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FIELD GUIDE TO THE  
QUATERNARY OF THE  
ISLE OF MAN

Edited by R.V. Dackombe & G.S.P. Thomas

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Quaternary Research Association

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1985

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prepared to accompany the Annual Field Meeting held  
at Douglas, Isle of Man  
13 - 15 April 1985.

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**Cover illustration :** The Bride Moraine viewed from Slieau Lewaigue (SC 456923); the main ridge intersects the coast at Shellag Point and separates proglacial outwash and lacustrine deposits to the south from the undulating topography of the re-advance tills to the north. In the far distance the Point of Ayre lighthouse marks the northern extremity of the Ayres shingle foreland. (original sketch by R.V. Dackombe)

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# **QUATERNARY RESEARCH ASSOCIATION**

## **ANNUAL MEETING**

April 12th - 16th, 1985

### **FIELD GUIDE TO THE QUATERNARY OF THE ISLE OF MAN**

**EDITED AND COMPILED BY: R.V. Dackombe and G.S.P. Thomas**

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## **CONTENTS**

<b>Introduction.....</b>	<b>1</b>
--------------------------	----------

<b>Day 1: Local deposits and relationship to foreign.....</b>	<b>11</b>
---	-----------

Introduction	12
Site 1: The Bungalow	14
Site 2: The Verandah	15
Site 3: Guthrie Memorial	18
Site 4: Ballure	19
Ramsey to Glen Mooar	24
Site 5: Glen Mooar	26
Site 6: Ballaleigh	30
Site 7: Druidale	30
Site 8: Llergyrhenny	32

<b>Day 2: Foreign deposits - East coast.....</b>	<b>36</b>
--	-----------

Introduction	37
Site 9: The Dog Mills	40
Site 10: Kionlough	44
Site 11: Bride Moraine	47
Site 12: Shellag Point	49
Site 13: Ballavarkish	56
Site 14: Lough Cranstal	67
Site 15: Phurt	72
Site 16: Point of Ayre	80
Subsurface Succession	81

<b>Day 3: Foreign deposits - West coast.....</b>	<b>84</b>
--	-----------

Introduction	85
Site 17: Sulby Glen and Alluvial Fan	88
Site 18: Curragh and Ballaugh	88
Site 19: Killane	92
Site 20: Jurby Head	92
Site 21: Orrisdale	95
Site 22: Glen Trunk	105
Site 23: Glen Ballyre	107
Site 24: Glen Wyllin	110
Mineral Magnetism of Manx Tills	116

<b>References.....</b>	<b>118</b>
------------------------	------------

## INTRODUCTION

Situated astride successive ice advances from the major source areas of Pleistocene ice in western Scotland, the Isle of Man was regarded by the original Geological Survey worker G.W. Lamplugh as an "unrivalled field for the study of the conditions that ruled in the northern part of the basin of the Irish Sea during the Glacial Period" and "pre-eminently an area wherein the various theories by which the drift phenomena of the Irish Sea basin have been explained, may be put to the test". In terms of its strategic position, the extent and quality of exposure, the rich diversity of both organic and inorganic sediments and the multiplicity of landforms encompassed in such a small area, the island provides a fruitful field of investigation for Quaternary scientists. Indeed, another early pioneer of glacial studies, P.F. Kendall, regarded the deposits and landforms to be of such extraordinary and diverse character as to be unsurpassed in the United Kingdom.

### Geology and geomorphology

The Isle of Man is essentially a fault bounded ridge of slate trending NE/SW, parallel to the Caledonian structural trend, and culminating in Snaefell at 610 m. Most of the uplands of the island are underlain by Ordovician Manx Slate, but Carboniferous conglomerates, limestones and volcanics outcrop in the south around Castletown, and Lower Devonian red sandstones in the Peel area (Fig. 1). Large Devonian granitic plutons intrude through the slates in the east and south. Further Carboniferous, Permian and Triassic strata occur beneath the thick drift of the north of the island.

The uplands of the island (Fig. 2), which are divided into two blocks by the low central valley running between Douglas and Peel, are truncated abruptly in the north by a bold escarpment that runs westwards from Ramsey towards Kirk Michael. This escarpment overlooks a broadly triangular area of drift covering about a third of the island. The triangle is broken across its northern apex by the prominent ridge form of the Bride Moraine. This ridge, reaching up to 100 m above sea level, swings westwards and is cut by a sinuous drainage channel at The Lhen. To the west, towards Jurby and Kirk Michael, the ridge form is more subdued and extensive areas of ice-distintegration topography, including many deep kettle basins, occur. Between the Bride Moraine and the slate escarpment the ground is more subdued and comprises a series of terraces, diversified locally by small morainic mounds, sloping south. These terraces are partly buried towards the escarpment by large alluvial fans issuing from the mouths of northward-draining upland valleys. These fans are in turn buried across their outer fringes by an extensive area of lowland peat accumulation around the Curragh.

Towards the northern extremity of the island the rear of the Bride Moraine is truncated by a distinctive post-Pleistocene raised cliff line which is fronted by a complex of beach ridges, dunes and slacks towards the Point of Ayre. The raised cliff can also be traced at Ramsey.

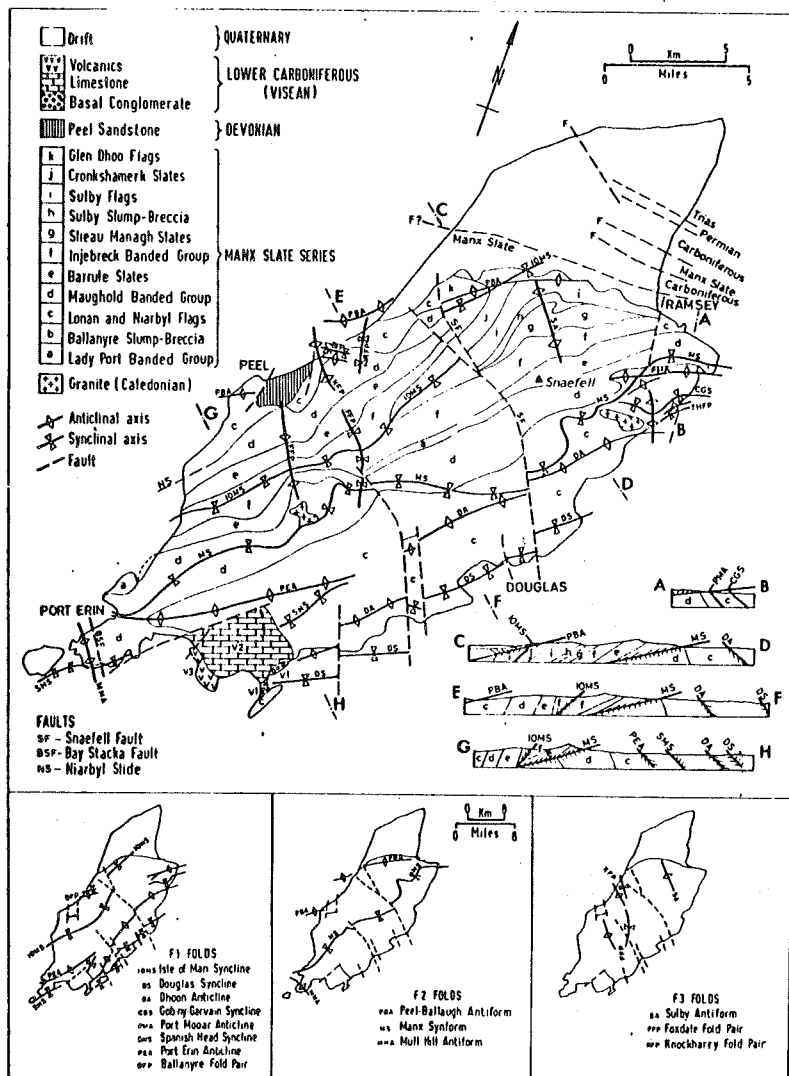


Fig. 1 The geology of the Isle of Man  
(from various sources).

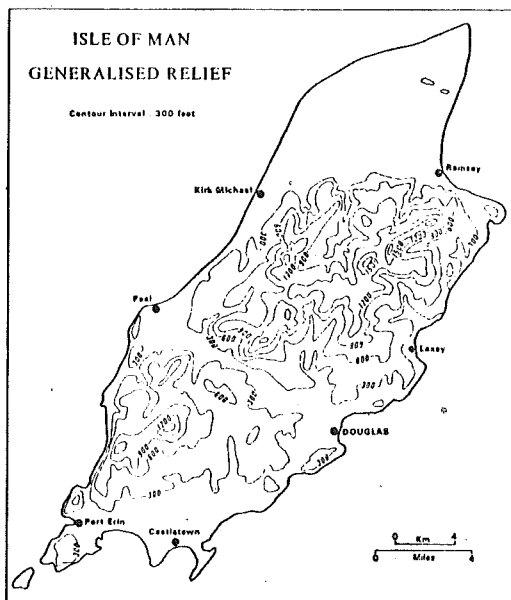
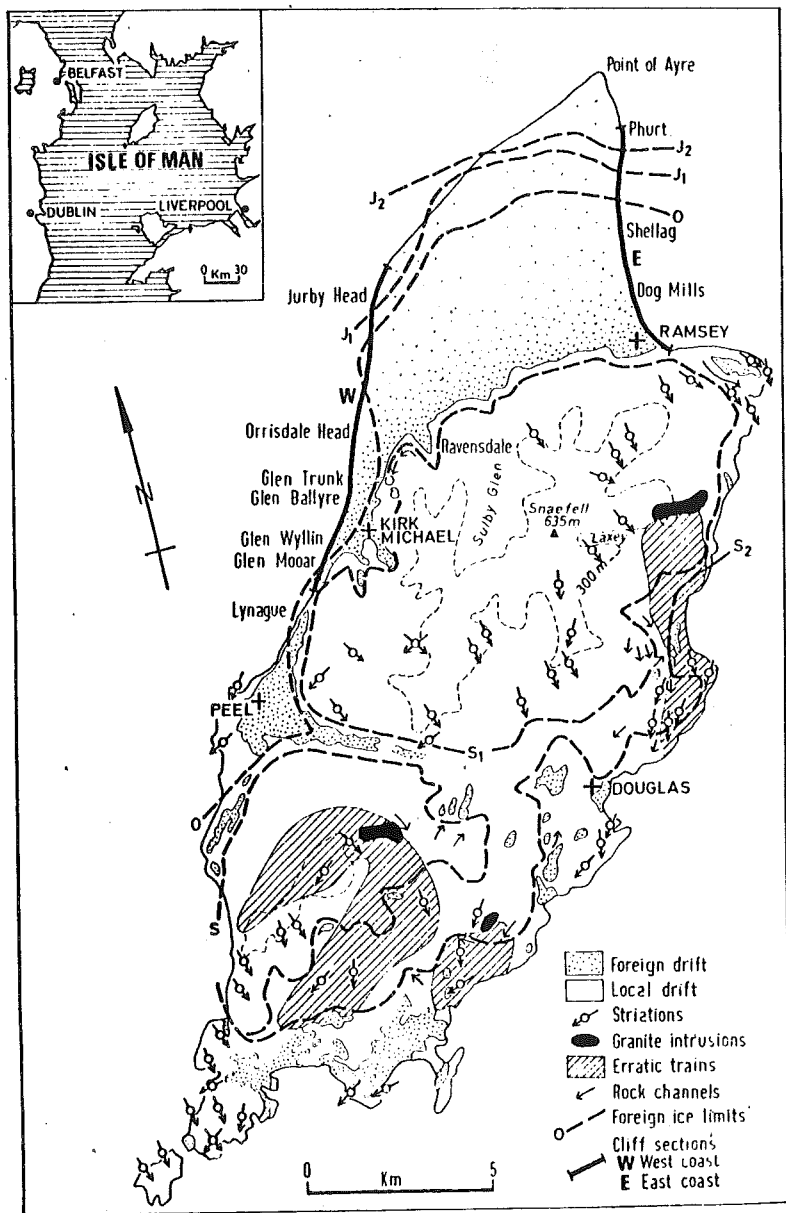


Fig. 2 Generalised relief of the Isle of Man.

### Quaternary deposits

Traditionally, the Quaternary deposits of the island have been divided into two great and mutually exclusive suites (Kendall 1894, Lamplugh 1903). A high-level suite (Fig. 3) of entirely insular origin is restricted to the area occupied by the Manx Slate and forms a relatively thin veneer across most of the upland surface, thickening to 10-15 m in valley bottoms. The low-level, or extra-insular suite is entirely composed of material foreign to the island and is most extensively developed in the northern area where it buries Permian, Carboniferous and Ordovician strata to depths of at least 125 m below O.D. (Lamplugh 1903, Smith 1930). The maximum thickness, including that above sea-level, is of the order of 250m and probably ranks as one of the thickest Pleistocene successions in Britain. The upper parts of this succession are exposed almost continuously in cliff section (Figs. 3) for some 20km around the northern area but thin southwards against the slate escarpment to intercalate with the insular suite around the island's rocky coast. The foreign deposits rarely extend higher than 60m onto the rock core of the island but locally reach 150m in the area of Kirk Michael.





**Fig. 3** Elements of the Quaternary geology of the Isle of Man  
(From Thomas 1977).

### Previous work

Most of our knowledge of the detail of the Manx Pleistocene succession derives from the works of Kendall(1894) and Lamplugh(1903). As convinced mono-glacialists, they regarded both drift suites as products of a glaciation "one and indivisible" (Kendall 1894, p.424) that swept across the island to its summit. Both workers explained the entire and somewhat enigmatic absence of foreign erratics in the insular suite by introducing the concept of a clean-ice shear across the island at heights in excess of 150m, the limit of foreign penetration.

Except for Erdtmann's(1925) pollen investigations of the kettle basins in the Kirk Michael area, little further work on the island was accomplished until Smith(1930) summarised the foreign drift succession from a series of boreholes drilled in an abortive search for coal in the northern area. This revealed a complex sequence of multiple boulder clays and sands and gravels including as Lamplugh(1903) had previously recorded, a supposed marine, shelly sand resting on a remarkably level rock platform at depths between 41 and 52m below OD. A little later, Slater(1931) published a detailed account of the cliff sections north of Shellag Point as part of his wider investigations into glacio-dynamic structures.

Wirtz(1953) included the Manx succession in his review of the Quaternary of Western Britain and Cubbon(1957) summarised the island data. Little further detail emerged, however, until Mitchell(1965) published his investigations into the succession exposed in the long cliff sections of the north-west of the Island. This provided the first stratigraphic division of the exposed succession and he correlated his two major till units with the Devensian and Walstonian glaciations. He also mapped in detail various stages of ice advance onto the slate core of the island and examined the rich organic sequences in the kettle holes of the area. Further work(Dickson et al 1970) refined the faunal investigations and yielded a series of Late Glacial  $^{14}\text{C}$  dates ranging between 12,210 and 10,250 yrs BP. The organic deposits from which these dates were derived were overlain by thick successions of alluvial fan gravels derived from the uplands. In Watson's(1971) view some of the enclosed depressions in the surface of the large Ballaugh alluvial fan were pingos rather than kettles, as Mitchell believed.

Thomas (1976 & 1977) remapped both the east and west coast sections of the northern area and provided a revised stratigraphic succession (Fig. 4, Table 1) that divided the foreign glacial deposits exposed above sea-level into three major formations. He considered that all three formations were of Devensian age and that they rested against a buried fossil cliff at Ballure of probable Ipswichian age. Investigation of the Coleopteran fauna of a kettle basin at Glen Ballyre by Coope and Joachim (unpublished) yielded  $^{14}\text{C}$  dates of 18,900 to 18,400 yrs BP (Shotton & Williams 1971 & 1973) and this led Thomas to suggest that as these deposits stratigraphically overlie the uppermost glacial formation, no ice could have passed south of the Isle of Man after this time. As Bowen(in Tooley 1977) has pointed out, however, these dates may be too old due to the

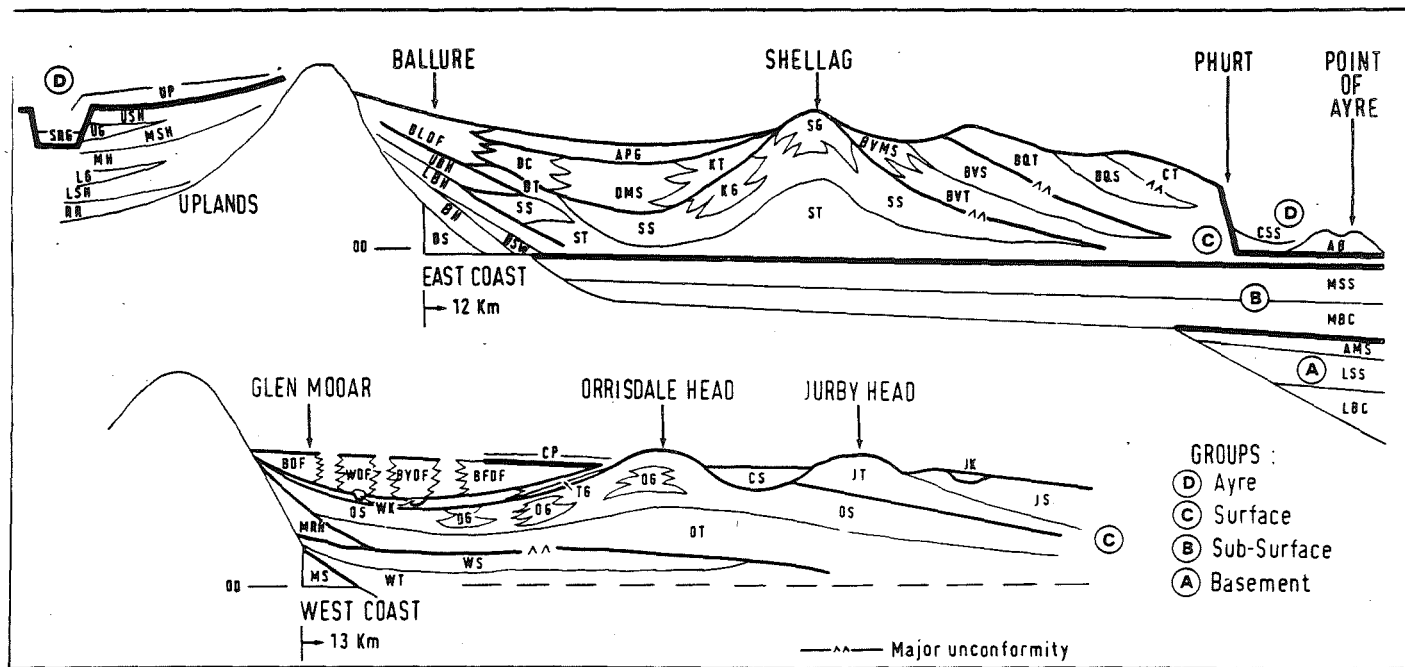


Fig. 4 Schematic representation of the Quaternary succession in the Isle of Man. For identification of members see Table 1 (from Thomas 1977).



incorporation of old carbon into the organic sediments at this site, which lies on a calcareous glaciogenic substrate. A further set of  $^{14}\text{C}$  dates from a kettle basin in a similar stratigraphic setting at Jurby has yielded younger dates in the range 15,150 to 12,250 yrs BP.

Thomas (1976 & 1977) also examined the high-level, insular suite of deposits and considered that they were heads, developed during the last glaciation when the upland area of the island protruded as a nunatak; a view shared, in part, by Wirtz(1953), Cubbon(1957) & Mitchell(1972). Evans and Athurton(1973), Bowen(1973 & 1978), Boulton et al(1977) and Boulton(1977), however, regard the suite as local till, deposited by Late Devensian ice at least 1.6 km thick over the Isle of Man, and subsequently much modified and reworked by slope processes.

Following the original interpretation by Slater(1931), Thomas(1984) re-examined the structure of the Bride Moraine and showed how its form, internal structure and stratigraphy result from a minor ice-marginal readvance during a late stage of the Devensian deglaciation. He also suggested that this readvance may have been prompted by a shift of the ice margin from a water-based to a land-based condition for immediately south of the moraine, at The Dog Mills, a series of laminated silts and clays have yielded a rich foraminiferal fauna(Wright 1902, Wright & Reade 1906, Thomas 1976 & 1977 and Thomas in Tooley 1977) tentatively interpreted as indicating a cold, estuarine-intertidal environment with a current-swept open-water component.

Recently, Eyles & Eyles(1984) have interpreted the whole of the exposed foreign glaciogenic succession in the Isle of Man as glaciomarine and regard both the fine-grained and coarse-grained diamict successions as having been formed by suspension rain-out, current reworking and density underflow adjacent to a grounded marine ice margin. Thomas & Dackombe(1985), however, have criticised this view and argue that none of the criteria used to support a subaqueous origin are diagnostic and can equally well be explained in terms of deposition at the base of a terrestrial ice-sheet. The thick and extensive outwash sediments of the west coast area, which Eyles & Eyles also regard as subaqueous, have been interpreted by Thomas et al(1985) as being deposited in a series of diachronous marginal sandur formed on an unstable, ice-cored supraglacial topography during a retreat stage of the Late Devensian.

Relatively little work has been undertaken on the Flandrian deposits of the island and the thick lowland peats of the Curragh, and the moorland peats of the uplands, are only poorly known. The extensive raised beach deposits of the north of the island, around Point of Ayre, have been examined by Ward(1970) and Phillips(1967), Mitchell(in Thomas, 1971) and Carter(in Tooley, 1977) have described the biogenic successions filling slack basins between beach ridges.

## Problems of the Manx Quaternary

A number of major problems of the Manx Quaternary succession remain unresolved. Foremost amongst them is the age and status of the local suite. Some regard these deposits as of wholly periglacial origin, formed by slope processes during the Devensian glaciation when a large part of the uplands of the island protruded as a nunatak through surrounding Irish Sea ice. Others, however, consider that the island was overtopped and buried by Late Devensian Irish Sea ice and that the local suite results from the reworking of locally derived tills by periglacial processes consequent upon retreat. A resolution of this issue is important for the nunatak view has considerable implication for Devensian events further south in the basin, especially in regard to condition and gradient of the ice sheet. That a glaciation of the uplands occurred at some time is substantiated by evidence from the south and east of the island, where local granitic erratics (Fig. 1) can be traced to heights of 483m, some 280m above the highest bed-rock source (Darwin 1848, Lamplugh 1903). There is no direct evidence of the age of this glaciation, however, and no unaltered till from it can be recognised anywhere in the upland area.

