate accumulation between the ice lobes centred in Carlingford Lough and Dundalk Bay. The only ice-free coastal segments at the Drumlin Readvance stage would then have extended between Dunmore Head and Ballykeel (Co. Down) and south of Clogher Head (Co. Louth).

It is precisely in these areas that benches and notches in drift have been observed at about 26m. and 22m. (Fig. 8). The outwash extending south from the Dunmore Head moraine to Mullartown and Annalong leaves no doubt that this segment of coast was ice-free at this stage. The benches and notches could be marine-eroded features, and therefore related to the high shorelines south of Clogher Head but equally they could represent merely the innermost edge of a very gently sloping outwash terrace against an irregular drift topography.

There are insufficient sections to prove either case conclusively but careful examination of the pattern of the late-glacial raised beach features in east-central Ireland tends to favour Model B.

There can be little doubt that the late-glacial upper marine limit on the Co. Down coast is a metachronous feature, although often traceable as a synchronous feature over very short distances, as first tentatively suggested in 1966 (Stephens and Synge 1966). As the ice downwasted and withdrew in the North Channel and in southwestern Scotland, the sea transgressed the isostatically depressed area, forming a series of strandlines which were closely related to local, phased ice-margins positions (Stephens et al. 1975). It is difficult to prove that any of the sequences of shorelines in Ulster are synchronous because of their different geographic locations in relation to the various centres of ice dispersion, and because of possible variations in the rates of ice wastage (Stephens and McCabe, 1978).

F. DISCUSSION

This field guide indicates that many problems still remain in the Quaternary geomorphology of south-eastern Ulster. These include:

1. There is little positive evidence on which to base the time intervals between the lowland and mountain phases of glaciation.

2. What is the absolute age of the Irish Sea tills on the Mourne plain in the absence of sub- or inter-till organic beds?

3. Is the upper limit of Irish Sea till in the Ballymartin area related to Late-Midlandian ice from the Irish sea on to the Mourne plain or is it an older event, possibly of Early-Midlandian or Munsterian status?

4. It is likely that ice caps and piedmont glaciers developed in the area on more than one occasion. Therefore the pattern and limits of the earlier events, identified in section, are difficult to determine.

5. The precise location of the limiting moraines of the Drumlin Readvance are a matter of conjecture at present. However, the drumlin swarms begin a few hundred meters behind the Killough - Killard point moraine whereas in Co. Louth they begin 6-8km. back from the limiting moraine. Does this imply that the drumlin ice in east Co. Down extended out into the Irish Sea and was not in the vicinity of the present coastline?

6. Since no inter-drift organic deposits are known from this area it is possible that all the deposits so far described relate to the Late-Midlandian Cold Stage. Therefore superimposed units of varying provenance may simply relate either to a composite ice sheet or to the changing strengths of ice masses with inland and Irish Sea sources.

G. REFERENCES

American Commission on Stratigraphical Nomenclature — 1961 — Code of stratigraphic nomenclature. Bull. Am. Ass. Petroleum. Geol. 45, 645-665.

Charlesworth, J.K. — 1939 — Some observations on the glaciation of north-east Ireland. Proc. R. Ir. Acad., 45B, 255-295.

Charlesworth, J.K. — 1955 — The Carlingford Re-advance between Dundalk, Co. Louth, and Kingscourt and Lough Ramor, Co. Cavan. Ir. Nat. J., 11, 299-302.

Dwerryhouse, A.R. — 1923 — The glaciation of north-east Ireland. Q. Jl. Geol. Soc. Land., 79, 352-422.

Emeleus, C.H. and Preston, J. — 1969 — The Tertiary volcanic rocks of Ireland (ed. E.A. Francis). I.A.V.C.E.I. symposium, Oxford, 70pp.

Hannon, M.A. — 1974 — The Late-Pleistocene geomorphology of the Mourne Mountains and adjacent lowlands. Unpub. M.Sc. thesis, The Queen's University, Belfast. 458pp.

Hill, A.R. and Prior, D.B. — 1968 — Directions of ice movement in north-east Ireland. Proc. R. Ir. Acad., 66B, 71-84.

Hoare, P.G. — 1976 — Glacial meltwater channels in County Dublin. Proc. Roy. Ir. Acad., 76B, 173-185.

Kilroe, J.R. — 1888 — Directions of ice flow in the north of Ireland. Q. Jl. Geol. Soc. Lond., 44, 827-833.

McCabe, A.M. — 1973 — The glacial stratigraphy of eastern counties Meath and Louth. Proc. R. Ir. Acad., 73B, 355-382.

McCabe, A.M. (ed.) — 1979 — Field guide to east central Ireland. Quaternary Research Association Field Handbook, 63pp. Dublin, 1979.

McCabe, A.M. and Hoare, P.G. — 1978 — The Late Quaternary history of east central Ireland. Geol. Mag., 115, No. 6. 397-413.

Mitchell, G.F., Penny, L.F. Shotton, F.W. and West, R.G — 1973 — A correlation of Quaternary deposits in the British Isles. Geol. Soc. Lond. Special Report No. 4 1-99

Shepherd, I. 1970 Dundrum dunes. From-Geographical excursions from Belfast. Department of Geography, The Queen's University, Belfast p. 34-36.

Stephens, N. 1963 Late-glacial sea levels in northeast Ireland. Ir. Geogr., 4, 345-359.

Stephens, N. 1968 Late-glacial and post-glacial shorelines in Ireland and southwest Scotland. Means of correlation of Quaternary successions, 437-456.

Stephens, N., Creighton, J.R. and Hannon, M.A. 1975 The late-Pleistocene period in northeastern Ireland : an assessment. Ir. Geogr. 8, 1-23.

Stephens, N. and McCabe, A.M. 1977 Late Pleistocehe ice movements and patterns of Late- and Post-Glacial shorelines on the coast of Ulster, Ireland. In the Quaternary history of the Irish Sea (eds C. Kidson and M.J. Tooley). Seel House Press, Liverpool.

Synge, F.M. 1979 Quaternary Glaciation in Ireland. Quaternary Newsletter, No. 28, 1-18.

Synge, F.M. and Stephens, N. 1960 The Quaternary Period in Ireland : an assessment. Ir. Geogr., 4, 121-130.

Synge, F.M. and Stephens, N. 1966 Late- and post-glacial shorelines and ice limits in Argyll and north-east Ulster. Trans. Inst. Br. Geogr., 39, 101-125.

Vernon, P. 1966 Drumlins and Pleistocene ice flow over the Ards peninsula/Strangford lough area, County Down, Ireland. J. Glaciol. 6, 401-409.

Watmough, J. 1970 Murlough Nature Reserve. From-Geographical excursions from Belfast. Department of Geography, The Queen's University, Belfast. p. 36a-36b.

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