The second major problem in the Manx glacial succession concerns the origin of the foreign suite. Since the demise of the nineteenth-century Diluvialist school, almost all workers have accepted the view that the glacial sediments of the Isle of Man, as elsewhere in the Irish Sea basin, were deposited by land-ice. For a number of years, however, Thomas (1976, 1977 & 1985) has argued, cautiously, that at certain stages in the retreat of the Devensian ice-sheet, margin conditions may have been more complicated than hitherto believed. Thus in a recent review (Thomas 1985) it has been suggested that palaeontological evidence from The Dog Mills, and from offshore areas to the east of the Isle of Man (Pantin 1978), indicate that at approximately 15,000 yrs BP, when ice was retreating from the northern Irish Sea basin, the margin may have had a marine accompaniment in the form of both small ice-shelves and grounded margins. Using a sedimentological approach Eyles & Eyles (1984) have extended this concept and argue that the whole of the Manx glacial succession is marine or glaciomarine and, as such, acts as a key to the interpretation of Late Pleistocene stratigraphic sequences in British continental shelf areas. The implications of this concept are profound, not only in terms of its effect on traditional interpretations of the landforms and sediments of the Isle of Man, but also in its broader implications for the nature of lowland glaciation. The visit of the QRA is thus timely for it will allow us to examine the evidence at first hand. In particular, it might focus some discussion on the one significant, but hitherto missing ingredient of the radical shift from a land-based to a water-based glacial conception, which is the explanation of cause.

A third major problem concerns chronostratigraphy. With the exception of dates from organic sediment overlying the glacialigenic succession, which indicate that the Devensian ice-sheet had retreated to at least the position of the Bride Moraine by approximately 15,000 yrs BP, the island is devoid of other dateable horizons. The only major datum is provided by the fossil cliff at Ballure which has been assigned to the last, Ipswichian interglacial on the grounds that nowhere in the complex of cold-climate deposits that occur above it is there any evidence for a subsequent temperate interlude. There is no biogenic evidence to support this assignment however. The chronology of the thick sequence of glacialigenic sediments beneath sea-level in the north of the island, including the supposed marine sequence, is also unknown but probably relates to glaciations earlier than the Devensian.

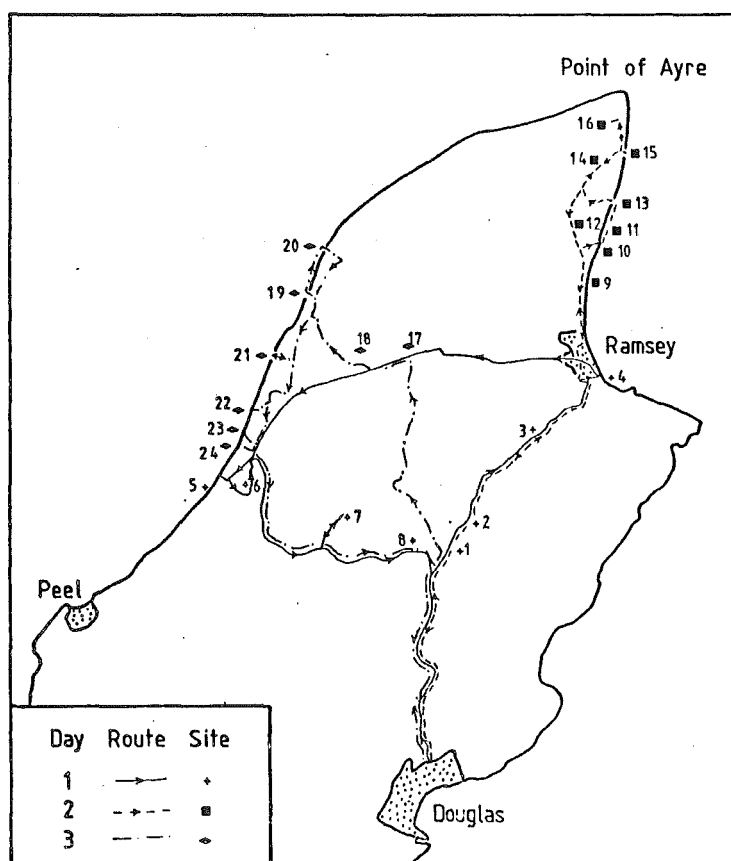


Fig. 5 Route map.

**Saturday April 12th -      Local deposits and relationship  
between local and foreign.**

**Route**

- Site 1:    The Bungalow - local drift, upland peats and soils.**
- Site 2:    The Verandah - valley asymmetry, solifluction  
terraces, slope form.**
- Site 3:    Guthrie Memorial - view across the northern drift  
plain.**
- Site 4:    Ballure - fossil rock cliff and cave, local scree  
and head deposits, alluvial fan gravels, relationship  
between local and foreign deposits.**
- Site 5:    Glen Mooar - possible interglacial beach, local  
scree and head deposits, Wyllin and Orrisdale tills,  
Orrisdale outwash deposits, relationship between local  
and foreign deposits, cryoturbated alluvial fan  
deposits.**
- Site 6:    Ballaleigh - rock-cut drainage channels.**
- Site 7:    Druidale - local deposits, valley asymmetry.**
- Site 8:    Lhergyrhenny - local deposits, solifluction terraces.**



## INTRODUCTION

The upland area of the Isle of Man is essentially a low penepplain between 250 and 350 m, above which rise two hill ridges that converge towards the SW. These ridges, comprising North Barrule, Snaefell and Beinn-y-Phott on the east, and Slieau Curn, Freoghane and Sartfell on the west, follow the outcrop of the resistant Barrule Slate as it plunges SW along the limbs of the Isle of Man Syncline (Simpson 1963). Within this frame other landforms can scarcely be divorced from the local drift deposits and the almost ubiquitous expression of Manx upland scenery is of gently rolling hills everywhere clothed with a smooth cover of drift that blankets all the minor lineaments of the underlying solid. As Kendall (1894, p. 408) put it "The deposits fill all the valleys and mantle the hills to such an extent that it is rare to find a bit of live rock peeping out, even on the highest hill".

The uplands contain no major, or even minor, erosional or constructional landforms and few rock features break the drift surface (Fig. 6). Lamplugh (1903) remarked on the absence of moraines and tarns and commented (p.45) that "indications of valley glaciers are conspicuously wanting in the island", a view shared by Kendall (1894). On the higher slopes and summits, especially around the flanks of North Barrule, the ground is diversified by rock outcrop, small aprons of scree, stone runs and small rubble fields, and on the flank of Slieau Dhoo a nivation hollow occurs fronted by distinct pro-talus ramparts (Cubbon 1957). Other incipient nivation hollows occur on the NE face of Snaefell. Downslope the drift thickens and merges at lower elevations into the smooth drift fill of valley heads. Modern streams have incised into this drift to create steep bluffs and gullies which in the central parts of valleys define the outer parts of smooth drift terraces. These are preferentially developed across slopes of particular facing directions, the most pronounced of which are almost exclusively in the sectors facing from northwest, through north, to northeast, producing a marked asymmetry in drift distribution.

On interfluvies and summits the local drift is a thin angular rubble with few fines. On lower slopes and terraces it is thicker, more compact and silty and displays much crude stratification parallel to slope. Clasts are usually angular to edge-rounded, occasionally lightly striated and the fabric is everywhere orientated downslope throughout the vertical sequence. Composition is entirely local and despite much search by many workers no foreign erratics have been found in the upland areas. On the more extensive terrace slopes, a number of distinct sedimentary types can be distinguished and some sections show a crude stratigraphy with alternation between thicker sequences of crudely bedded, sometimes massive stony clay, or head, and thinner units of sorted, sometimes open-work gravel. The contact between the drift and the underlying bedrock is gradational and is often marked by a distinctive layer of rock rubble. Polished or striated rock surfaces underlying the drift have not been observed though Lamplugh mapped a series of striations on high-altitude exposed surfaces showing an overall trend from north or north-west.

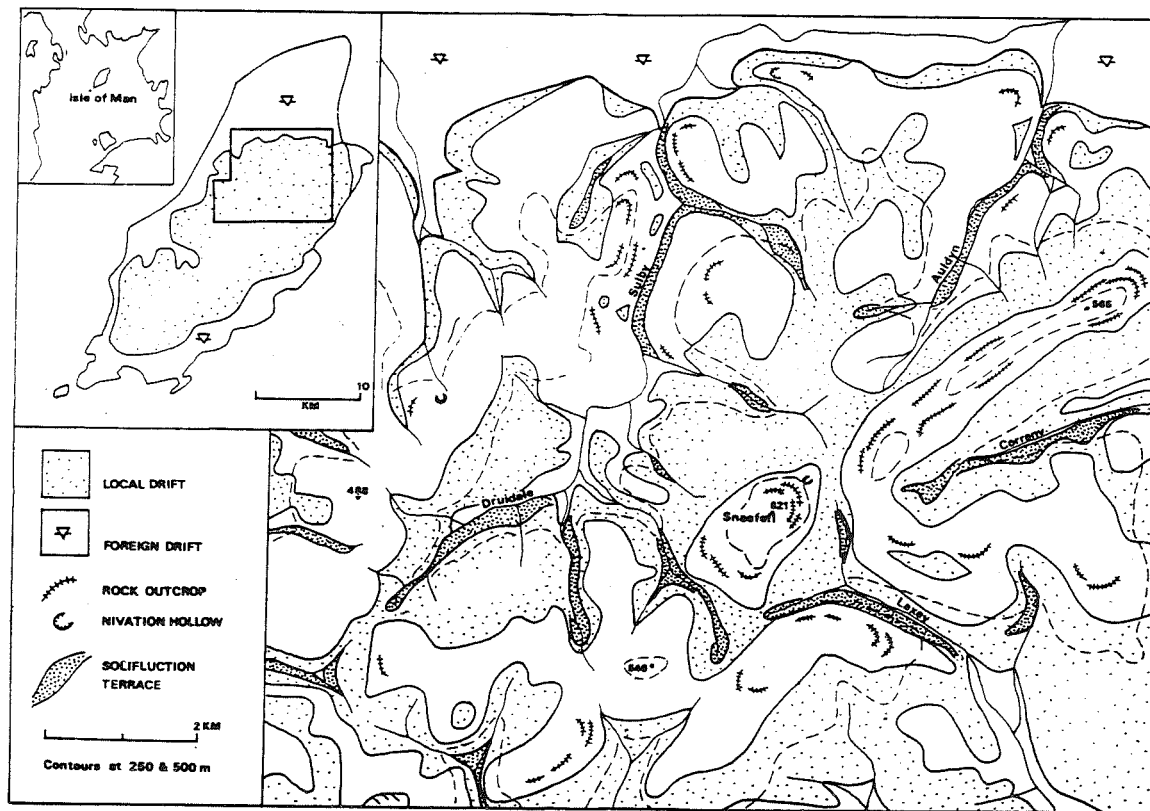


Fig. 6 The drift deposits and landforms of the northern uplands of the Isle of Man.

Although largely restricted to the upland area, the local drift is also seen overlying the Manx Slate on the east and west coastal margins of the island, and in some cases descends to beneath sea-level. On the east coast, from Ramsey southwards, the foreign drift rarely extends higher than 20 m above OD though single, or small groups of foreign erratics reach 75 m. South of the outcrop of the Dhoon Granite (Fig. 3) large local granitic erratics occur in a southward train and some occur at heights in excess of the source. On the west coast foreign drift is banked against the Manx Slate to a much greater height and a series of irregular mounds of foreign sands and gravels sweep up the slate escarpment to heights of 180 m (Lamplugh 1903) in the Kirk Michael area. Foreign drift also penetrates a little way into the mouths of valleys draining north from the uplands, especially in Glen Dhoo.

During the day we shall examine the soils, landforms and deposits at a number of sites in the northern upland massif (Fig. 5), and two major low altitude sites on the NE and NW coastal margins of the island that show the relationship between the local and foreign drift sheets.

#### THE BUNGALOW (SC 397868, Site 1, GSPT & BK)

To the east of the Bungalow, where the Manx Electric Railway crosses the TT course, exposures in a headwater stream of the Laxey valley show typical sections in both the local deposits and the soils derived from them. At this location the stream has entrenched a narrow gully through a shallow basin of drift and 1.5 m of peat occurs beneath the surface. In the upper part the peat is brown, loose and fibrous and contains many roots, stems and seeds. Below it becomes increasingly silty, grey and banded and contains thin lenses of angular gravel. The peat overlies 35 cm of fine angular gravel, displaying weak cryoturbation structures, and is underlain by 1.5 m of dull brown, becoming grey-blue, well stratified head packed with angular slaty particles showing a pronounced down-slope parallelism in long-axis orientation. Sections further down the gully show this head to be underlain by thin, edge-rounded slaty gravel, thin alternations of head and gravel, and further blue-grey head. The latter passes down gradually into 1.6m of coarse, angular rock rubble, with little fines, showing an intimate relationship to structural planes in the underlying bedrock. The character of the local deposits varies widely from section to section but all display a pronounced off-slope dip and fabric. A number of sections indicate that the otherwise smooth blanket of drift obscures considerable local irregularity in the bed rock surface.

Acid peats, derived from the remains of *Sphagnum* sp, cotton sedge grass (*Eriophorum vaginatum*) and ling (*Calluna vulgaris*) provide very impoverished organic soils over wide areas of the uplands. These reach over 4 m in thickness and an extensive area occurs across the slopes of Mullagh Ouyr, and on the west and north facing slopes of Snaefell. Seepage lines issuing from the edges of the peat blanket extend for considerable distances down hill sides and they can usually be picked out as "flush lines" by the dense cover of soft rush (*Juncus effusus*) adjacent to the free-draining soils under bracken or heather. Peat cutting and

burning has accelerated erosion in these areas to produce a complex pattern of shallow flats and exposed raw mineral soils.

On very steep slopes soil profile development is largely inhibited and topsoils are shallow. Soil creep produces terraces on unstable slopes and soils are dominated by humic and podzolic rankers. On interfluvial areas impeded drainage has created surface wetness problems and soils are classified as stagnogleys or humic stagnogleys, according to the proportion of organic matter. Weathering processes release iron from the slate fragments and the reddish brown colours contrast with the pale greenish grey of the gleyed soil matrix. Where slope angle increases, and especially on convex upper slopes such as those overlooking the Laxey valley, drainage improves and communities of bell heather (*Erica cinerea*) and *Calluna* indicate a change in soil conditions. Topsoil acidities of pH 3.2 - 3.8 are not uncommon and the mobilisation of iron and aluminium by polyphenols has created thin iron pans in typical ferric stagnopodzols. Cemented and convoluted iron pans, seldom more than a few mm thick, occur at varying depths. This prevents the downward movement of surface drainage water so that seasonal perched water tables create anaerobic conditions above the iron pan. The development of iron pans is attributed to the clearance of the original deciduous forest cover and the degradation of forest soils by repeated burning and grazing with subsequent colonization by heather communities. On slopes of more than 12 degrees there is a range of soils from shallow rankers to fully developed brown podzols. The latter are easily recognised by their intense yellowish red, friable subsoils enriched in sesquioxides (iron and aluminium) by weathering. They lack the pale coloured bleached subsurface horizons and the cemented B horizons of podzols.

#### THE VERANDAH (SC 405878, Site 2, GSPT & RVD)

As the mountain road skirts the eastern flank of the Snaefell ridge the view to the right looks down the head of the Laxey Valley (Fig. 7). In some respects this valley is typical of many in the uplands for it displays a distinct asymmetry in drift distribution. In other respects it is not for it exhibits an uncharacteristic U-shaped cross-section. Drift distribution and slope form are intimately related and three principal elements can be identified, though there is much gradation between them. The lowest, or deposit slope element, takes the form of a smooth terrace generally sloping between 6 and 10 degrees (Fig. 8). This is fronted by a steep bluff resulting from post-glacial stream incision and is often backed by a sharp break of slope. The terrace is underlain by up to 10m of compact, clay-rich local deposit similar to that seen at the Bungalow. The terraces are preferentially developed on one or other side of the valley and this leads to a pronounced asymmetry, as here in Laxey, with the majority of terraces facing directions in the sector from west to north-east, through north (Fig. 9).

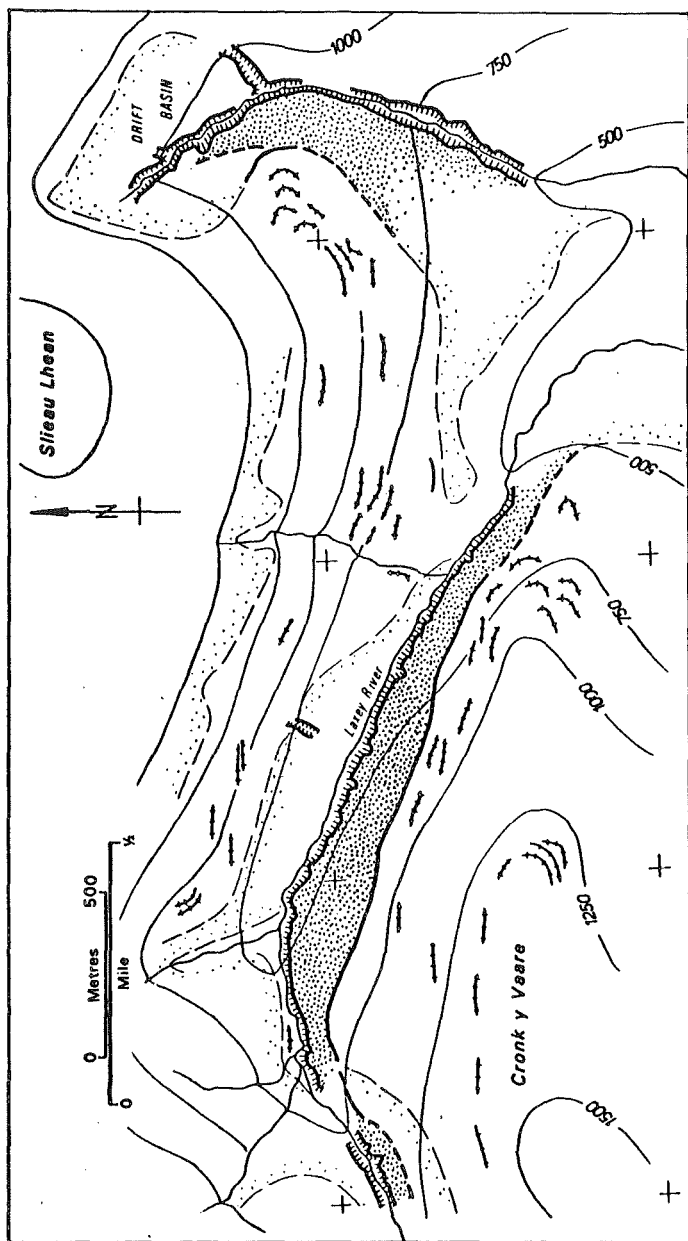


Fig. 7 Drift distribution in the Laxey valley.

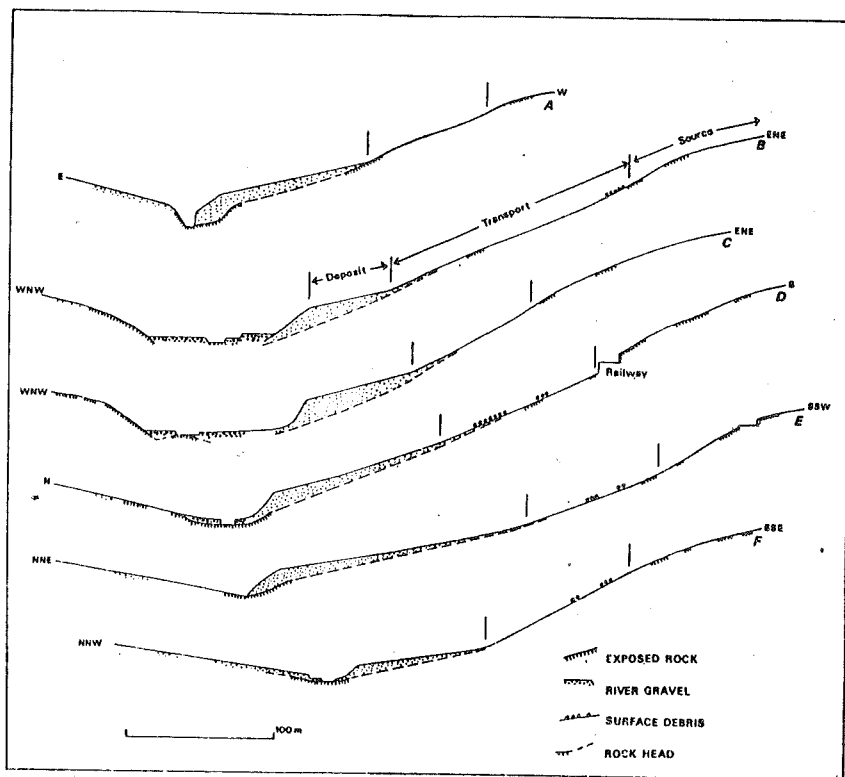
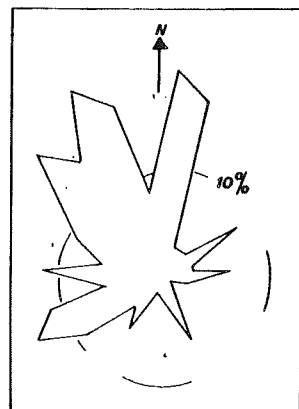


Fig. 8 Characteristic slope and terrace profiles from the upland valleys.

Fig. 9 Facing direction of terrace fragments, weighted by terrace length.



Above the terrace is a generally rectilinear transport slope at between 12 and 15 degrees. This element is locally diversified by shallow gullies, small debris fans and a litter of surface debris, and is underlain by 1-2 m of coarse rock-rubble, usually openwork. Clasts are angular and platy and are frequently imbricated. The junction with the underlying solid is usually sharp, giving a planed appearance to the bedrock. The third element occupies extensive areas on the flanks of North Barrule and Snaefell and is identified as the source slope. It forms the steepest portions of the upland slopes, usually greater than 15 degrees, and merges below into the transport slope and above into the convexity of summits and interfluves. It is within this element that almost all the exposed solid is seen and surface relief is thus much diversified at the small-scale. Between rock outcrops the surface is obscured by an irregular cover of loose, incoherent rubble, less than 30 cm thick, with a disorganised fabric and a strong relationship to cleavage planes in the underlying solid.

These three slope elements, though characteristic of much of the uplands, frequently grade one into the other. This can be seen as we drive north around the flank of Snaefell, where some incipient nivation hollows occur, and along the north side of the North Barrule ridge.

Refraction seismic surveys in the Laxey valley show that the drift is fairly thin, often less than 5m even on the depositional slope element. It is extremely variable in character and covers an uneven topography. Nowhere in the three areas surveyed in detail is it possible to define a clear seismic stratigraphy. Weathered surface material of low velocity (0.4-1.0m/msec) overlies Manx Slate with a velocity of between 2.5 and 4.5m/msec. Both units show large local variations in the velocity which are probably due to the heterogeneous nature of the local bedrock. The thicker, more psammitic units of the Lonan Flags yield large resistant boulders which cause local high velocities in the weathered mantle while the more pelitic units are prone to deep in-situ weathering. There is no evidence to suggest the presence of a clean, glacially scoured bedrock surface which might be expected beneath the drift terraces in such a U-shaped valley.

#### GUTHRIES MEMORIAL (SC 435915, Site 3, GSPT)

At this location the view to the north (weather permitting) provides an excellent sketch of the topography of the northern drift plain. From our vantage point on a peneplain surface above the bold Manx Slate escarpment, a distinct fossil cliff line can be traced through the northern outskirts of Ramsey, the inner town-site of which is largely built on Flandrian raised beach shingle. Beyond, and to the west, lies a large area of relatively flat sandur surface broken occasionally by subdued morainic ridges. In the middle distance lies the tumultuous ridge form of the Bride Moraine, running west from Shellag Point where it is truncated by the east coast, towards Jurby. About half way along its length the moraine ridge is breached by a wide melt-water channel draining southwards at The Lhen. Beyond the moraine the

Flandrian beach ridges at Point of Ayre, the northernmost extremity of the island, are clearly marked by the lighthouse standing guard over them.

In clear conditions the granite crests of Cairnsmore of Fleet and Criffel in the Southern Uplands are visible, as is the Lake District massif to the east. The Solway Lowland lies to the NE and the North Channel, distinguished by the low, sloping outline of the Mull of Galloway, to the NW. From this vantage point it takes little imagination to visualise the environmental conditions that pertained here during the withdrawal of the Late Devensian ice sheet through the northern part of the Irish Sea basin, though there may be some dispute as to where the sea was then.

#### **BALLURE (SC 459934, Site 4, GSPT & GH)**

On the east coast of the island the northern drift plain terminates immediately south of Ramsey, at Ballure. At this location the foreign drift is banked against, and interdigitates with, the local drift. Both drift suites, in turn, are banked against a buried cliff cut in the Manx Slate at the point where the slate escarpment cuts the coast. The section has been figured previously by Cumming (1846), Horne (1874), Kendall (1894) and Lamplugh (1903) (Fig. 10) and a section drawn in 1970 is shown in Fig. 11. Table 1 lists the main stratigraphic divisions. The rock cliff forms a vertical face passing beneath beach level and is fronted by a small sea-stack. A seismic line shot across the foreshore suggests that the cliff terminates in a narrow rock platform at about -3 m OD. Excavations in the floor of the small cave between the main cliff and the inner face of the sea-stack hit bedrock a metre below the floor but no beach material was revealed.

The cliff and sea-stack are buried by an apron of scree which is broadly divisible into two units. In the lower part it consists of a very angular rock rubble with blocks up to 2 m; whilst in the upper it is locally more stratified, less coarse and shows impersistent development of lenses of graded sand and fine gravel. It also contains occasional small rounded foreign erratics and streaks of red clay.

Away from the cliff the scree passes beneath beach level and is overlain by thin bands of laminated silty wash. This is succeeded by 4.80 m of stratified Brown Head, crowded with angular slate fragments. It is conformable with the scree and dips off the rock slope to the rear at some 15 degrees. Further thin bands of silty wash divide the unit and it is overlain by a distinctive sequence of laminated clays and sands containing occasional small clasts of both local and foreign provenance. Conformable with this is 4.50 m of compact Lower Blue Head, also dipping off the rock slope at angles between 7 and 10 degrees. This deposit is coarser than the Brown Head below and contains angular clasts up to 65 cm.



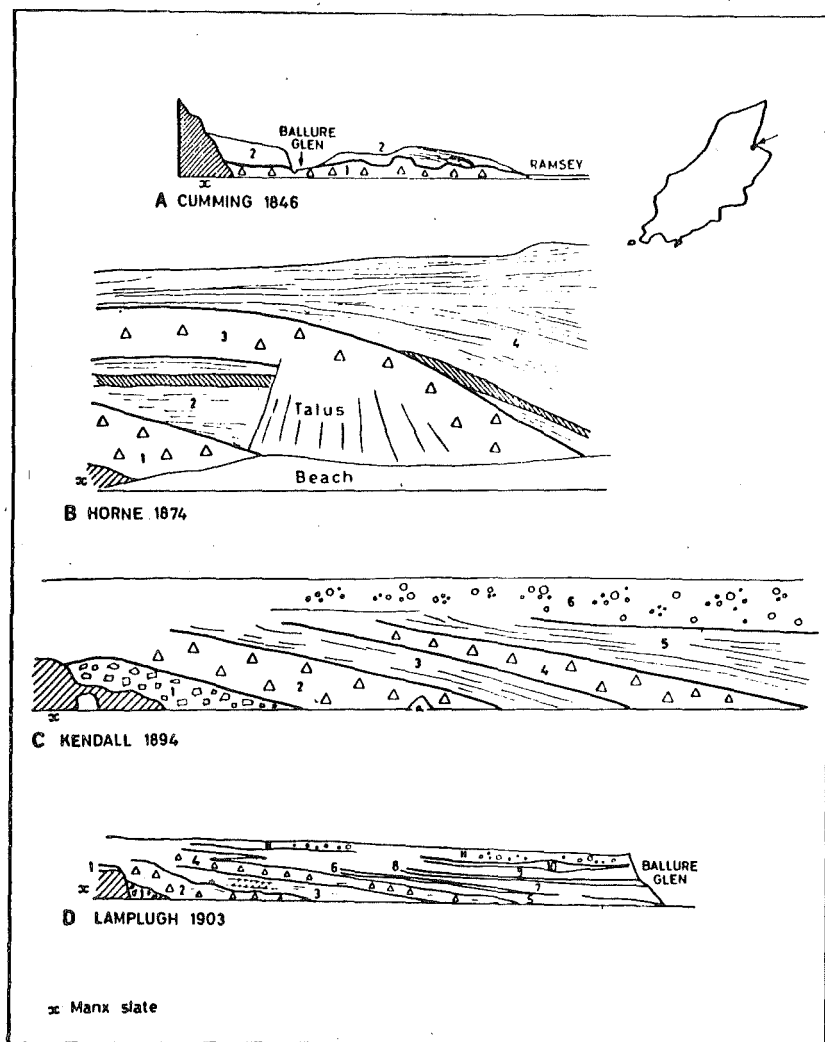


Fig. 10

The stratigraphy of the Ballure section according to;  
 A: Cumming(1846); B:Horne (1874); Kendall(1894) and  
 Lamplugh(1903).

The Lower Blue Head is succeeded very abruptly by up to 6 m of partially contorted foreign sands and gravels thickening rapidly to the north. No till is seen directly associated with these deposits but Kendall (1894) noted "a boss of clay", containing shell fragments and foreign boulders, between them and the underlying head. The sands are abruptly overlain by an Upper Blue Head, banked off the rearward rock slope and thickening rapidly down the dip. This deposit differs from those below in showing a higher proportion of silt-clay matrix, a wider size-range in the coarse fraction and a less pronounced pseudo-stratification. It is succeeded by the Ballure Till, a yellow-brown, sandy deposit containing mostly local slate, but up to 25% foreign erratics. On the foreshore this till is overlain by, and partially intruded into Shellag Till, which can be traced discontinuously on the foreshore both north and south of Ballure.

From this point upwards in the succession the sequence becomes repetitive and large thicknesses of well-washed local slaty gravel, and subordinate sands and silts, intercalate with massive sheets of red, virtually stoneless clay and red sand. These thicken rapidly northwards such that the northern half of the section is made up entirely of them, with the predominantly local deposits against which they are banked having dipped beneath beach-level. Fabrics from the local deposits in the lower half of the section show derivation from the degraded rock slope to the rear (Fig. 12). The Shellag Till, in contrast, shows ice movement from the north and the Ballure Till from the north-west. Fabrics from the local gravels in the upper parts of the section show transport towards the NE, away from the mouth of Ballure Glen.

A series of boreholes sunk to investigate the instability of the drift cliff of the Ballure section revealed that the Manx Slates are deeper than -2.3m AOD in the area of Ballure Walk and deeper than -4.0m AOD on the beach immediately at the base of the cliff. The rock-head then rises rapidly and appears at 0.6m to 4.3m beneath the Douglas to Laxey road (40.1m to 57.1m AOD). The scree above the rock was located beneath the Ballure Walk area at 0.2m and -2.1m AOD, but beneath the road it is absent or very thin. The Brown Head, slope wash, Lower Blue Head, foreign sands and gravels, Upper Blue Head and Ballure Till were all located in boreholes in Ballure Walk. These appear to thin out onto the rock to the south and west with the dips decreasing up the sequence. Along the line of the Manx Electric Railway the Upper and Lower Blue Heads and possibly the Brown Head appear to be combined and gravel and sand layers are absent. Along the line of the Douglas to Laxey road the heads rest directly on the Manx Slate and layers of sand and gravel and red clays are absent. The uppermost sequence of layered red clays and sands occur in the area of Ballure Walk and along the Manx Electric Railway but are generally absent along the road. The highest level attained by the red clays was in a borehole adjacent to the MER. The highest level of shelly drift with a substantial foreign gravel component was at 58.2m in a borehole near the entrance to Carmel Mount Holiday Cottages (SC462933).

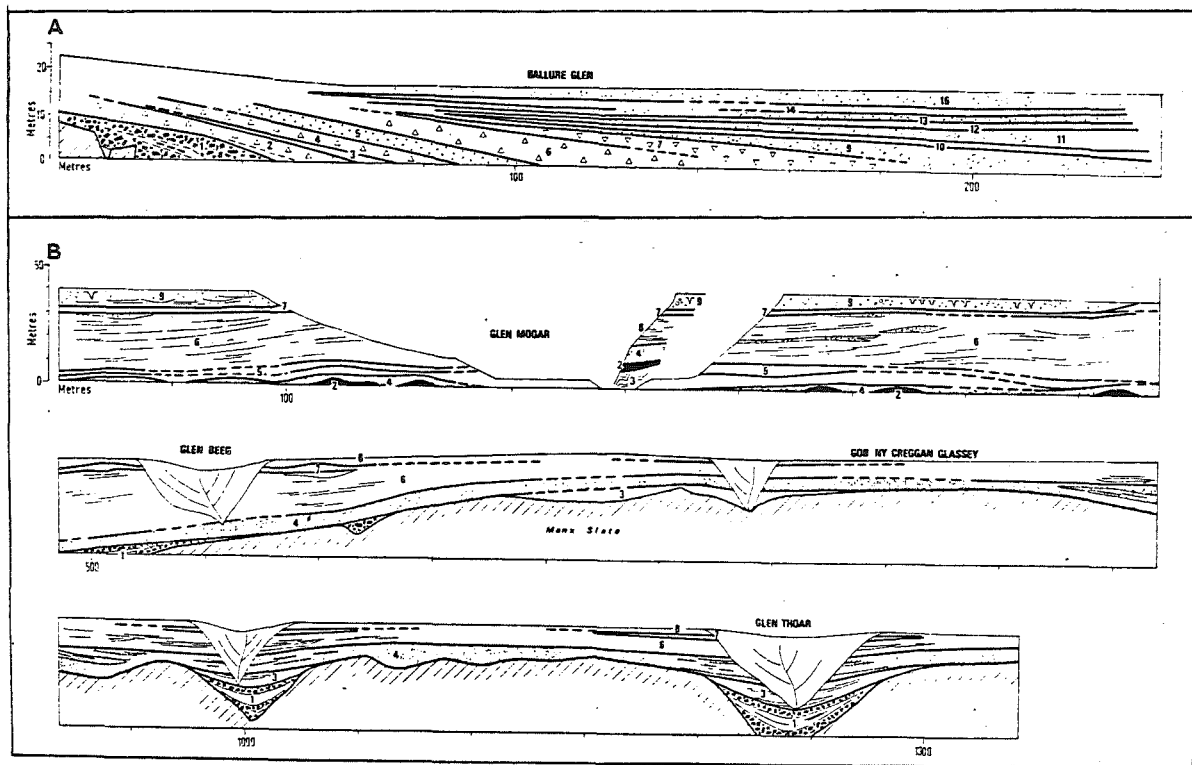


Fig. 11 The stratigraphy at Ballure and between Glen Mooar and Gob-ny-Creggan-Glassey; for notation see Table 1. (from Thomas 1977).

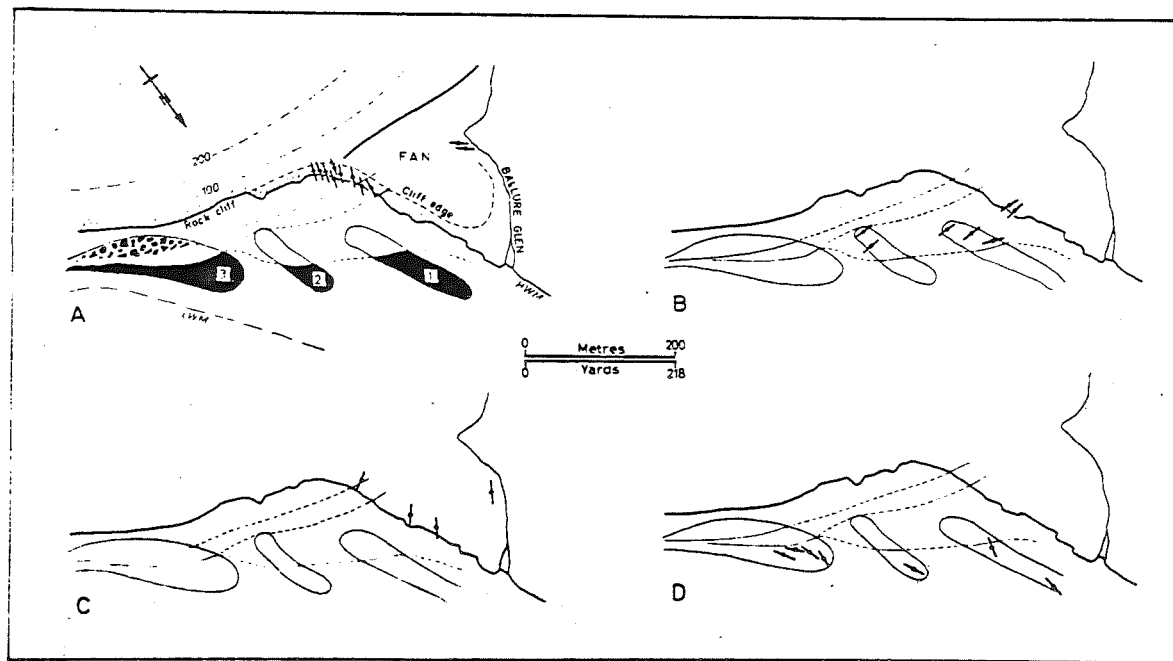


Fig. 12 Fabric patterns from the Ballure section:  
 A: Local deposits; B: Ballure Till;  
 C: Alluvial Fan gravels; D: Irish Sea Till.

A number of problems arise at Ballure. The first concerns the status of the buried cliff. This evidence of a former high sea-level at a level only a little lower than the present is probably best referred to the last (Ipswichian) interglacial, for nowhere in the complex of cold climate deposits seen above it is there any evidence of a substantive climatic break. The view of Mitchell (1972) that a leached horizon in the upper part of the Upper Blue Head represents Ipswichian weathering cannot be substantiated. No progressive decalcification is observed for the deposit is local and almost carbonate free.

The second problem concerns the status of the local deposits and their relationship to the foreign. Save for the inclusion of a small proportion of foreign erratics, the Brown, Lower Blue and Upper Blue Heads are identical to the insular drift, and their slope derived origin is confirmed by their off-slope fabric and bedding dip. The Brown and Lower Blue Heads underlie the foreign deposits of the Shellag Formation and indicate that periglacial conditions existed on the island prior to the first extensive penetration of the Devensian Irish Sea ice. As they directly overlie the buried cliff and its apron of scree, they probably represent early and mid Devensian time. Following foreign ice advance, further slope deposition took place though it is possible that the Upper Blue Head, which is more massive and clayey, represents reworked local till. This episode was followed by further ice penetration and the Ballure Till appears to represent some marginal till facies of mixed local and foreign provenance derived by oblique passage against the slate massif. An episode of local alluvial fan sedimentation then occurred, though this must have been penecontemporaneous with foreign ice activity for these deposits are intercalated with foreign red clays that can be traced, via boreholes in Ramsey Harbour, into The Dog Mills Member to the north.

#### **RAMSEY TO GLEN MOOAR (GSPT, RVD & GH)**

The drive from Ramsey to Glen Mooar passes along the foot of the great fault scarp that marks the northern termination of the exposed Manx Slate. The scarp is broken in places by valleys descending from the uplands to the south and large alluvial fans have been built at their exits out across the drift plain.

The first of these fans is seen issuing from the mouth of Glen Auldyn on the outskirts of Ramsey. Sections in the fans are rare but boreholes show that they are made up of predominantly locally derived material and that the diamicts beneath them are deeply channelled. A borehole at Ramsey Grammar school shows a mixed sequence consisting of both local and foreign material in a sequence of muds and fine gravels capped by local muddy gravels with occasional detrital organic material.

At Sulby Bridge we cross the Sulby River which currently flows along the south-east side of the well defined Sulby alluvial fan. The fan is clearly outlined by the 15m contour which is pushed northwards into the Curragh basin by about 1 km. Again sections are rare but a borehole at Sulby Chapel (SC 381945) shows an exclusively locally derived suite of alluvial sediments (Fig. 13).

From Sulby we skirt the southern margin of an extensive peat basin at the Curragh and towards Ballaugh we pass the apex of the largest of the alluvial fans, that issuing from the mouth of Glen Dhoo. To the west, towards Kirk Michael, the scarp loses its distinction and the topography becomes more varied. A major moraine ridge, truncated by the western edge of the Ballaugh fan, is seen to the NW at Orrisdale, and between it and the road a complex area of ice-stagnation topography steals up against the edge of the Manx uplands. A number of shallow kettle basins occur on the right of the road and the view to the left, towards the uplands, shows a line of mounds marking the maximum limit of foreign ice penetration into this area. Passing through Kirk Michael, along the crest of a low ridge, we descend into Glen Wyllin, a narrow gorge cut through the foreign drift. On the far side we rise across a series of morainic mounds to pass across a narrow alluvial fan draining from Glen Mooar, to meet the Manx Slate again at the coast.

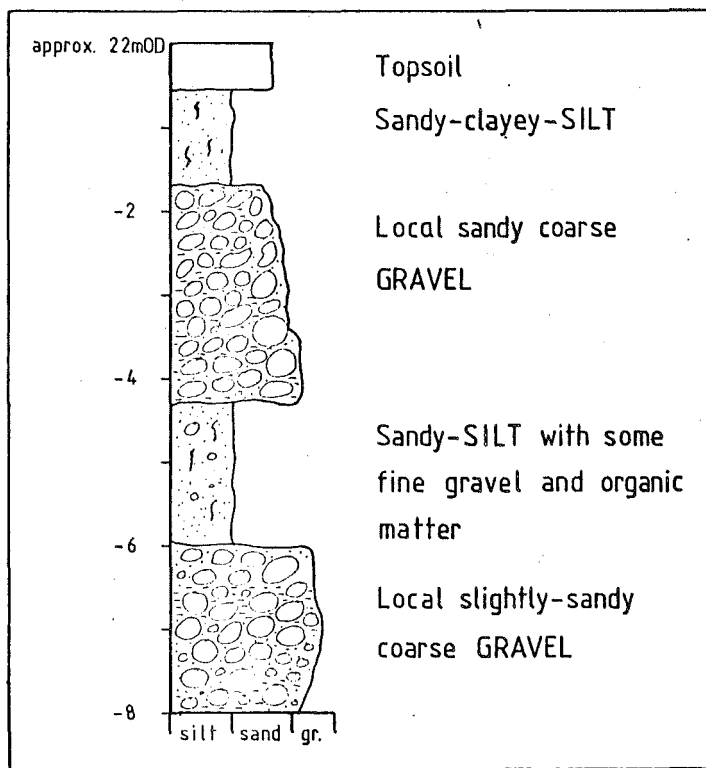


Fig. 13 The sequence in the Sulby borehole.

**GLEN MOOAR (SC 305895, Site 5, GSPT)**

On the west coast of the island the foreign deposits of the northern drift plain thin against and rise up onto the Manx Slate at and south of Glen Mooar (Fig. 14). Sections here have been described or figured by Horne(1874), Kendall(1894), Lamplugh(1903), Mitchell(1965) and Thomas(1977). In this area two major foreign glacial formations concern us. The lowest, the Shellag Formation, consists of two members; the Wyllin Till - a stiff red clay with few stones, and the Wyllin Sand. Both these members are disturbed and are separated by a major "unconformability"(Lamplugh 1903) from the succeeding Orrisdale Formation. This consists of three members; the Orrisdale Till - a sandy, stony diamict, and Orrisdale Sand and Gravel.

In the south wall of Glen Mooar a thick sheet of blue-grey local deposit, crowded with angular slate clasts and rare foreign erratics, dips off the rock slope to the rear of the site (Fig. 15a). This rests unconformably upon deformed Wyllin Till and Sand and is succeeded by thick sands of the Orrisdale Sand Member. These foreign outwash deposits, which display palaeocurrent indicators showing flow to the SW, are overlain by a thick sheet of heavily cryoturbated local slaty gravel forming part of a large surface alluvial fan, the Ballaleigh Debris Fan(Mitchell 1965).

At the coast, exposure both to north and south shows a similar succession (Fig. 11), though thin Orrisdale Till overlies the local deposit. Passing south from the entrance to the glen towards Glen Beeg the Manx Slate rises from beneath the beach and the drift succession thins against it. No distinct fossil cliff is displayed here, as at Ballure, but the rock passes gradually upwards into angular, coarse scree. The slate at this point dips seaward and large slip blocks occur locally within the scree. During December 1984 a large slip block was observed (RVD & GH) overlying a coarse, rounded gravel containing both local and foreign clasts, and possibly indicative of a former beach horizon. The scree is overlain in its lower parts by Wyllin Till and Sand and then by a thick succession of local slate rubble.

Towards the headland of Gob-ny-Creggan Glassey, to the south of Glen Beeg, the slate rises high in the cliff and thick successions of local deposits are draped directly across the rock surface. At this point the deposits are intercalated with thin units of washed material. To the south, towards Glen Thoar, deep rock gullies descend beneath beach level and are plugged with thick scree. This passes upwards into local gravel and then into foreign yellow sands, succeeded by thick successions of local slaty rubble and further foreign outwash.

A critical question at this location is the status of the local deposit. Mitchell(1965) referred to it as the "Mooar Boulder Clay" but fabric investigations (Fig. 16) indicate that deposit forms an apron, or fan banked off the solid and suggests that it is either a slope deposit or a soliflucted local till laid down after the major ice advance responsible for the deposition of the Wyllin Till.

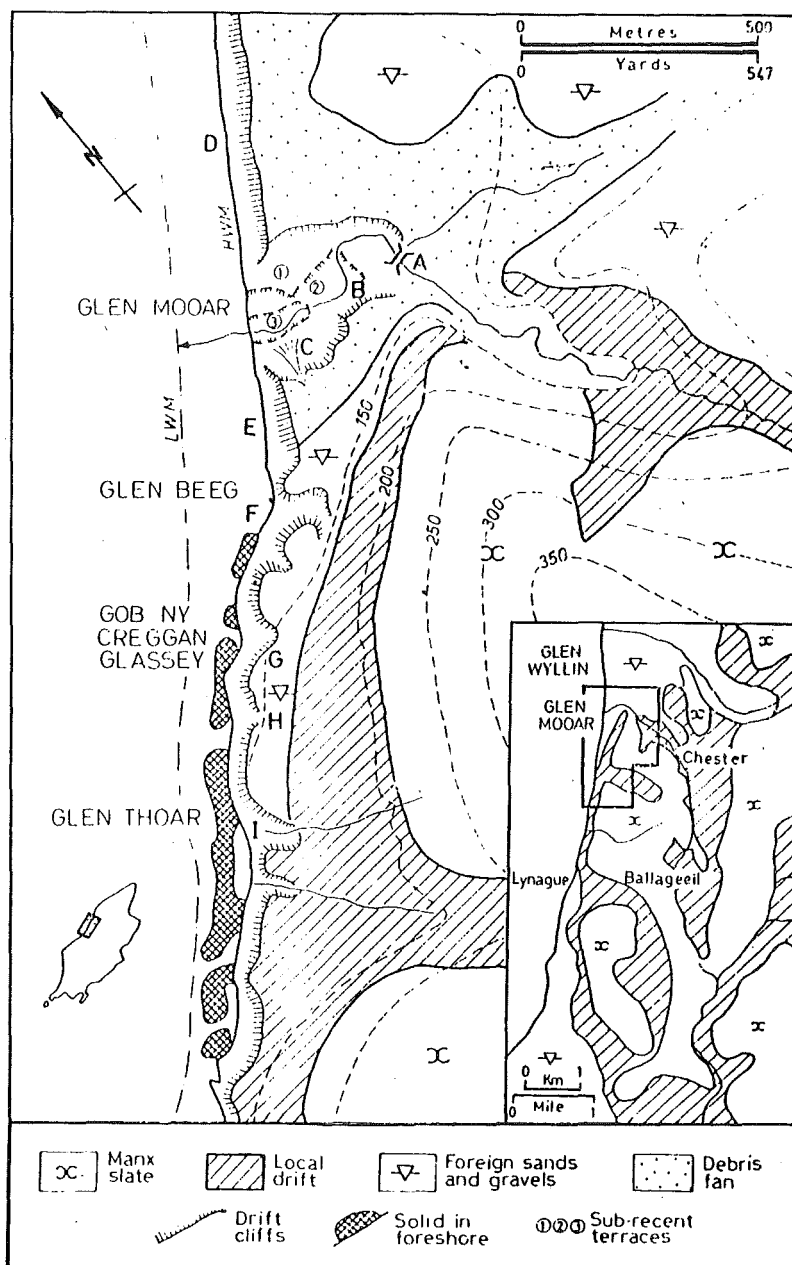


Fig. 14 The surface deposits of the Glen Mooar and Gob-ny-Creggan-Glassey areas.



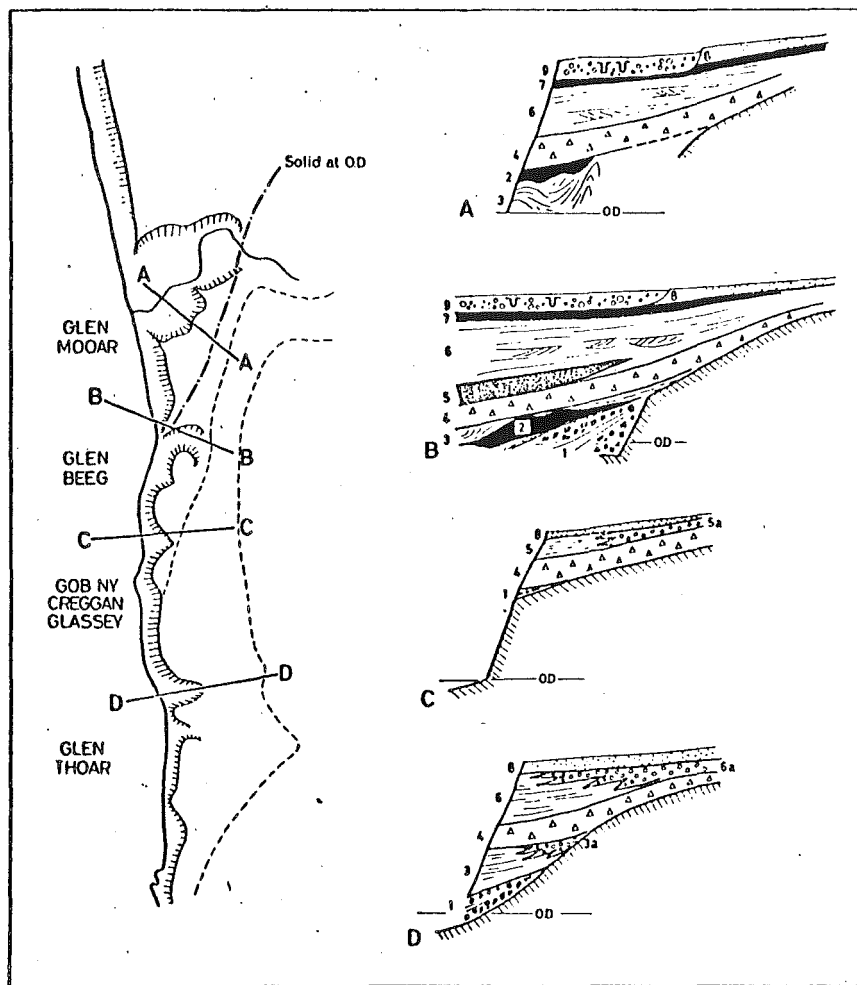


Fig. 15 Schematic representation of the succession between Glen Mooar and Glen Thoar.

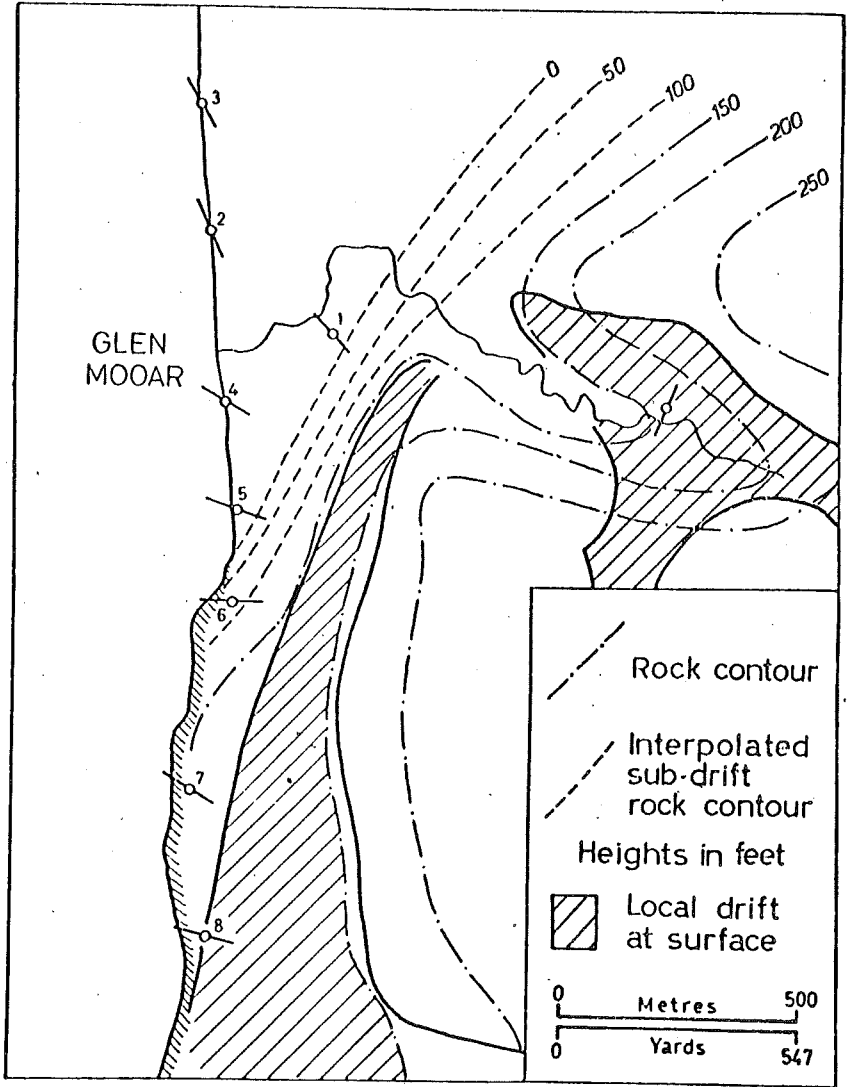


Fig. 16 Fabric pattern in the Moor local deposit.

**BALLALEIGH DRAINAGE CHANNEL (SC 316894, Site 6, GSPT)**

From the coast at Glen Mooar we drive south-east across the rock ridge between Glens Mooar and Wyllin. Large morainic mounds diversify the ground, but on the crest a deep rock channel crosses the ridge. This channel, some 350m long and 20 m deep, falls 50 m in its westward course. According to Mitchell(1965) the channel was formed when Irish Sea ice dammed the upper part of Glen Wyllin and impounded a lake. The waters from this lake burst westwards across the western rim of the valley at about 85 m and cut the channel. The rock excavated during its incision was deposited as a fan of slaty debris now seen capping the surface around the mouth of Glen Mooar.

**DRUIDALE (SC 355881, Site 7, GSPT & RVD)**

From Ballaleigh we pass across the maximum limit of penetration of foreign deposits at a height of about 150m, climb back onto the margin of the Manx uplands and pass up the northern flank of the Little London valley, on the floor of which a large drift terrace may be seen (SC 334860). Like that at Laxey this terrace is preferentially developed on the north facing slope only, and the south facing slope is relatively drift free. Sections on the side of the road show thin, slaty local deposits overlying fractured and broken Manx Slate. We pass through an upland coll between Sartfell and Slieau Maggle and turn into the Druidale valley, a main tributary to the Sulby River.

The headwaters of Druidale collect in a small drift basin through which deep gullies are entrenched. Downvalley, a long, gentle, almost rectilinear drift slope falls from the summit ridge between Injebreck Hill and Beinn-y-Phott and aprons the eastern side of the valley to terminate in a marked line of bluffs overlooking the stream. The opposite, western side of the valley is steeper and is only thinly covered with drift. Upstream of the bridge a set of active gullies fret the face of a 22 m bluff. The exposed local drift displays little variation here but throughout the vertical range it is well-stratified offslope. Dip increases progressively with depth, from about 7 degrees below the surface to 30 at the base (Fig. 17). At the base, heavily broken and shattered bedrock rises behind the section and the basal layers of drift are bedded parallel to it. Local drift underlies the flood gravels on the floor of the valley but solid is seen exposed on the opposite bank.

Detailed drift mapping and seismic investigation in this valley indicates that the local deposits are banked into a pre-existing rock gorge whose western margin has been exhumed but whose eastern margin is still buried (Fig. 17). This is associated with a distinct asymmetry in drift thickness, which is invariably greater on the eastern bank. In contrast to the Laxey valley there is a distinct seismic stratigraphy. The uppermost layer has low velocity (0.4-0.7m/msec), a fairly constant thickness, is present throughout the area and is interpreted by comparison with the exposed sections as a loose weathered head. Beneath this, the unweathered head has a velocity of 1.3-2.0m/msec which makes it easily distinguished from the rockhead with a velocity of 2.5-3.1m/msec. Tests show that the intact

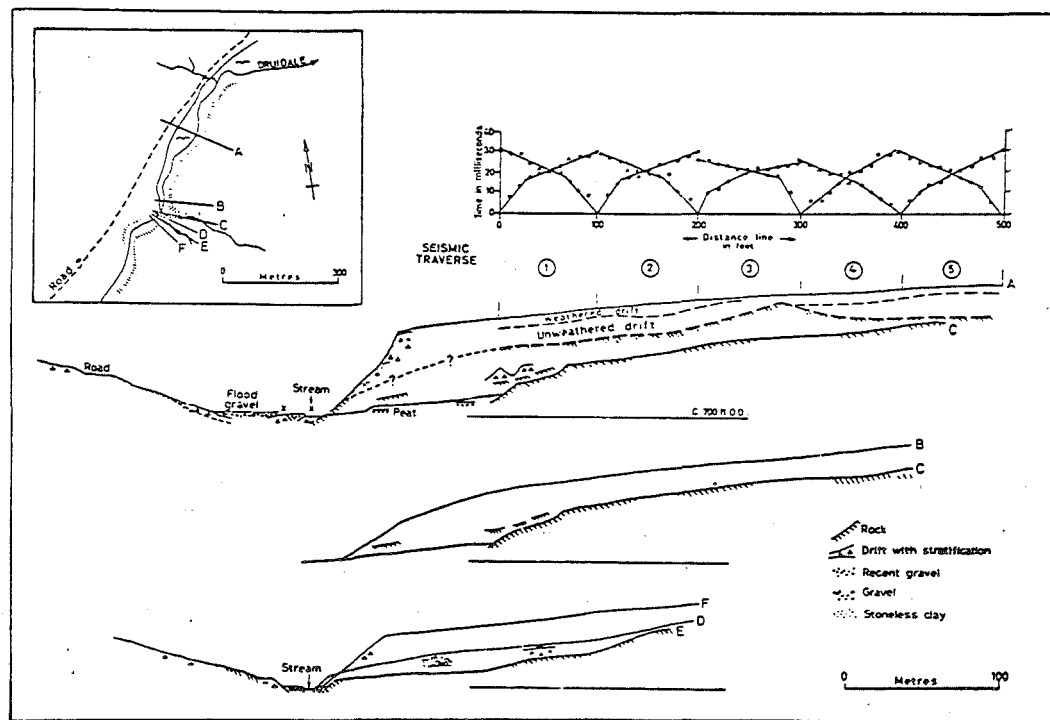


Fig. 17 Cross sections through the local drift in Druidale, based on seismic refraction and rock-head mapping.

local bedrock velocity is of the order of 4.2m/msec which suggests that the rockhead is well weathered. The unweathered head is absent from the record about 200m east of the section where about 2 or 3m of weathered head rests directly on low velocity, weathered bedrock. The rockhead rises rapidly behind the bluffs and drift thickness 50m back has fallen to about 16m and some 150m to the rear it has declined to about 7 or 8m. Rockhead relief beneath the smooth slope behind the bluff is locally very variable and the drift forms an even blanket whose function is to bury and smooth out a diversified rock topography beneath.

**LHERGYHENNY (SC 382873, Site 8, GSPT)**

Returning up Druidale we turn east along the north flank of Beinn-y-Phott to pass a further small headwater tributary of the Sulby River. On its east bank, near its confluence with the Sulby River, a type section in a steep bluff below a long 7 degree NW-facing slope shows considerable vertical variation in the character of the local drift (Fig. 18). Broken and shattered bedrock occurs at the base and this is overlain by the following succession:

- (1a) 0.65m Coarse rock rubble consisting of sharp, yellow stained blocks up to 30 cm, set in a small proportion of olive grey clay matrix. Contact with underlying solid is gradational.(RR)
- (1b) 0.25m Dark blue rock rubble similar to (1a) but finer. Becomes open work in places. Clasts slightly edge-rounded.(RR)
- (2) 2.25m Olive brown head crowded with angular slaty clasts averaging 10 cm, set in stiff clay matrix. Crude pseudo-stratification caused by minor alternation between coarser and finer bands. Two prominent lenses of coarse, open-work, slightly edge-rounded gravel occur.(LSH)
- (3) 0.45m Grey-blue, coarse, edge-rounded gravel. Matrix in part open-work; in part composed of fine gravel and coarse sand.(LG)
- (4) 5.25m Massive, dull-brown head or soliflucted till. Differs from head(2) in having no pseudo-stratification, and a higher proportion of clay matrix. Angular, sometimes striated clasts up one metre are scattered through. Passes gradually upwards into:(MB)
- (5) 2.20m Olive-brown or blue-grey head, similar to (2).(MSH)
- (6) 0.95m Coarse, yellow-stained, well-rounded gravel, interstratified with thin lenses and layers of well-sorted yellow sand and laminated grey silt. Top of gravel marked by prominent indurated band of fine gravel and coarse sand, dipping at 7 degrees down-slope.(UG)
- (7) 2.10m Olive or blue head, similar to (2) and (5). Badly weathered in upper part.(USH)
- (8) 0.48m Dark grey to light brown fibrous peat underlying terrace slope.

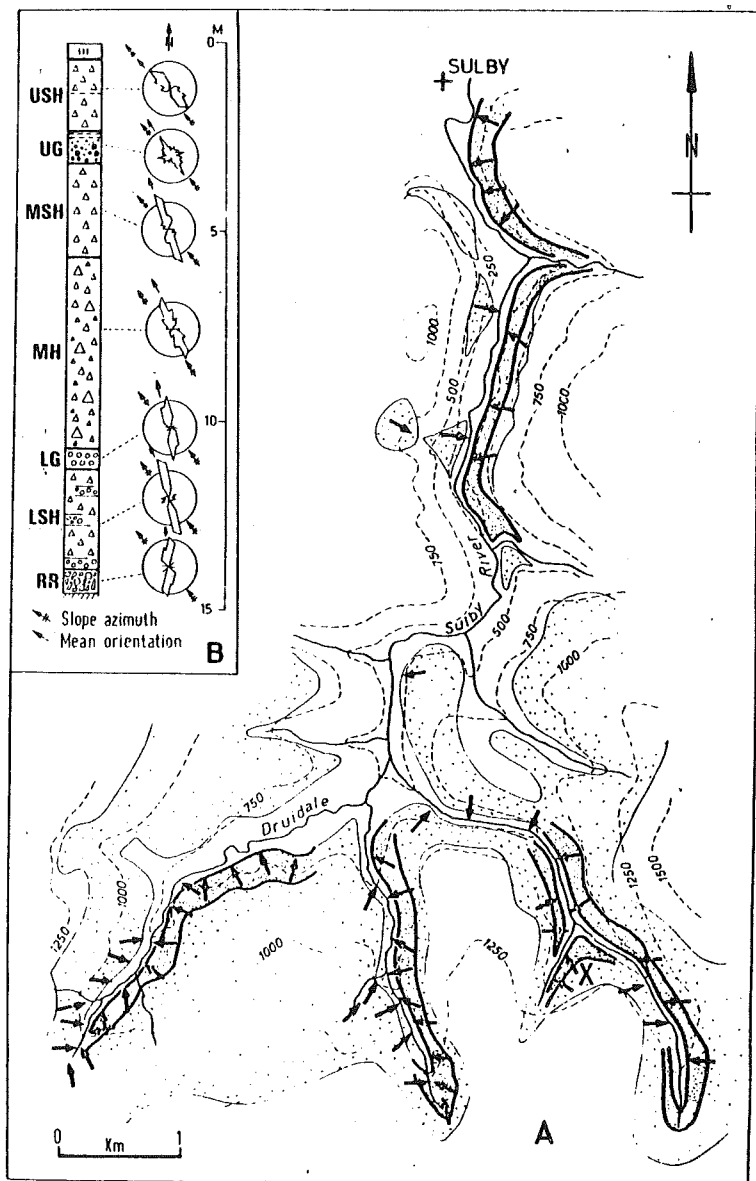


Fig. 18 A: Distribution of slope deposits in Sulby River basin showing fabric patterns. B: Section at Lhergyrhenny showing variation of fabric vertically. (from Thomas 1977)

Similar sections showing vertical passage between rock rubble, stratified head, massive head or soliflucted till, and a variety of washed gravels and sands can be found throughout the uplands (Fig. 19). Fabrics taken vertically through the succession at this site show that in the upper units mean transport direction is essentially parallel to slope azimuth. In the lower parts, however, this direction swings up to 45 degrees from slope direction, though it is commonly coincident with the dip of adjacent rock surfaces. General fabric pattern for the local deposits filling the Sulby River basin is everywhere orientated down-slope.

Two major questions posed by this site are crucial to the origin of the local deposits as a whole. The off-slope bedding, down-slope fabric, gradational rock contacts and general asymmetry of drift development all suggest that the deposits are slope deposits. If so, the critical questions are first, did they originate by in-situ break-down of the local solid rock during severe periglacial conditions when the uplands were ice free, or are they all, or in part, reworked tills. Second, what significance, if any, do the intercalated gravel sequences have. Do they represent a response to particular climatic fluctuations during which slope-wash processes predominated, or are they random fluctuations of purely local importance?

Thomas(1977) concluded that the upland deposits were largely a response to periglacial conditions operative throughout the Devensian cold stage, when the uplands existed as a nunatak, and tentatively interpreted the gravel sequences as representing the various interstadial episodes that occurred within it. Although direct evidence for the origin of the deposits is still wanting, the author would no longer favour this view. It now seems most likely that the upland area was glaciated during the Devensian and that the local suite of deposits were developed by the reworking of a relatively thin sheet of local till during periglacial conditions following retreat.

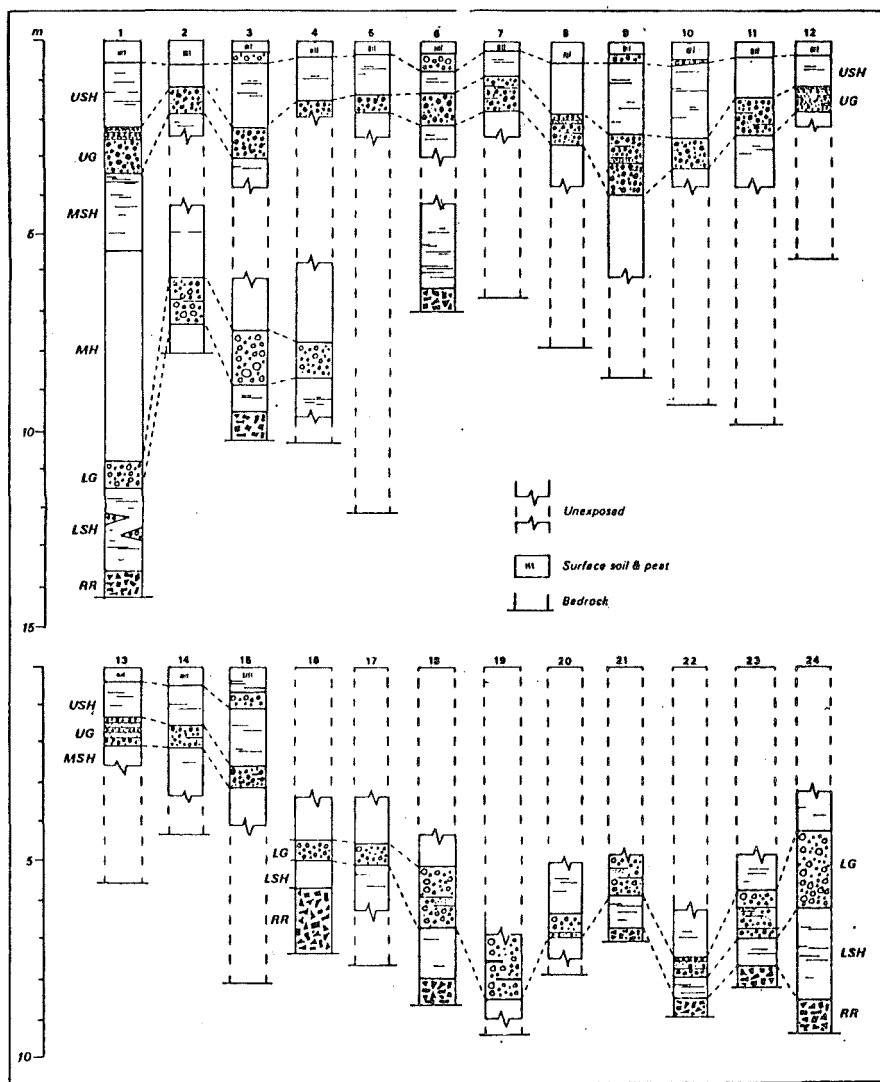


Fig. 19 Sections in local drift deposits showing distribution of head, slope-wash gravel and rock-rubble.



**Sunday April 14th - Foreign deposits (East coast)**

**Route:**

- Site 9:**        **The Dog Mills** - glacio-lacustrine/glaciomarine(?) sediments including diamicts.
- Site 10:**       **Kionlough** - proglacial outwash deposits.
- Site 11:**       **Bride Moraine** - moraine topography, meltwater channel systems.
- Site 12:**       **Shellag Point** - Shellag Formation tills and outwash deposits, large-scale glacio-dynamic structures.
- Site 13:**       **Ballavarkish** - readvance till facies and outwash deposits. Glaciomarine diamicts(?).
- Site 14:**       **Lough Cranstal** - Flandrian fresh-water, brackish and marine sediments.
- Site 15:**       **Phurt** - cryoturbated and dissected till surface, fluvial channel deposits, lagoonal peats, aeolian sands, palaeosols and Neolithic and Bronze age artefacts.
- Site 16:**       **Point of Ayre** - Flandrian raised beach ridges and dunes. Sub-surface succession.

## INTRODUCTION

From Ballure, where they overlie both the local suite and the Manx Slate, the foreign deposits of the island thicken northwards. No further solid rock is exposed and the Pleistocene sequence rests on a level platform of Carboniferous strata at about -45m OD. Towards the Point of Ayre this platform shelves northwards and a maximum of 126m of Pleistocene sediment overlie Permian strata. The surface topography of the area (Fig. 20) is dominated by the Bride Moraine, a series of ridges running E-W from Shellag Point towards Jurby, and rising to 100m OD. The northern slope of the moraine is underlain by till and is abruptly terminated towards the northern extremity of the island by a Flandrian raised cliff fronted by dune sands, lagoonal basins and prograding beach ridges. The southern slope is composed of sand and gravel and forms a complex morphological assemblage of ridges, mounds and kettle basins. Large numbers of meltwater channels, running both directly off the moraine face and parallel to it, feed gently sloping outwash fans to the south.

Three lithostratigraphic formations are exposed in the 10 km of cliff section between Ramsey and Point of Ayre (Fig. 21, Table 1). The lowest, the Shellag Formation, comprises four members. The lowest of these, the Shellag Till Member, is discontinuously exposed along the base of the cliff sections and is the only till seen to pass south of the Bride Moraine and onto the rock-core of the island. It is succeeded by the Shellag Sand and Shellag Gravel Members, both of which outcrop at and to the south of the Bride Moraine. North of, and within the moraine, all the members of the Shellag Formation are tectonically disturbed; south of it the degree of disturbance diminishes rapidly.

The Shellag Formation is succeeded by the Orrisdale Formation. This is divided into two geographic and lithologic provinces; one south and one north of the moraine. There is no direct stratigraphic connection between them for the members of neither province pass the moraine ridge. In the north the Ballavarkish Till Member unconformably overlies tectonically disturbed Shellag Formation and terminates a little to the rear of the moraine ridges. Further north, this till is succeeded by outwash deposits of the Ballavarkish Sand Member. To the south the Shellag Formation is conformably succeeded by the Kionlough Till Member, which thickens rapidly off the moraine face to pass into the Dog Mills Member, a series of laminated clays, silts and sands containing a rich micro-fauna. North of the Bride Moraine the Orrisdale Formation is succeeded, again unconformably, by the deposits of the Jurby Formation which consists of a number of major diamict and outwash members. Towards Phurt the glacial succession passes beneath sea-level and is replaced by a complex suite of Flandrian lagoon-slack and beach sediments.

Thomas (1976, 1977 & 1984) has interpreted the glacial succession of the east coast as representing the advance, retreat and marginal oscillation of the Late Devensian ice-sheet. Thus, the Shellag Formation represents advance onto the island margin followed by subsequent outwash sedimentation on retreat. The till and outwash members of the succeeding Orrisdale and Jurby

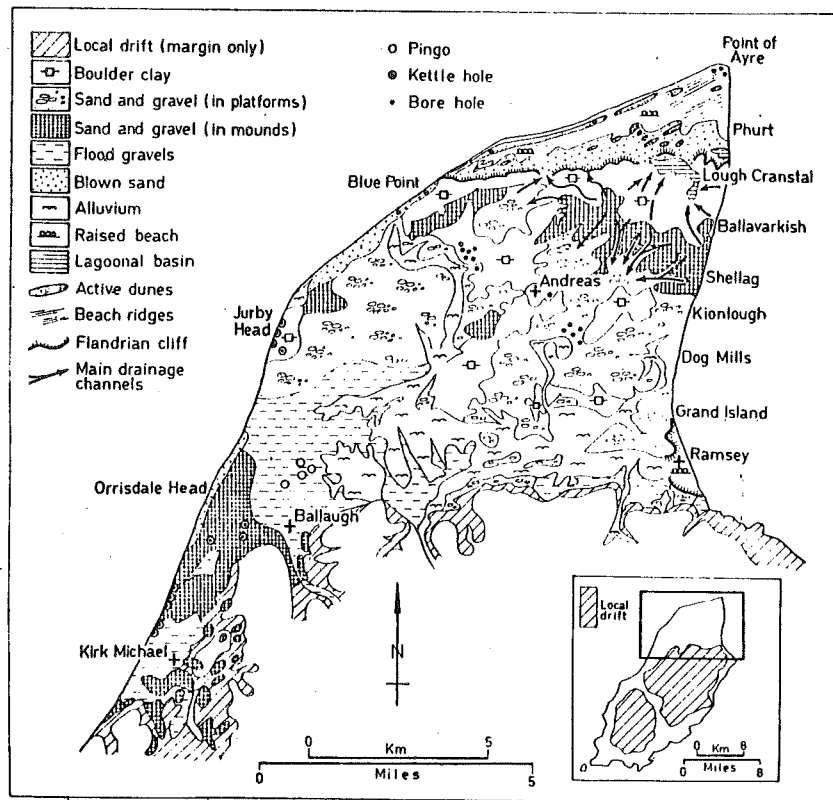


Fig. 20 Geomorphology and drift distribution in the area between Ramsey and Point of Ayre.

Table 2. Key to stratigraphic units in Fig. 21

- 16 Cranstal Silts
- 15 Ayre Beach
- 14 Andreas Platform Gravel
- 13 Crosby Channel Gravel
- 12 Cranstal Till
- 11 Ballaquark Sand
- 10 Ballaquark Till
- 9 Dog Mills Member
- 8 Kionlough Till
- 7 Ballavarkish Sand
- 6 Ballavarkish Till
- 5 Ballavarkish Marginal
- 4 Kionlough Gravel
- 3 Shelllag Gravel
- 2 Shelllag Sand
- 1 Shelllag Till

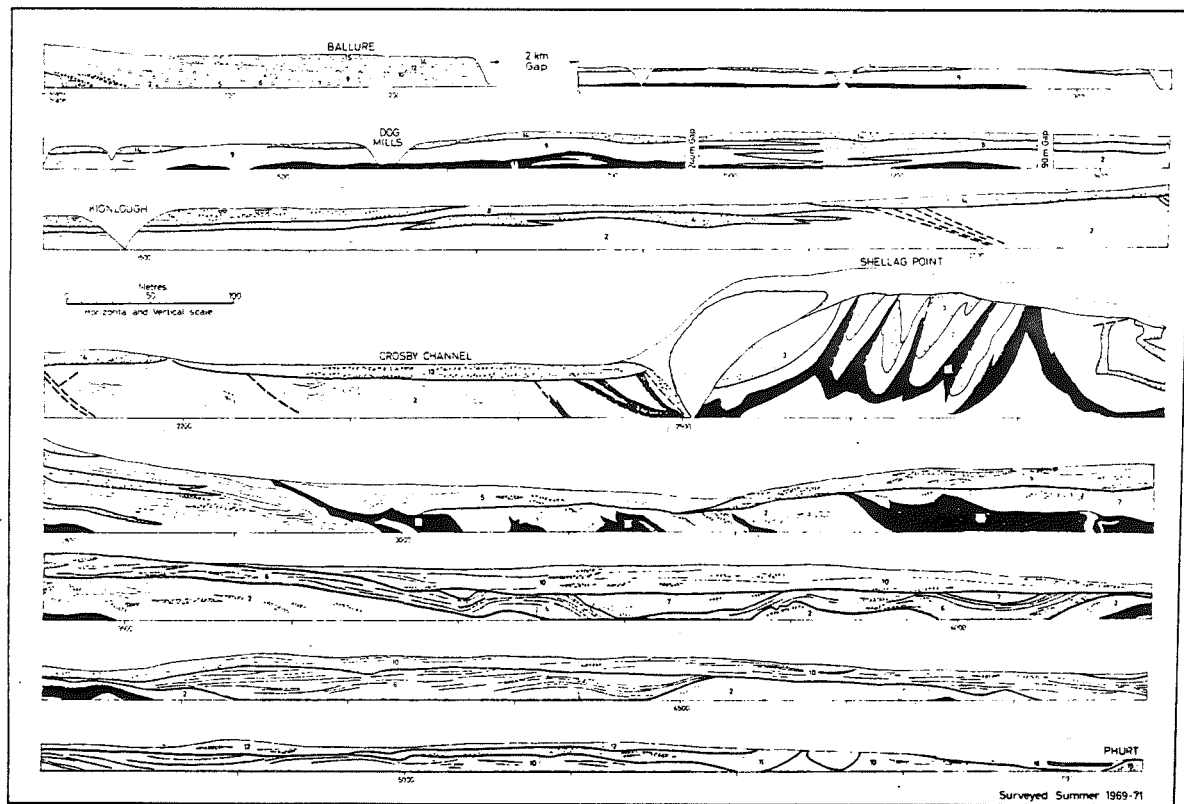


Fig. 21 The stratigraphy between Ballure and Point of Ayre. See Table 2 for identification of stratigraphic units (from Thomas 1977).

Formations to the rear of the Bride Moraine indicate successive minor oscillation and readvance of the ice margin and the generation of large-scale glacio-dynamic structures. Thomas also suggested that the microfauna of The Dog Mills Member, if in-situ, may represent a penecontemporaneous estuarine-intertidal environment indicative of a major shift from a marine-based to a terrestrial-based glacier system. Eyles & Eyles (1984) have extended this concept and propose that the whole of the Manx foreign succession is glaciomarine and was formed by subaqueous sedimentation beneath and beyond a grounded ice margin lying along the Bride Moraine.

During the day we shall visit eight sites and provide opportunity to examine lacustrine/marine sediments, glacio-dynamic structures, diamict lithofacies, moraine morphology and Flandrian fresh and brackish-water organic sediments and beach sediments.

#### THE DOG MILLS (SC 455885, Site 9, GSPT & RVD)

Between Ramsey and Shellag Point the Dog Mills Member is exposed in the cliff sections and consists of a series of laminated silts and clays and massive and laminated sands that rest conformably on the Shellag Till. The member exhibits distinct vertical and lateral facies changes and shows a general coarsening to the north where it passes laterally into the Kionlough Till and its associated sands and gravels (Fig. 21).

In the sections between Ramsey and the Dog Mills preliminary facies analysis suggests that the sequence may be split into a lower, relatively fine grained and an upper rather coarser facies (Fig. 22). The lower part is characterised by fine, silty sands and laminated and massive clays (Fig. 23). The sands are massive (Sm) or crudely horizontally laminated (Sh) and often include thin laminae of silt or clay disrupted by dish and pillar water-escape structures and a variety of types of convoluted bedding. Rippled fine sands (Sr) are present as are the parallel 'draped' laminae of sand, silt and clay (Sw) described by Gustavson et al (1975). Post-depositional soft-sediment deformation is common but is mainly restricted to particular horizons rather than occurring generally throughout the sequence. These particular horizons are laterally extensive and are disturbed throughout. Markov analysis suggests that there is a well-developed fining upwards cycle developed in this lower fine grained facies and this persists throughout the sections between Ramsey and the Dog Mills. Three types of sequence are typically developed (Fig. 22); in the first a thick unit of massive fine sand (Sm) is succeeded by a thin laminated or massive mud (Fl, Fm), the whole cycle being disrupted by soft-sediment deformation. The second sequence consists of parallel, draped laminae of sand, silt and clay ('wavy beds', Sw) which pass up into massive or laminated muds. Finally, but less common, are transitions from rippled sands (Sr) up into muds. These sequences suggest sedimentation in a shallow standing water body where the latter two types of cycle indicate traction sedimentation from gentle bottom currents giving way to suspension fall-out. Although the same sequences may be formed in overbank fluvial environments, the lateral continuity of these units, the relative lack of either cross-bedded units or coarse

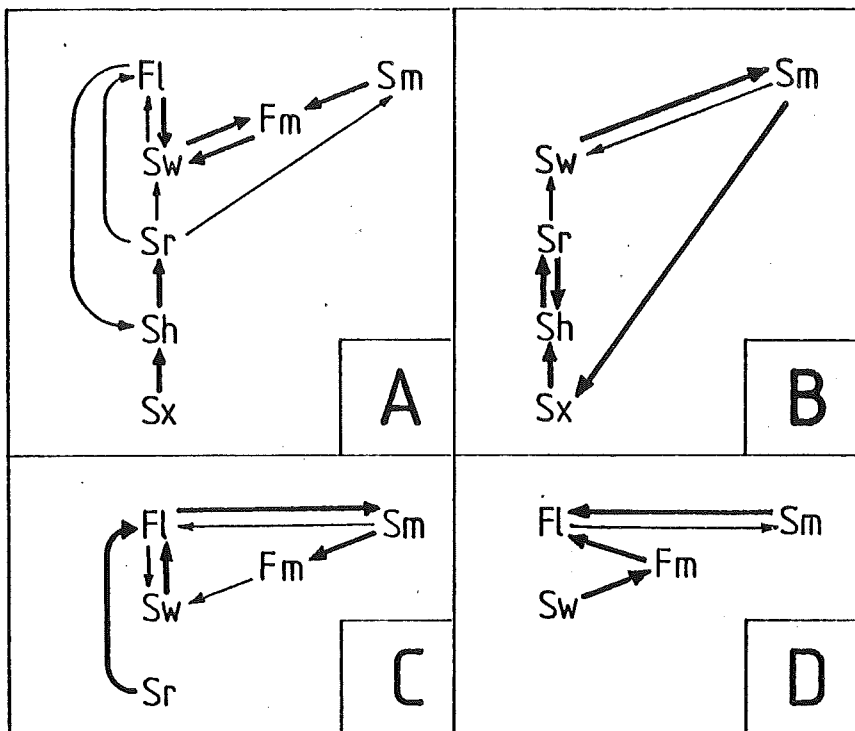


Fig. 22

Facies relationship diagram for the Dog Mills Member to the south of Dog Mills;

- A. Upper sandy facies, southern sections
- B. Upper sandy facies, northern sections
- C. Lower fines facies, southern sections
- D. Lower fines facies, southern sections

See text for discussion.

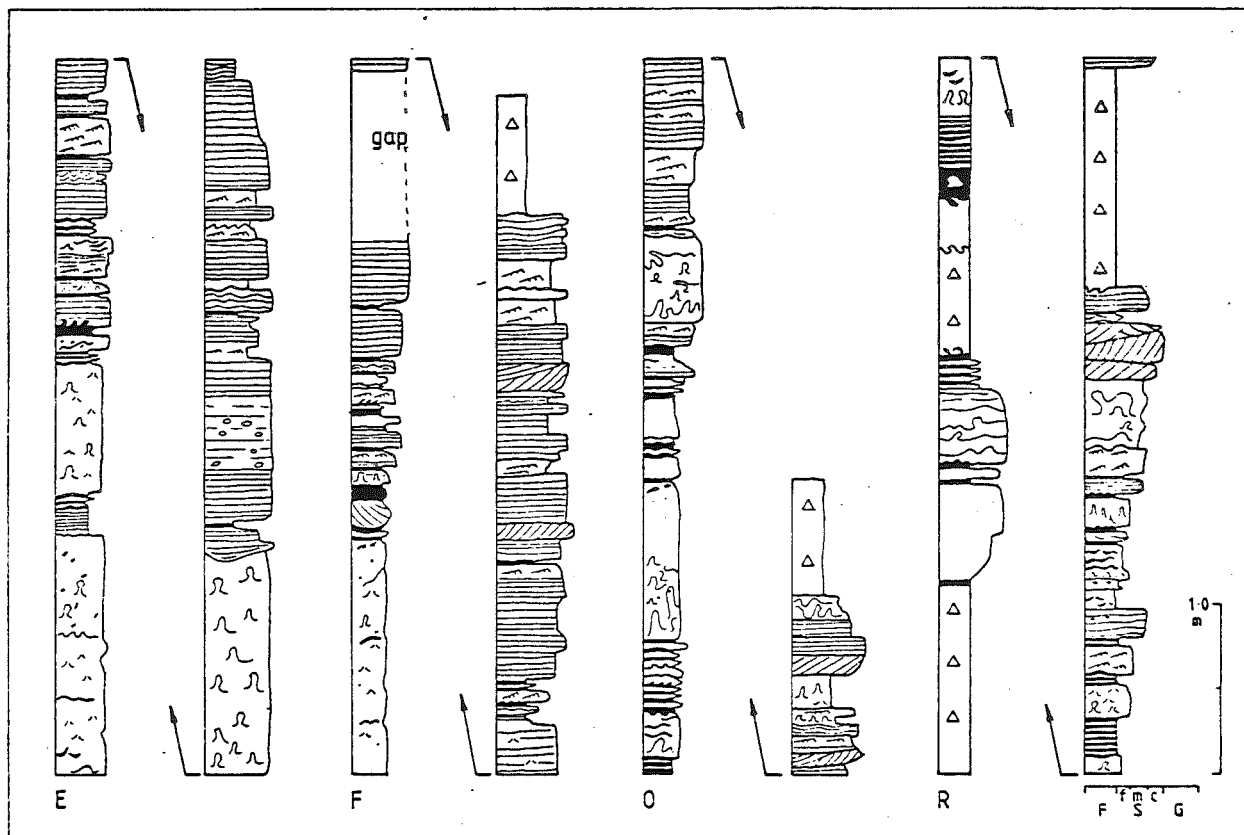


Fig. 23 Typical graphic logs for the Dog Mills Member.  
 Southern section; Log E, SC45079672 Northern section; Log O, SC45229773  
 Log F, SC45079676 Log R, SC45279883

clastic components and the lateral continuity of deformed horizons favours a lacustrine setting. The thicker deformed cycles may represent periods of increased sediment supply or may represent material deposited by rare, catastrophic underflow turbidity currents (Sturm and Matter, 1978) upon their transition from eroding supercritical flow to depositing subcritical flow (Komar, 1971)

The upper sandy facies consists of a suite of occasional trough or planar cross-bedded sands (Sx), horizontally laminated sands (Sh), various types of rippled sands (Sr) and massive sands (Sm) (Fig. 23). Fine grained mud units are much less frequent than in the lower facies as are the wavy beds. It is also notable that the incidence of soft-sediment deformation is much lower and where it does occur it is much more localised. Typical facies relationships (Fig. 22) consist of an upward passage from cross-bedded sands (Sx) through horizontally laminated sands (Sh) and into rippled sands (Sr). In the south of the sections towards Ramsey, this sequence may be completed by an upward passage into a laminated mud (F1), while in the north, around The Dog Mills, it may continue with a further Sh unit or, less often, a draped or 'wavy' laminated unit (Sw). The absence of significant fines and the dominance of a declining current sequence of structures suggests a distal, sand dominated fluvial system. The change in the nature of the upper part of the idealised cycle from Sw in the north to F1 in the south may indicate the presence of standing water with the coarser, northern facies being deposited by gentle bed aggradation under backwater conditions. The finer, more laminated units to the south may represent true suspension fallout whilst the lower parts of the cycle (Sh, Sr) represent bottom traction deposits.

Immediately to the north of the Dog Mills the sequence becomes dominated by thick diamict (Fig. 21; Fig 23, log R) and massive mud units and clean current-swept sands become much less frequent. Although the cliff sections are poorly exposed it appears that the dimict units rise towards the north to form a 'bank' separating the Dog Mills Member to the south from the sands and gravels to the north. The presence in this section of abundant soft-sediment deformation structures and some horizons showing clasts of dimict and clay suggests a significant change of environment with dimicts being discharged over a bank formed by the underlying sands and gravels. The abrupt change from a dimict dominated sequence to a low energy aquatic sequence with accompanying evidence of reworking of the dimicts may indicate that they were discharged into a standing water body.

Lamplugh (1903) termed the Dog Mills deposits 'warp', a term used in Holderness to describe estuarine and intertidal laminated clay, and he considered they were probably the bottom deposits of Lake Andreas, a large pro-glacial lake postulated to have been trapped between the Bride Moraine and the island rock margin. There is little in the sedimentological evidence presented above to refute this view. In fact, it is possible to add further detail to the picture suggested by Lamplugh. The lower fine-grained facies seen in the sections south of Dog Mills may be interpreted as bottom deposits in a shallow lake, whilst the upper, sandier facies may represent the later stages of infilling



by a Hjulstrom type supra-aquatic delta (Church and Gilbert, 1975; Hjulstrom, 1952). the northern margin of the water body was probably just north of the Dog Mills and in the early stages considerable dimict was deposited and reworked at its margins. This would account for the relatively high proportion of fines in the lower parts of the Dog Mills Member and could provide the source for turbidity current sedimentation.

## Discussion

It is not clear whether Lamplugh's Lake Andreas-Ramsey was in fact a fresh-water lake or whether it may have been a marine embayment. Wright(1902) and Wright & Reade(1906) provided lists of foraminifera from the sequence and an interpretation(J.R. Haynes) suggests cold-water accumulation. Apart from *Texularia globulosa* and *Globotruncata cretacea*, both Cretaceous, all other species from the sequence are found in the Atlantic today. The majority are open-water, but two estuarine and intertidal species, *Nonionina depressula* and *Polustomella striato-punctata*, occur in abundance. This suggests that deposition was either cold-water marine with an introduced brackish-water element or, more likely estuarine-intertidal with a current-swept, open-water component. Foraminifera obtained from a vertical sequence show that the fauna is much the same throughout the vertical range and is dominated by *Elphidium clavatum*(Cushman), a cold-temperate to arctic species. As *Protelphidium obiculare* also occurs the environment indicated is definitely cold-water marine. The dominance of *E. clavatum* compares with the present day in a number of shallow-water localities, as for example near Spitzbergen where this species is abundant both in-shore and near glacier termini.

A firm interpretation of the Dog Mills Member depends on whether the microfossil assemblage is regarded as being in-situ or derived. In general the foraminifera are well preserved, clean, glassy and often showing fine detail. On the other hand many of the specimens of *Elphidium clavatum* show breakage of the last chamber which does suggest limited transport. The presence of the microfauna throughout all facies of the Member together with the virtually complete absence in the distal facies of any macrofossils does suggest some selective current sorting since broken and abraded shells are common in all of the more proximal deposits to the north as well as in the tills themselves.

## KIONLOUGH (NX 455986, Site 10, RVD & GSPT)

The sections between The Dog Mills and Kionlough Glen, although generally poorly exposed, show a change from dominant dimict and fines to a greater preponderance of coarse sands and gravels. Logged sections to the north and south of Kionlough Glen (Fig.24) are dominated by medium gravels, cross-bedded sands (Sx), horizontally laminated sands (Sh), low angle cross-bedded sands (Sl) and massive sands (Sm) with ripple-laminated sands (Sr), fines and dimicts present in small amounts. Strong reciprocal association exists in the simple Gm to Sh to Sx to Sr cycle and in the essentially similar Gm to Sl to Sx to Sr sequence. Both of these two cycles suggest a combination of bar

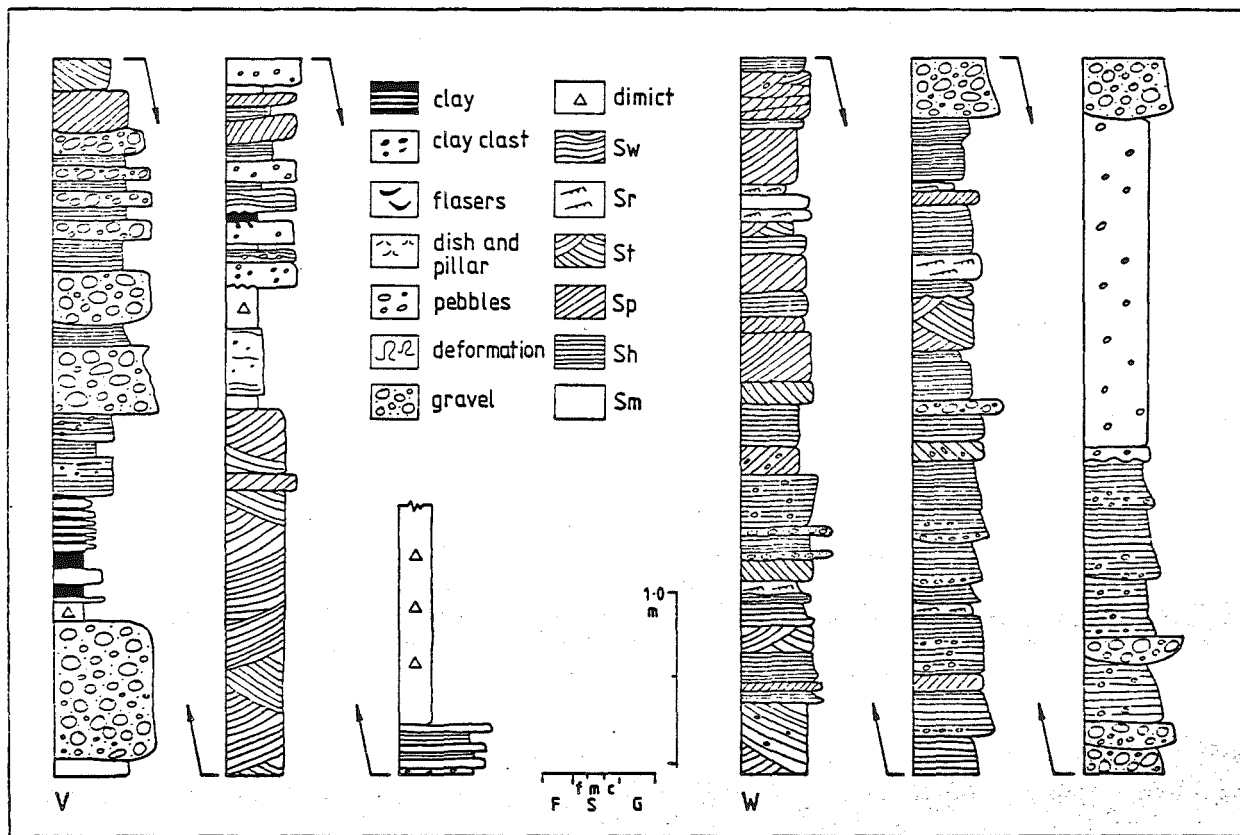


Fig. 24 Typical graphic logs from the Kionlough Glen area.  
 South of Glen; Log V, SC45379830  
 North of Glen; Log W, SC45499865

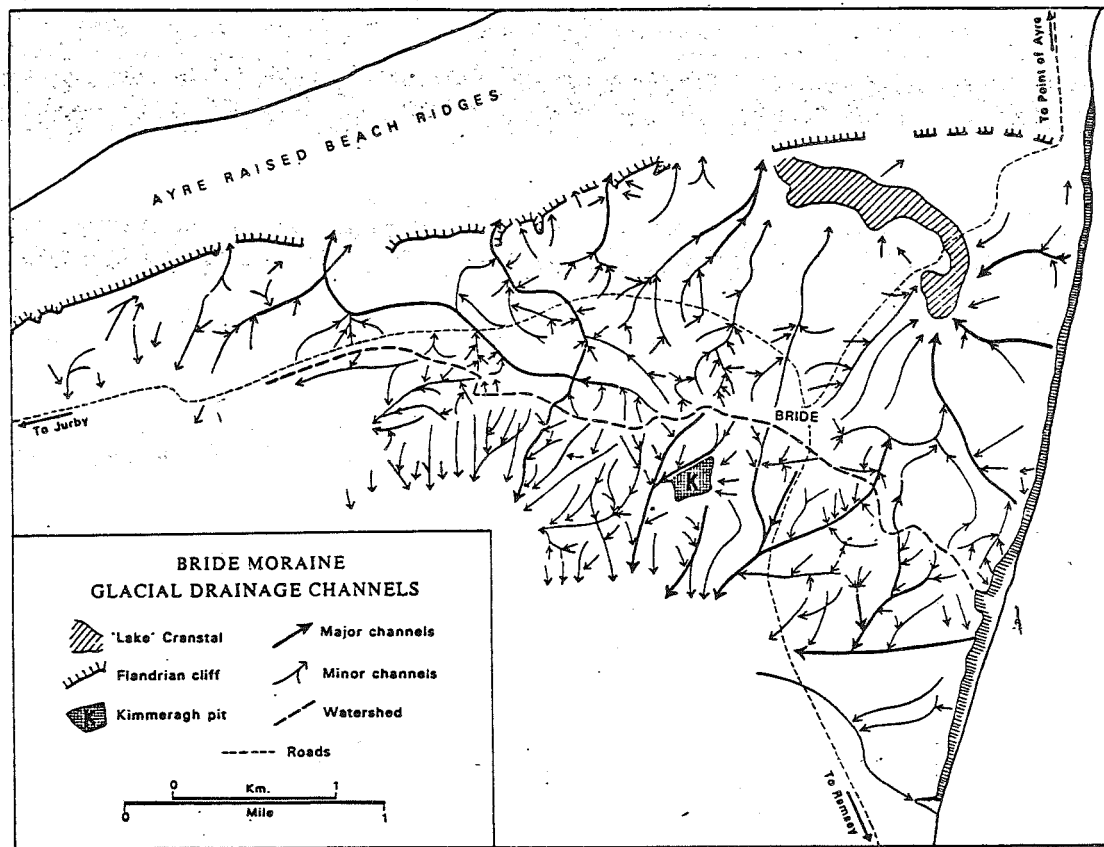


Fig. 25 The channel systems of the Bride Moraine.

growth and vertical accretion in a proximal location with the gravels forming the bar core and the superimposed horizontally laminated and low-angle cross-bedded sands representing sheet flow across the bar surface. The undifferentiated cross-bedded sands represent both avalanche face deposits and scour features while the rippled sands are probably due to flow across almost emergent bar tops. Less well developed is the association between the finer grained facies with simple upward-fining sequences from Sr to Fm and Sw to Fl indicating slack-water and overbank deposition respectively (Gustavson et al, 1975).

Between Kionlough Glen and Shellag Point the outwash deposits are tectonically disturbed by overthrusts dipping towards the north. These thrusts cause repetition of the sequence and obscure the stratigraphic relationship between the sands and gravels described above (referred to by Thomas, 1971, as the Kionlough Sands and the Kionlough Gravels) and the Shellag Sands and Shellag Gravels to the north. It seems probable, on the basis of their deformation, proximal-distal and thickness relationships, that the Kionlough Sands and Gravels and the Shellag Sands and Gravels are equivalent and represent the deposits of a proglacial outwash fan.

#### **THE BRIDE MORaine (NX 430015, Site 11, GSPT)**

The Bride Moraine comprises a complex of ridges, basins, mounds and channels trending roughly E-W from Shellag Point towards Jurby. Elevations commonly exceed 100m in the east but decline westwards. Till underlies the rear of the moraine but the crest and pro-moraine area are largely sand and gravel. To the west, at The Lhen, the curve of the moraine ridge is broken by a wide and shallow meandering channel, readily identifiable on the 1:50000 map, that once fed meltwater south towards the low ground of the Curragh. The conspicuous channel systems that fret the moraine (Fig.25) can be divided into three types:

(1) **Ice marginal channels.** Most of the larger channels run parallel to the trend of the moraine and a type example, which gives access to the sections at Shellag Point, fronts the outer part of the moraine ridges east of the Bride Road. This channel, some 100m wide, 30 m deep and with steep sides falls westwards to merge into a low angled outwash fan. Thick, flat-bedded sands and gravels underlie its floor in cliff sections at its upper, eastern end. North of the moraine crest a similar channel runs NW from Thurot Cottage towards Smeale and further examples occur NE of Bride village. These channels operated as major melt-water systems trapped at successive stages between the ice-margin and dead-ice or moraine ridges fronting it.

(2) **Direct channels.** Many smaller channels run normal to the trend of the moraine, mostly on its southern side. A good example, 35m deep and 40m wide, intersects the Ramsey to Bride road. This channel, like others, has numerous narrow tributaries, one of which follows the road into Bride village. Gradient is usually steep, compared to the marginal channels, and often exceeds 1 in 20. Most of these channels drain from the moraine crest and served to feed either the marginal channels or small ice-front alluvial fans. A number, however, pass through the

moraine ridge and have characteristic humped profiles. They probably mark the position of major sub-glacial drainage routes.

(3) **Minor channels.** A great variety of minor channel forms, usually short, steep and often open-ended, occur throughout the moraine. Many of them drain north, rather than south, and probably have a composite origin. Some may have acted as sub-glacial feeders to the snout; others to drain dead and decaying ice in a subsequent proglacial environment.

A number of major channels have crossing junctions with one another, indicating operation at different stages. Except to delimit their distribution, no work has been undertaken on the detailed morphology of the ridge and channels systems but this might yield profitable data to reconstruct ice-margin stagnation.

The Bride Moraine has frequently been correlated with other major moraine structures (Fig. 26) on the shores of England and Ireland (Charlesworth 1926 & 1939, Synge 1952, Cubbon 1957, Mitchell 1960, 1963 & 1972, Penny 1964, Sissons 1964, Gresswell 1967, Stephens et al 1975, Stephens & McCabe 1977), and many workers have postulated the existence of a major, so-called "Scottish Readvance" that occurred at a late stage in Devensian deglaciation of the Irish Sea basin. In the authors view (Thomas 1985) the concept of such a readvance is largely illusory, is devoid of stratigraphic or chronological foundation, and cannot be used as substance for stratigraphic classification based on an assumed response to climatic fluctuation. Consequently, the Bride Moraine is best regarded as a response to minor snout oscillation caused by essentially local controls.

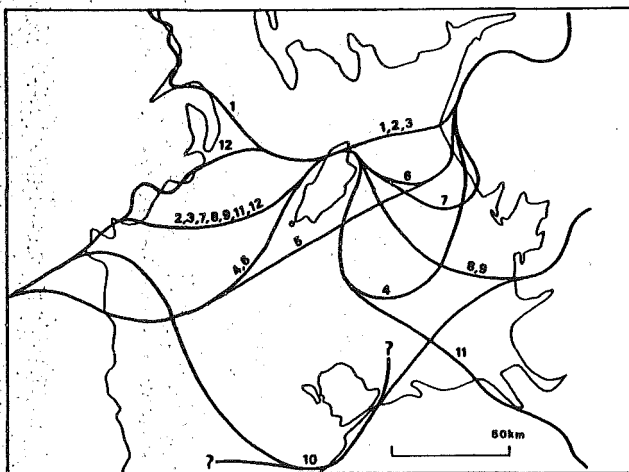


Fig. 26 Postulated limits for the "Scottish Readvance" correlations with the Bride Moraine.

- |                       |   |
|-----------------------|---|
| 1: Charlesworth(1926) | 7: Penny(1964)  |
| 2: Charlesworth(1939) | 8: Sissons(1964)                                      |
| 3: Synge(1952)        | 9: Gresswell(1967)                                    |
| 4: Cubbon(1957)       | 10: Saunders(1968)                                    |
| 5: Mitchell(1960)     | 11: Mitchell(1972)                                    |
| 6: Mitchell(1963)     | 12: Stephens et al(1975),<br>Stephens & McCabe(1977). |

# SHELLAG POINT (NX 460000, Site 12, GSPT)

At Shellag Point the highest ridge of the Bride Moraine is truncated by active sea cliffs and excellent sections are displayed (Fig. 27). The locality provides the type-site for the Shellag Formation, which includes three major and highly contrasting members. The lowest, the Shellag Till Member, is a cohesive, calcareous, clay-rich till containing occasional erratic clasts. It is massive in undeformed state, displays limited lithological variation and is characteristically thixotropic when wet. It passes sharply upwards into the Shellag Sand Member; a medium to coarse, well-sorted, usually parallel- or ripple-bedded sand displaying occasional intraformational frost wedge structures. The sand is overlain by the Shellag Gravel Member; a coarse to very coarse gravel, generally massive or poorly bedded and frequently heavily cemented. Many gravel clasts are frost shattered and small ice wedge casts are common. The gravel is seen only in the immediate vicinity of the moraine and north of the crest it passes into the Shellag Sand. It reaches its maximum thickness on the south face of the moraine but further outcrop is lost by tectonic disturbance. Andrews and King (1967) obtained a  $^{14}\text{C}$  date of 30,300 BP from shells within the Shellag Gravel but as the fauna is exclusively derived from pre-existing strata (Lamplugh 1903), its validity is much in doubt.

Thomas (1984) considered the morphology of the Bride Moraine, its glacio-dynamic structure and parts of its stratigraphy to be a function of a minor ice-sheet readvance during a late stage in the Devensian deglaciation of the Irish Sea basin. In his view, the moraine is a structural rather than a constructional or depositional landform and is best classified as an ice-thrust ridge (Kuptch 1962) or ice-thrust moraine (Prest et al 1968). Structural disturbance extends from the unconformity beneath the Ballavarkish Till Member to the rear of the moraine, through the core area of the moraine ridge, to an area of rapidly diminishing disturbance to the south. Within this kineto-stratigraphic zone occur four distinctive, but related styles of structure (Thomas 1984):

(1) **Foliation:** In areas where it is deformed by larger scale structure the Shellag Till Member is traversed by numerous planes of foliation that give the appearance of a pronounced slaty cleavage. The foliation is independent of the occasional lithological boundaries in the till and is absent where the till is undeformed south of the moraine. It shows a strike (Fig. 28) trending 105-285 degrees, with dip ranging from vertical to a dominant 70 degrees to the south and is frequently folded into low amplitude, upright or steeply inclined isoclines plunging NW or SE. Mean trend of fold axes is 130-310 degrees.

(2) **Folds:** Major folds are found only in the moraine core which forms a tight, asymmetric anticline with an amplitude of some 100m and slightly overturned to the north. The Shellag Till Member forms the main outline of the structure. Superimposed upon the southern limb of the main anticline is a series of four congruent, isoclinal overfolds whose axial surfaces are steeply inclined to the south. All three members of the Shellag Formation

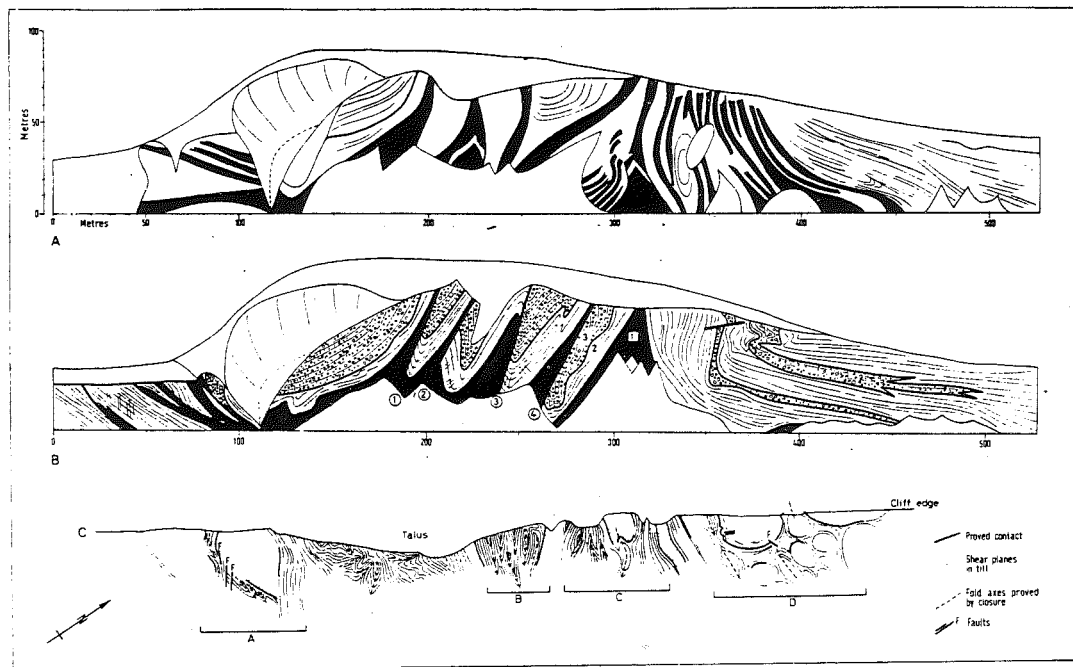


Fig. 27 The structure of the Bride Moraine.  
 A: section through the moraine (Slater 1931)  
 B: section through the moraine (Thomas 1984)  
 C: outline structural map across foreshore  
 fronting sections (from Thomas 1984).

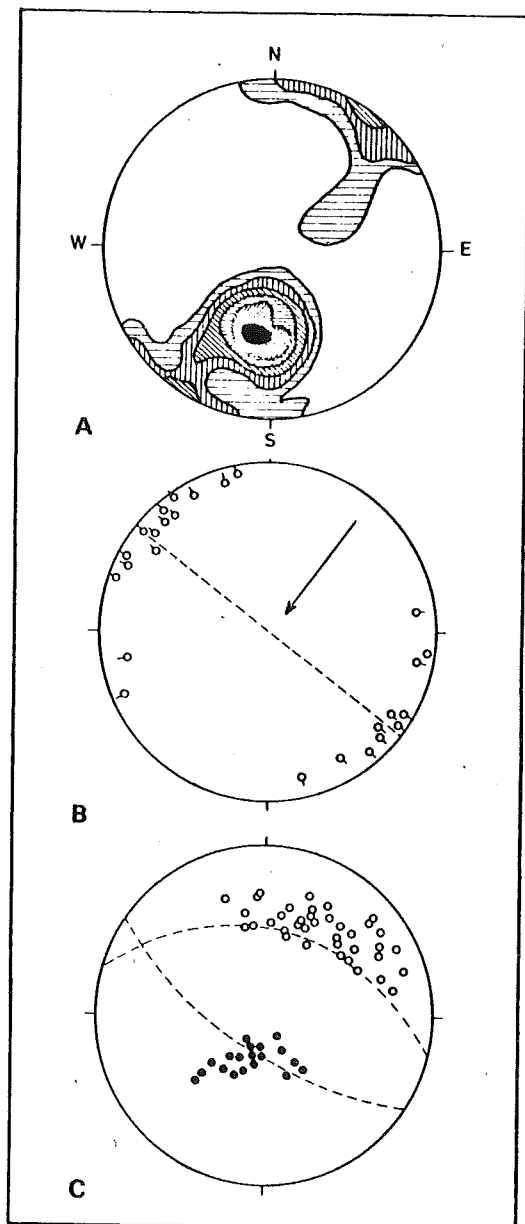


Fig. 28 Structural stereograms; (from Thomas 1984).  
 A: contour plot of poles to foliation  
 B: plunge of fold axes  
 C: open circles - poles to high-angled reverse faults  
 solid circles - poles to low-angled overthrusts



are involved in the folding and tectonic thinning on the limbs and thickening around the crests is considerable. A further series of folds occurs to the north of the main structure but the intensity is diminished and folds form a series of shallow elliptical basins (Fig. 29).

(3) **High-angled reverse faults:** These faults are associated with, and are the complement of the major isoclinal folds of the moraine core. Four occur and each dips steeply south, sub-parallel to the axial surface of the complementary isoclinal fold and trend 125-305 degrees (Fig.28). Slip, in each case, is of the order of 20 m and downthrow is to the north. Slip diminishes into the roots of the moraine structure and faults do not crop on the foreshore (Fig. 29).

(4) **Low-angled overthrusts:** Overthrusts, or low-angled reverse faults, occur beyond the moraine front and below the unconformably lying Ballavarkish Till Member to the rear. In all cases the thrusts dip north and not south, which is the case with the high-angled faults (Fig. 27). For a kilometre south of the moraine, overthrusts form a fan of progressively increased dip and reduced spacing northwards to the moraine front. Between many of them Shellag Sand Member is carried forward as a large, asymmetric anticline. As thrust spacing decreases, suites of anticlines appear stacked one behind the other and at the moraine front the dip increases and Shellag Till Member is dragged up as slices along thrust planes. Although some planar structures occur most thrusts are concave upwards with dips of up to 60 degrees at the forward end, declining to less than 10 degrees to the rear, and are analogous to a series of stacked, nested spoons, dipping north.

Slater(1931) interpreted the Bride Moraine as a classic push-moraine built up by the override of an active ice margin which caused the development of a series of thrust planes at the snout dipping up-glacier. Thus, building was by a processes of continued deposition, layer upon layer, of thin lenses of sub-glacial detritus released at the sole of the thrust. Structures resulting would build up in two directions: firstly from below upwards and secondly backwards, leading to increasingly higher angles of deposition iceward.

Slater's interpretation can be criticised on two grounds. First, it requires that deformation was penecontemporaneous with deposition of the Shellag Till Member. This cannot be the case for all members of the Shellag Formation are involved and deformation must, therefore, have occurred epigenetically. Second, Slater attached no significance to the major isoclinal overfolds and high-angled reverse faults and suggested they were post-deformational slump structures. If this were the case then the faults that separate the 'slumped' folds should be normal, with downthrow to the south. This is not the case.



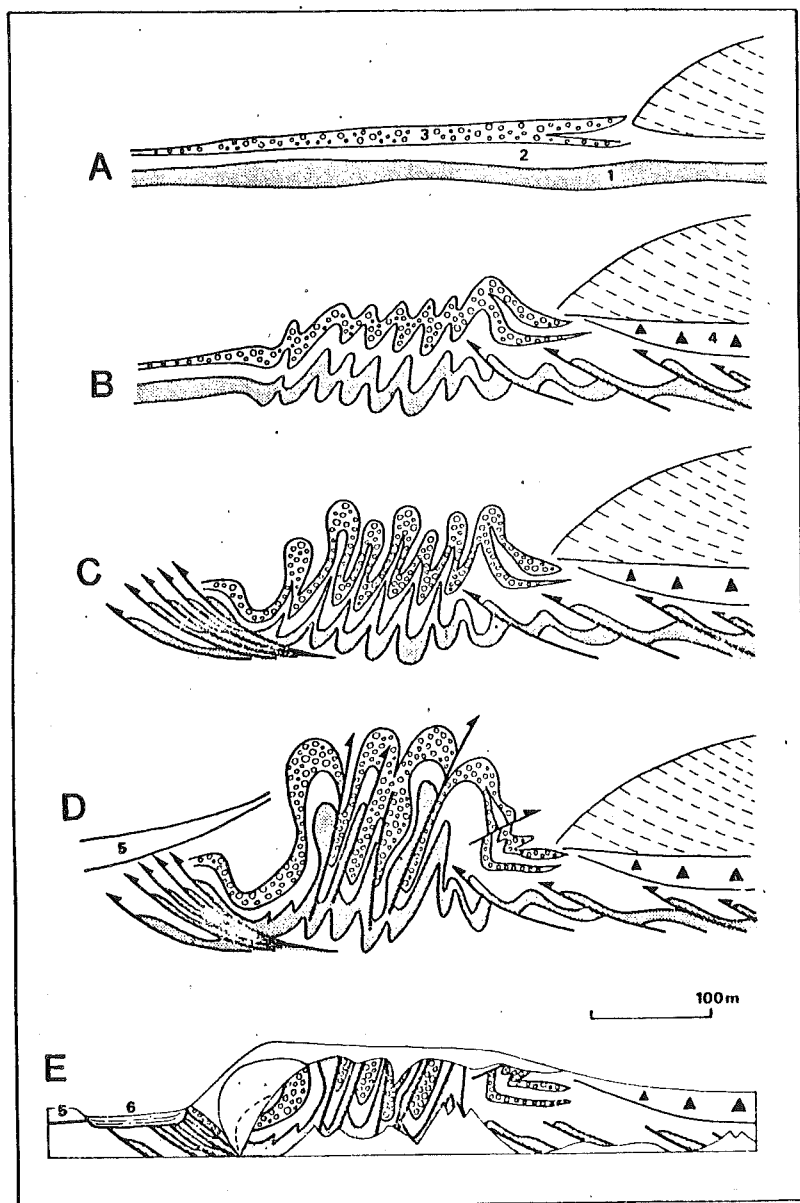


Fig. 30 Stages in the development of the Bride Moraine.  
(from Thomas 1984).

- Key:
- (1) Shellag Till;
  - (2) Shellag Sand;
  - (3) Shellag Gravel;
  - (4) Ballavarkish Till;
  - (5) Kionlough Till;
  - (6) Marginal channel.

Thomas(1984) interprets the structures as resulting from the development of differential permafrost in a lithologically contrasting substrate and the consequent generation within it of high pore-water pressure during ice-marginal readvance and loading. In the early stages of readvance (Fig. 30), pore water pressure was low and compression from the ice margin caused folding rather than thrusting. As pressure increased, however, shear strength in the Shellag Till Member reduced drastically and widespread failure resulted in the development of low-angled overthrusting. With increased dislocation by overthrusting, potential for further expulsion of pore-water pressure reduced and the saturated till burst vertically upwards by diapiric action along the axial surfaces of folds to form a series of mushroom-shaped, sheared isoclines. This process was assisted by water passage along brittle fracture planes formed around rising fold crests and by reduction of superincumbent weight by disintegration of the fold structures at the surface. After release of excess pore-water pressure further structural development ceased and the upper parts of the structure disintegrated as unstable, water saturated debris slid off the forward face.

Following their view that all members of the Shellag and subsequent glacial formations were deposited subaqueously, Eyles & Eyles(1984) argue that the Bride Moraine is a subaqueous push ridge formed close to a grounded marine ice margin (Fig. 31). The Shellag Till Member is consequently interpreted as a subaqueous mud deposited by suspension and subsidiary ice-rafting and limited traction-current; the Sand Member as a shallow-water tidally-reworked sand; and the Gravel Member as a possible shoreface facies.

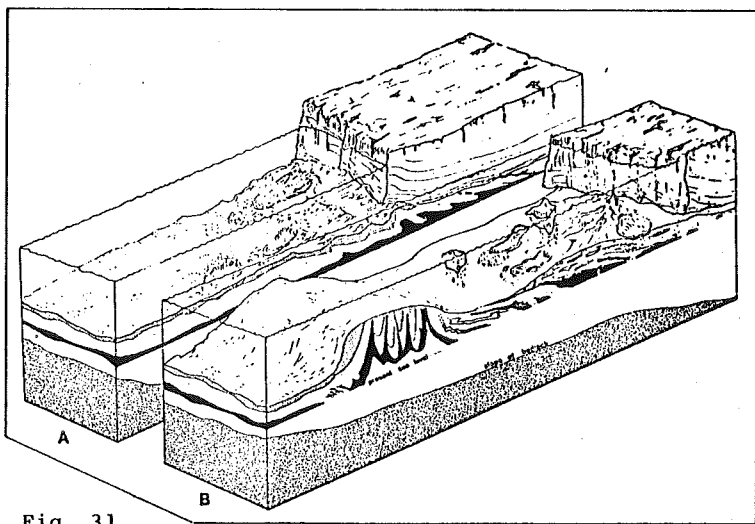


Fig. 31

Simplified schematic model of "push-ridge-subaqueous-outwash" depositional system around Shellag Point (from Eyles & Eyles 1984).

**BALLAVARKISH (NX463007, Site 13, RVD, NE)**

Between Shellag point and Phurt the sections display a series of re-advance tills which are banked off the rear of the Bride Moraine and disappear below sea level to the north. Thomas (1976a, 1977) identified three major dimict units and three accompanying outwash units. Subsequently Dackombe (1978) has revised the stratigraphy and demonstrated essentially two dimict-stratified sediment assemblages (Fig. 32).

**Ballavarkish Assemblage**

The lower of the two assemblages consists of the Ballavarkish Till and the Ballavarkish Sands. The Ballavarkish Till, which first appears in the sections 1km north of the crest of the moraine (3500m, Fig. 32) beneath the overstep of the succeeding Ballaquark assemblage, is folded into a series of open undulations in the lower part of the cliff before being cut out once again by the Ballaquark Till after 500m. The Ballavarkish Till is absent from the sections for 200m before reappearing again as low amplitude open folds before being finally cut out by the Ballaquark Till some 300m further north. Sandwiched between the Ballavarkish Till and the Ballaquark assemblage are the Ballavarkish Sands which are poorly preserved in the synclinal cores of the Ballavarkish Till. The Ballavarkish Till is a sandy till (Elson 1961) with about 20% gravel, a silty-sand matrix and only a minor proportion (< 5%) clay and it is generally of uniform particle-size distribution. Although shell fragments are fairly common complete specimens are rare and the unit could hardly be termed 'shelly'.

A variety of types of contact between the Ballavarkish Till and the underlying Shellag Sands are seen including sharp, erosive contacts, interdigitating contacts and apparently intruding contacts. Although the top of the unit can only be reached at a restricted number of sites, there is a range of contact types. The top contact is usually either sharp and shows erosion during the deposition of the succeeding fluvioglacial sands or gravels, or consists of a series of thinly interbedded sands and thin sandy tills of the Ballavarkish type.

The Ballavarkish Till can be divided into a number of facies (Fig. 33) on the basis of subtle changes in particle size distribution and internal structure and these facies occupy consistent stratigraphic positions within the unit. At the base of the unit and marking a transitional zone into the underlying Shellag Sands is a sequence of thin tills interbedded with a variety of sands and fine gravels. Features described as 'till wedges' by Dreimanis (1969) are also seen in this facies. This is succeeded by a weakly laminated, rather heterogeneous sandy till, often containing inclusions of Shellag Sand (Fig. 33). These inclusions are frequently deformed and in some cases streaked out and barely recognisable although there are a significant number of sites where undeformed inclusions are seen and these may be up to about a metre in size. Both of these two facies are interpreted as the initial deposits of the advance with ice depositing a frontal apron of stratified sediments and

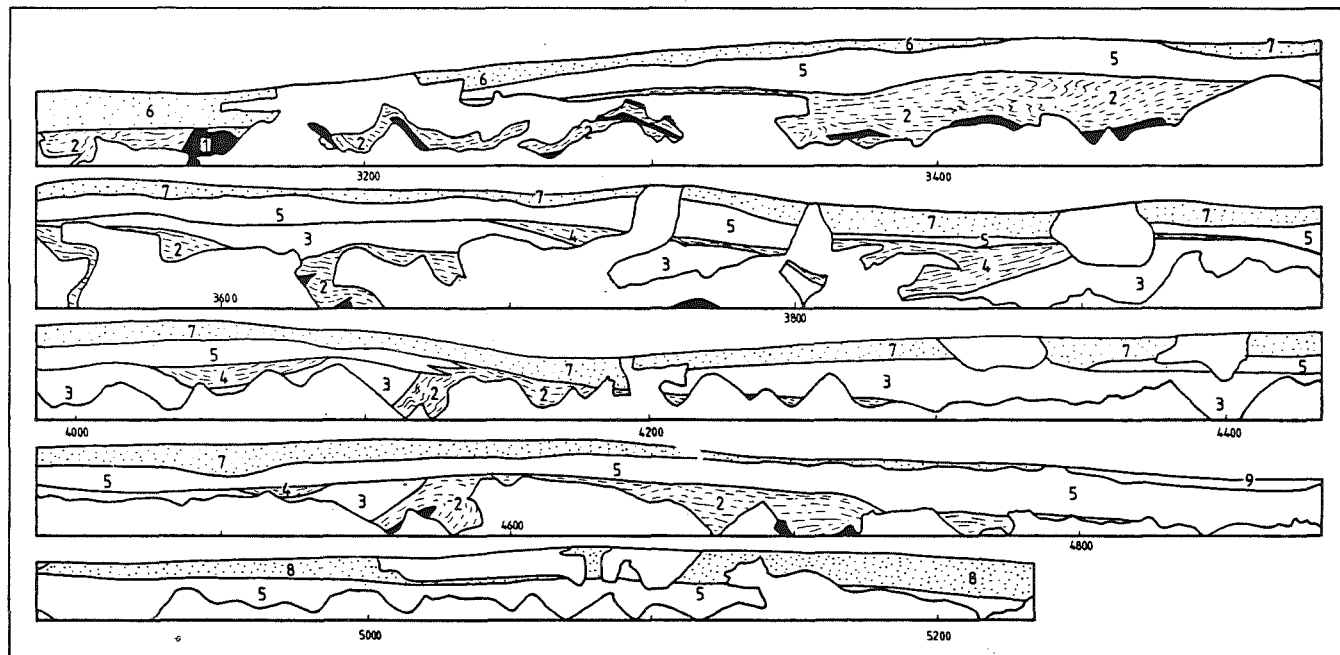


Fig. 32 Stratigraphy of the east coast between Shellag Point and Phurt.

- |                           |                       |                         |                                 |
|---------------------------|-----------------------|-------------------------|---------------------------------|
| Key:                      | 1. Shellag Till       | Ballaquark assemblage — | 5. Ballaquark Till              |
|                           | 2. Shellag Sands      |                         | 6. Ballavarkish Marginal Member |
| Ballavarkish assemblage — | 3. Ballavarkish Till  | 7. Cronk Bane Member    | 8. Cranstal Member              |
|                           | 4. Ballavarkish Sands |                         |                                 |

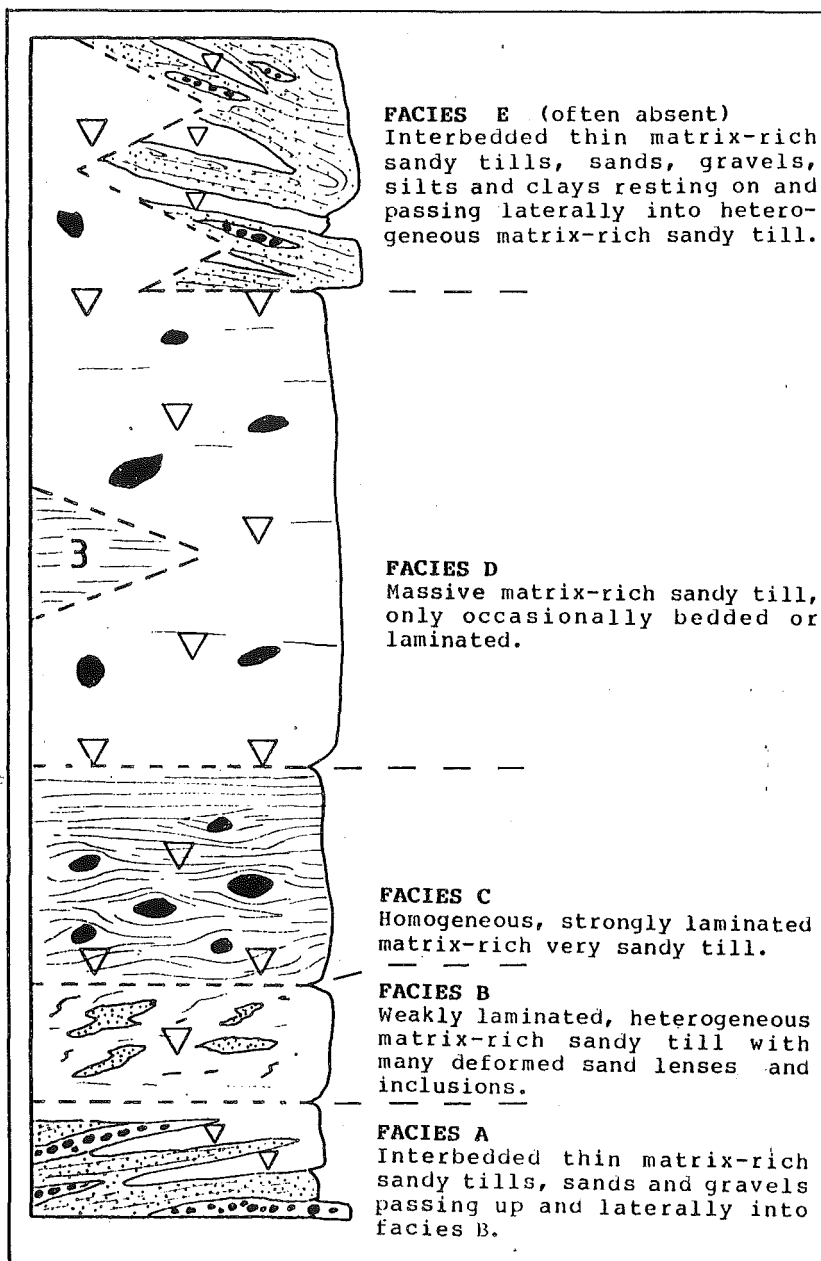


Fig. 33

The generalized sequence in the Ballavarkish Till. See text for discussion.

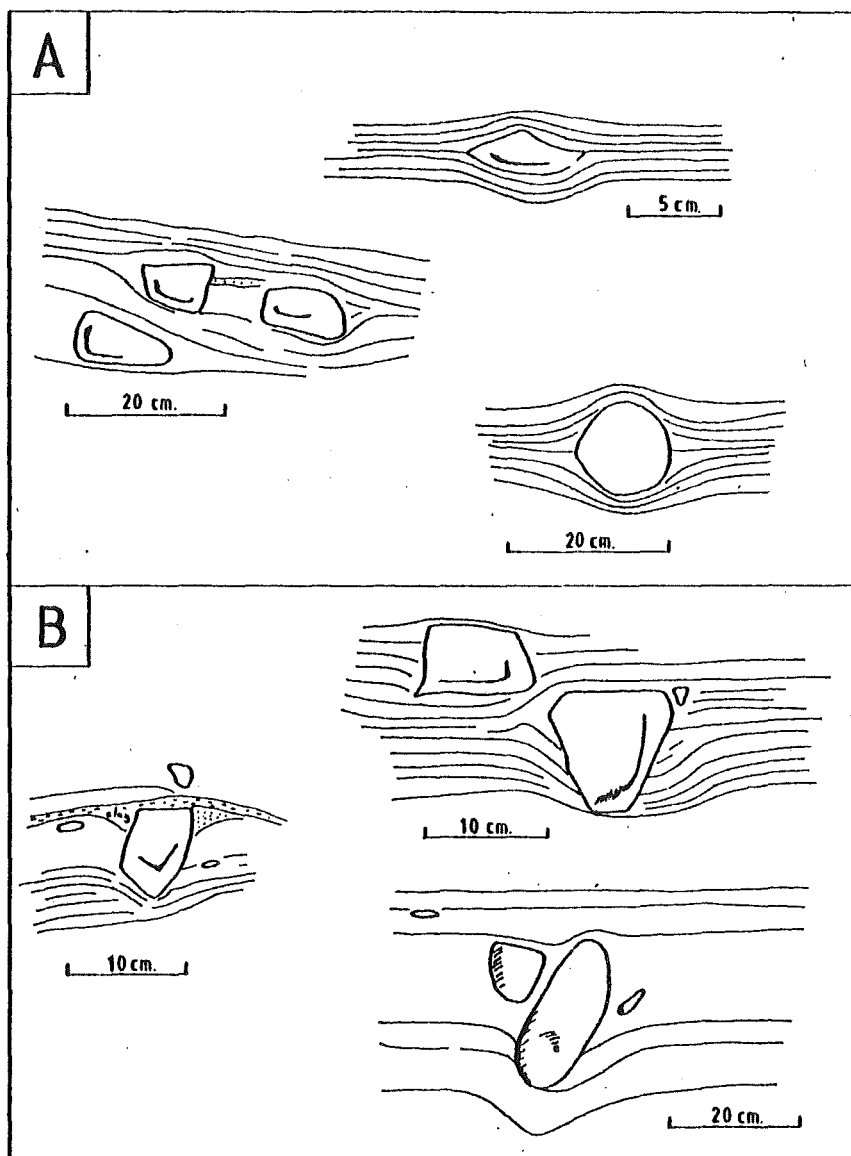


Fig. 34

Lamination styles in the Ballavarkish Till

A. 'Augen'-like structures; B. Dropstone structures



thin flow tills which are subsequently over-riden and deformed and along with earlier substrate materials incorporated within the basal till (Dackombe, 1978; Shaw, 1977). The presence of both ground-ice structures and soft-sediment deformation in the underlying sands implies seasonal freezing of the ground around the snout during this readvance.

Above this heterogeneous facies the lower parts of the Ballavarkish Till are characterised by a strongly developed lamination. The precise nature of the relationship between the clasts and the lamination seems to be crucial in arriving at an interpretation of the mode of deposition of this facies. Dackombe (1978) suggested, on the basis of the 'augen'-like structure (Fig. 34), that the lamination represents englacial stratification preserved by slow basal melt-out. However, since the general consensus is that such tills are likely to be restricted to no more than a couple of metres in thickness and this laminated facies is frequently several metres thick such a view seems untenable. At some sites (e.g. 4000m - 4100m, Fig. 32) the lamination is deformed and disrupted beneath the larger clasts and is suggestive of dropstone structures (Fig. 34). On the other hand the absence of distinct penetration and disruption of the lamination around clasts is common and suggests that the lamination is more likely to have originated in a zone of high subglacial shear probably aided by high pore-water pressures in the recently deposited till.

The major proportion (>60%) of the thickness of the Ballavarkish Till comprises a massive, sometimes crudely bedded, sandy till. Only very occasionally are thin bands of laminated dimict found far above the base of the unit and at most localities this facies persists to the top of the unit. There is little evidence to suggest that this facies is anything other than a basal lodgement till deposited by the 'particle by particle' lodgement mechanism proposed by Boulton (1975). Although occasional thin laminae of washed sand, sometimes with current ripples and other evidence of current traction occur within this facies they are not inconsistent with a terrestrial lodgement mechanism and can be explained by confined water seepage at the ice-sediment interface.

Only a few localities exist where the uneroded top of the Ballavarkish Till is seen but at these sites a continual passage from the massive lodgement facies up through a series of interdigitating sands and thin flow tills and into the Ballavarkish Sands occurs. This suggests that supraglacial sedimentation occurred during retreat although the dominance of an erosional break at the top of the till suggests that the majority of the material was reworked during the deposition of the sands. The largely inaccessible Ballavarkish Sands consists of fine to medium grained cross-bedded and rippled sands with occasional gravels.

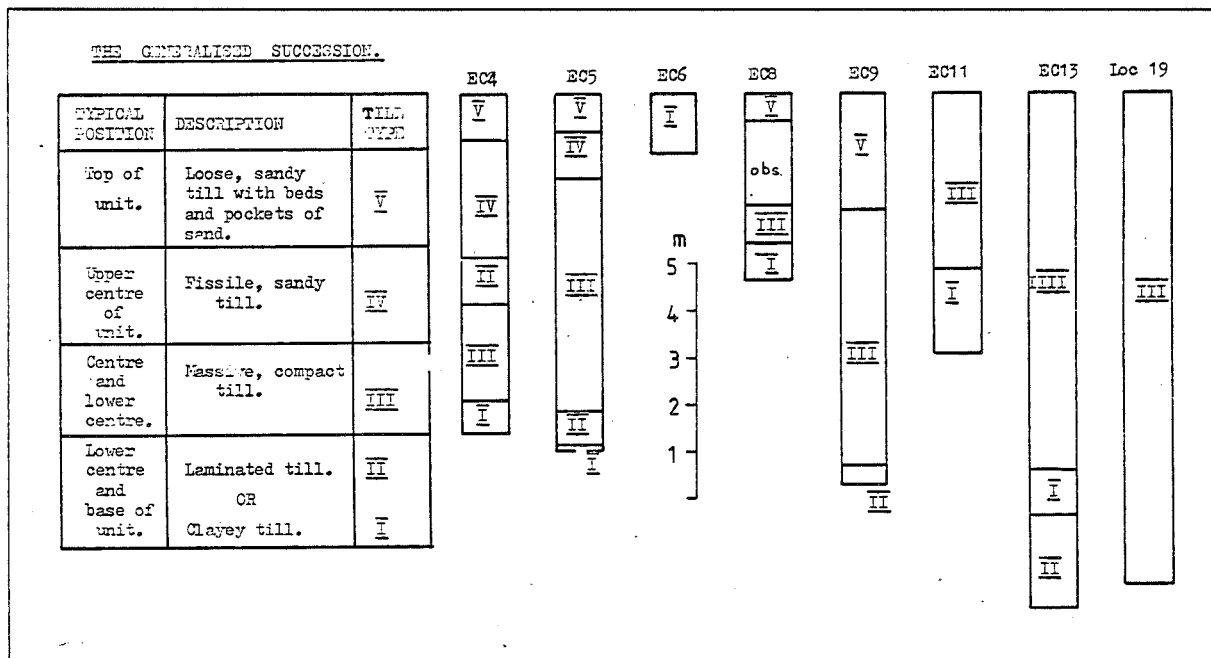


Fig. 35 The generalized sequence in the Ballaquark Till and the sequence of facies in measured sections.

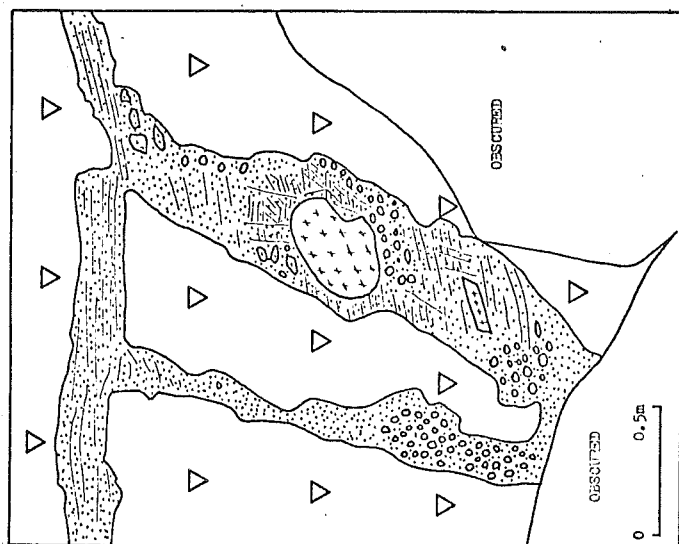
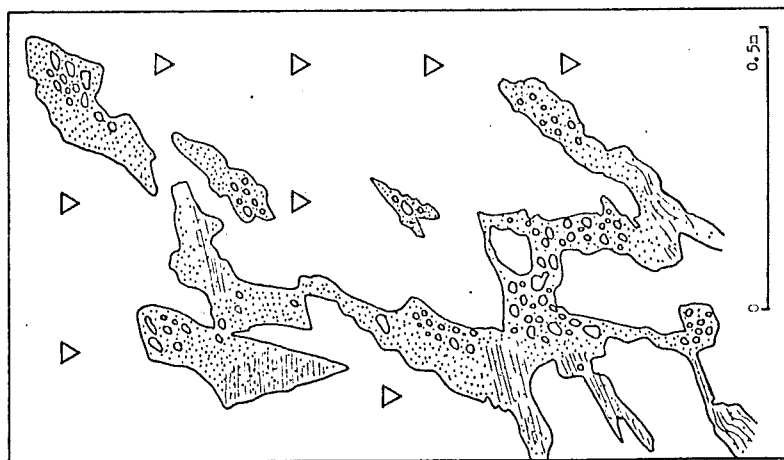


Fig. 36 Fissure fillings in the Ballaquark Till  
(3790m on fig. 32)



## Ballaquark Assemblage

The upper assemblage comprises the Ballaquark Till, Ballaquark Sands, Cranstal Till and the Ballavarkish Marginal Series of Thomas (1977). Detailed remapping of the sections (Dackombe, 1978) shows that the Ballavarkish Marginal Series is incorrectly related by Thomas to the Ballavarkish Till and it is in reality a lateral equivalent to the later Ballaquark Till and the succeeding sands and tills. Unlike the Ballavarkish Till the Ballaquark assemblage shows major lateral variations in the vertical arrangement of facies (Fig. 35) and is intimately related to the succeeding sequence of stratified sediments.

The assemblage is exposed throughout the length of the coastal sections from just north of the Bride Moraine at Shellag Point through to Phurt and it occupies a position near the top of the cliffs. The Ballaquark Till is texturally similar to the Ballavarkish Till and is differentiated from it only by internal structure and the presence of an angular unconformity. Where the two tills are juxtaposed without an angular discordance they are difficult to separate. Wherever the Ballaquark till is thin the succeeding stratified sediment thicken up and wherever the till is thick the stratified sediments are thin or absent.

Four distinct facies can be recognised in the Ballaquark Till and although they do occupy typical stratigraphic levels within the unit the pattern is not as simple as it appears in the Ballavarkish Till. Typically the base of the Ballaquark Till consists of about a metre of rather clay-rich sandy till which is either massive or poorly stratified. It is succeeded by a massive, compact sandy matrix-rich till which dominates the unit and is probably a basal lodgement till. Some 90% of the thickness of the Ballaquark Till in the northern, more proximal sections is of this facies while in the southern more marginal parts the proportion is less than 40%. At some localities within this facies there are substantial bodies of stratified sands and gravels occurring as isolated pockets, vertically elongated pipes and fissure-fillings (Fig. 36) and as crude horizontal lenses. The absence of deformation of most of these bodies, in particular the lack of compaction structures and marginal faulting suggests that they must have been cut into compact or frozen till. Ruszczyńska-Szenajch and Lindner (1975) describe similar structures and interpret them as cavity fillings developed in melt-out till. At the top of the Ballaquark Till in the more marginal areas to the south two further facies are developed; a compact sandy till similar to the lodgement facies described above but characterized by the presence of a pronounced sub-horizontal fissility which may represent the modification of the till by the growth of segregation ice lenses (Fitzpatrick, 1956; Boulton and Dent, 1974). Above this and forming the top of the Ballaquark Till is a loose, heterogeneous sandy till with frequent pockets and lenses of well sorted sands and gravels, sometimes interdigitating with the succeeding stratified sediments.

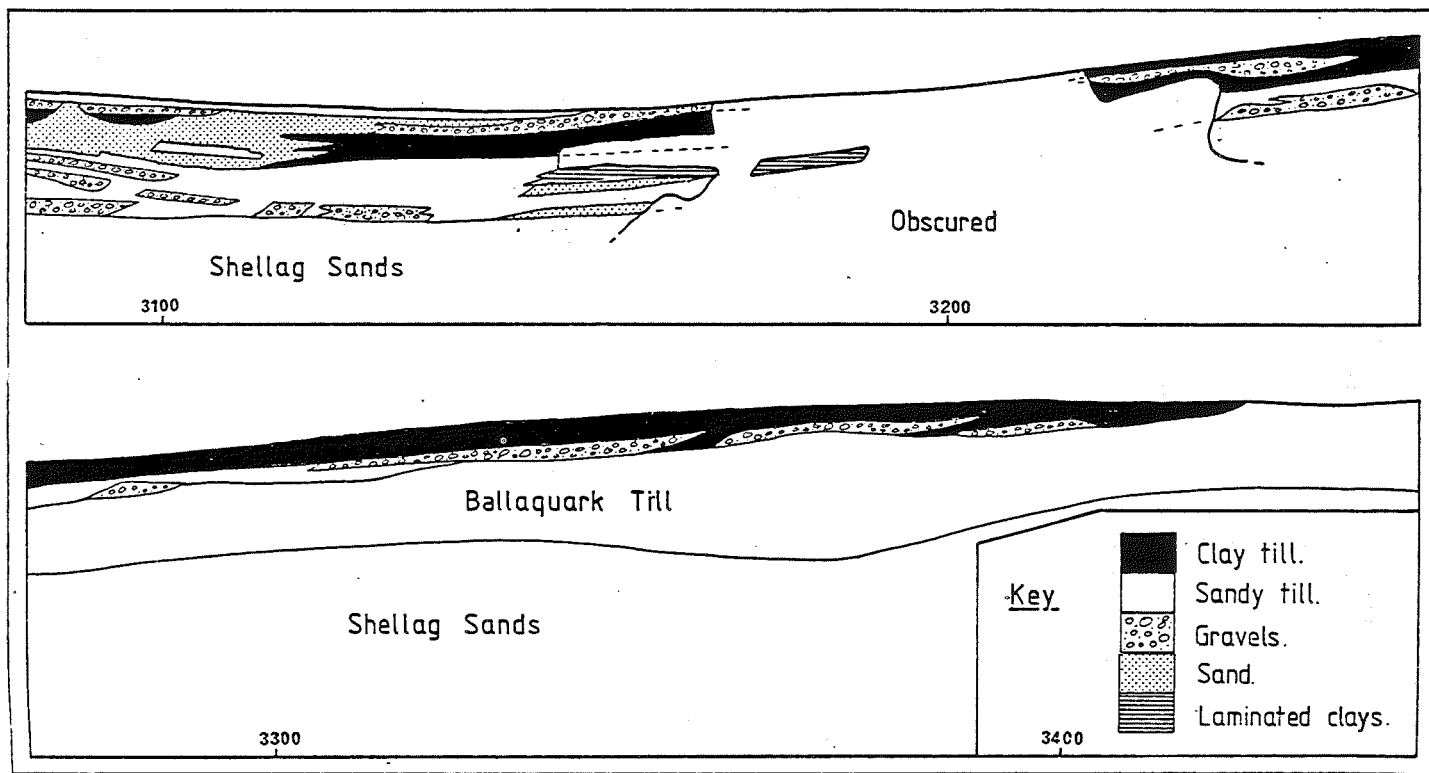


Fig. 37 Stratigraphy of the Ballavarkish Marginal Member

Above the Ballaquark Till the rest of the Ballaquark assemblage consists of three geographically separate basins of mixed diamicts, stratified sands, gravels and clays. The southernmost basin consists of the Ballavarkish Marginal Series of Thomas (1977) but can be shown to be a lateral, probably marginal, facies of the Ballaquark Till. This consists of a series of thin lenticular beds of sandy diamict, interbeds of stratified sand and some laminated clays which form a southward thickening wedge (Fig. 37) off the distal margin of the Ballaquark Till into the major valley to the north of the Bride Moraine. Within some individual diamicts lateral changes in facies may be traced between a coarse grained, gravelly proximal facies through to rather finer grained sandy or laminated silt and clay facies. The structure within the unit is concordant with the ground surface and suggests that the present topography is constructional with flow tills and fluvial sediments infilling a major channel cut by melt-water impounded between the melting ice and the rear of the moraine ridge.

Further north the Cronk Bane Member (Dackombe, 1978) forms the second basin of interdigitating lenticular beds of gravels, sands, diamicts and clays. Again bedding within the member is parallel to the top of the Ballaquark Till near the base and conformable with the ground surface near the top. The sympathetic relationship between thickness of the Ballaquark Till and that of the Cronk Bane member suggests that the latter is an assemblage of thin flow tills and stratified outwash deposited in a topographic hollow, probably a channel, between major ice cored ridges. The contact relations between the two members are consistent with such an interpretation with conformable and gradational contacts between thin Cronk Bane sediments and the thick Ballaquark Till at the ridges and abrupt and often unconformable relations dominating in the base of the channel.

At the northern end of the sections at Phurt the Cranstal Till is similar to the Ballavarkish Marginal Series in comprising a series of stratified sediments and thin diamicts. Here however, the regional slope of the top of the Ballaquark Till is towards the north and any melt-water would have been ponded along the margin of the retreating ice. This is indicated by the abundance of soft-sediment deformation structures in the upper parts of the Ballaquark Till and involving the overlying sands.

In a recent contribution Eyles and Eyles (1984) divide the Manx diamicts and associated sediments into two categories; a **fine-grained diamict assemblage** consisting essentially of the Shellag and Jurby tills of Thomas (1977) and a **coarse-grained diamict assemblage** consisting of the Ballaquark, Ballavarkish, Kionlough, Orrisdale, Cranstal and Trunk Tills.

The fine-grained diamict assemblage is typified by the Shellag diamict assemblage which is described as consisting of clast-poor fine-grained stratified and massive diamicts with traction current deposited sand laminae, a transitional upper contact with laminated silty-clays containing dropstones and passing up into an upwards coarsening sequence of massive muds with sand pillows, and horizontally laminated, rippled and deformed sands containing abundant mollusc fragments. The

combined characteristics of the Shellag diamict assemblage are interpreted (Eyles and Eyles, 1984) as the result of a subaqueous origin by mud deposition from suspension with subsidiary ice-rafting and limited traction current activity. The extensive soft-sediment deformation of sand interbeds indicates a low-strength mud substrate and with the laminated silty clays overlying the diamict at Dog Mills containing a cold water foraminifera fauna an environment similar to that of the present-day shallow-water environments close to the ice-fronts in Spitsbergen is envisaged. The succeeding sequence is seen as representing a tidally influenced shallow marine shelf environment and the uppermost gravel as shoreface deposits.

The coarse-grained diamict assemblages have a muddy-sand to silty-sand matrix, are poorly consolidated, massive or crudely to well stratified and contain discrete beds of rippled, graded and trough cross bedded sands and abundant dewatering structures. Lateral variations in texture are common and where contacts are sharp there is evidence of rapid dewatering and loading. Flow noses are present in some diamicts. It is suggested that these diamict assemblages originate in an ice-proximal position in a marine environment with the fine sands and muds being deposited by density underflows and pelagic rain-out while episodic and variable traction currents, due either to melt-water discharge or wind or tide generated, winnow the fines and deposit current bedded sand interbeds.

Eyles and Eyles (1984) recognise an upward coarsening trend in the east coast sections which they attribute to increasing proximity to the sediment source resulting from ice readvance subsequent to the deposition of the Shellag assemblage. This readvance caused glacitectonism and the construction of the Bride push ridge with the Kionlough and Trunk diamicts which contain flow noses, deformed sand interbeds and which have sharp bases which truncate the dewatering structures in the underlying sands being the result of downslope resedimentation by gravity flows. These assemblages can therefore be categorized as component parts of a "push-ridge/subaqueous outwash" depositional system.

## Discussion

Thomas (1977) and Dackombe (1978) using traditional stratigraphic and sedimentological methods and Eyles and Eyles (1984) using "detailed field logging and vertical profile analysis" arrive at radically different conclusions concerning the origin of the Manx glacial sequence. There seems to be little dispute about what features exist and where in the sequence they are found, rather there is a difference in the interpretation of those features most of which are not exclusive to any particular process or environment. Some of the main points of contention seem to be:-

1. The significance of shell material contained within the diamicts; Thomas and Dackombe (1985) maintain that in common with most other "shelly" tills around the Irish Sea basin the fauna is derived. Eyles and Eyles imply that it is in situ.
2. The significance and origin of lamination in the coarse grained diamicts; Dackombe (1978) maintains that it is sub-or englacial in origin and is due to high rates of shear in water saturated sediments. Eyles and Eyles suggest that it is due to variations in the balance of suspension and traction deposition.
3. The origin of outsize clasts and stone clusters; in the sub-aqueous model these are seen as drop-stones while in the subglacial model stone clusters are attributed to lodgement by collision and outsize stones considered to be a normal part of the glacier load.
4. In the sub-aqueous model the paucity of fines (silt and clay) in the coarse grained diamicts is seen as a result of current winnowing whereas in the subglacial model the sandy texture is considered to be a result of erosion of the underlying sands and, over a longer distance up-ice, of the mainly sandy Permian and Carboniferous sediments flooring the northern basin of the Irish Sea.
5. The model of Eyles and Eyles (1984) interprets all indicators of water saturation as being indicative of substantial submergence whereas it is quite possible for soft-sediment deformation and water-escape to take place subaerially. Similarly the presence of flow folds is not necessarily diagnostic of subaqueous slumping, especially if water contents are high.
6. Eyles and Eyles (1984) maintain that gravel and current bedded sand interbeds are common in the coarse-grained diamicts; Thomas and Dackombe (1985) counter that they are rare and that they appear common is in large part a function of selectivity in the choice of sections to log and partly a function of the lack of significance attached to stratigraphic divisions.
7. Taken at face value the foraminifera assemblage from the problematic Dog Mills Member could be interpreted as indicating a sea level some 8 metres above that of the present. Other than that, there is little if any independent evidence for a high sea level in the Isle of Man after the deposition of the Shellag Till which both Thomas (1976,1977) and Dackombe (1978) have suggested tentatively to be of marine origin. In particular there are no obvious shoreline features on the northern slopes of the upland massif which are clad with a veneer of periglacial and fluvial deposits.

#### **LOUGH CRANSTAL (NX 455025, Site 14, GSPT, from PC)**

Lough Cranstal lies in a depression on the northern margin of the Bride Moraine at an elevation of about 9m. It is bounded to the north by a low ridge of till, the northern face of which is cut by the Flandrian raised cliff that overlooks the Ayre raised beach. The lough contains a developing fen dominated by *Iris*, *Equisetum*, *Lotus*, *Phragmites*, *Menyanthes*, *Alnus* and reed and sedge.



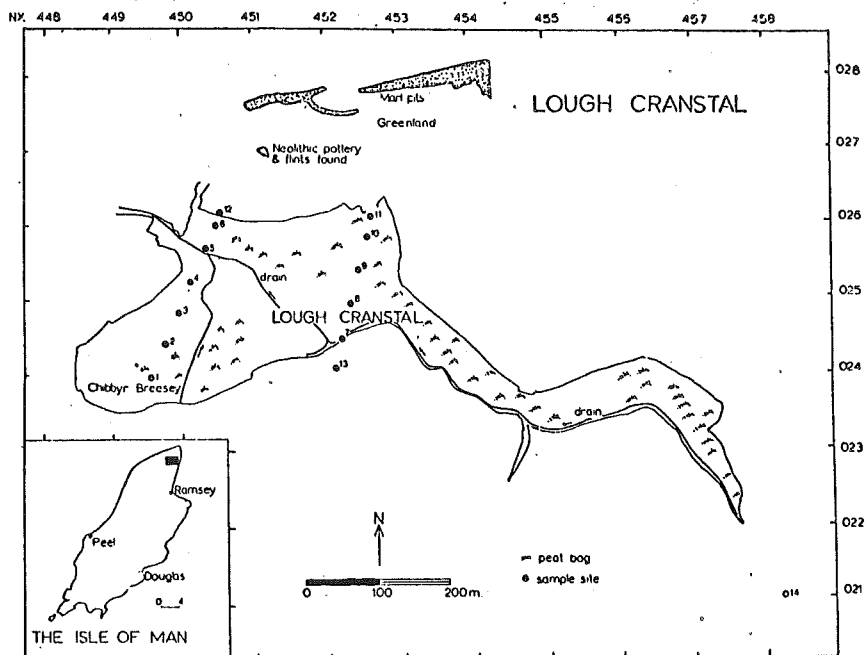


Fig. 38 Location of borings in Lough Cranstal

Borings through the lough reveal two distinct basins (Carter, in Tooley 1977). The smaller, southern basin is occupied by terrestrial sediments of turfa and detritus suggesting that fen conditions have persisted throughout deposition. The larger, northern basin is more complex (Fig. 38) and sedimentation began in Flandrian Zone I at 7,825 yrs BP (Hv 5226). The basement till is covered by a complex succession of silty gyttjas, silts, sands and clays indicating slope instability (Fig. 39). Significant amounts of mineral material were washed into the lough at this stage and the basal succession reflects a period of high precipitation causing erosion of the surrounding till ridges. It is evident from the  $^{14}\text{C}$  date at the base that the onset of deposition pre-dates the Boreal-Atlantic transition, normally dated at c. 7,500 yrs BP, but it is considered that the greater part of the basal succession was laid down during the Atlantic period of high oceanicity and increased precipitation. Diatom analysis (Fig. 40) shows no marine connection at this time.







Marine sedimentation began at a depth of +1.53 m OD, and a tenacious grey clay containing frustules of halophytic diatoms was laid down. The clay is rich in *Ruppia*, a plant of brackish water ditches and salt marsh pools. Marine diatoms, however, are quickly supplanted and then replaced by fresh water species including *Fragillaria construens*, *F. brevistriata* and *Amphora ovalis*, and by +2.21 m most salt water indicators have been removed from the flora. The basin at this time was a lagoon affected by a high sea level to the north. This impeded drainage from the lough, increased the height of the water table and encouraged the development of salt tolerant communities. The lough, however, never had an open water connection with the sea but was separated from it by a barrier beach. Marine deposition ceased at 7,370 yrs BP (Hv 5225). The marine event correlates closely, both in age and elevation, with the Lytham III transgression described by Tooley (1974) from the Fylde.

Estuarine sedimentation was replaced by deposition of lake muds. The sediments contain pollen spectra (Fig. 41) indicative of a well developed mixed oak woodland community including *Alnus*, *Ulmus*, *Quercus* and *Coryloid*. Shrub, aquatic and open habitat are very poorly represented. A Biozone II age is suggested. The Biozone II-III boundary is drawn at +5.38 m OD and at this level *Ulmus* and *Cyperaceae* frequencies fall, whilst *Graminae*, *Filicales* and open habitat expand markedly. These features are indicative of the Elm decline. One metre above the Elm decline the depositional environment changes from a limnic to a terrestrial regime and at this level *Cerealia* enters the flora in consistent frequencies. The introduction of cultivated species into the assemblage is linked with finds of Ronaldsway culture artifacts in adjacent marl pits.

Lough Cranstal provides irrefutable evidence for a post-glacial high sea during the Flandrian Zone I. This formed a cliff line along the northern limit of the Bride Moraine and impeded drainage from morainic hollows. Estuarine clays were laid down in one such basin to a height of +2.20 m OD, suggesting a maximum sea-level approaching -1.0 m OD at 7,370 yrs BP.

**PHURT** (NX 467027, Site 15, RVD and JPS)

On the coast a kilometre east of Lough Cranstal the till succession to the rear of the Bride Moraine passes beneath beach-level and is replaced in the low cliff sections by sandy clays and peats. Further north this sequence is itself replaced by the gravels of the Ayres raised beach. The section at Phurt has previously been described by Phillips (1967) (Fig. 42) Ward's (1970) account of the Ayres provides a general stratigraphic setting for the section (Fig. 43). Over the years tipping has obscured the original section but winter gales in 1984 caused extensive erosion and lowered the beach to a deeper level than seems to have been available to these previous workers.

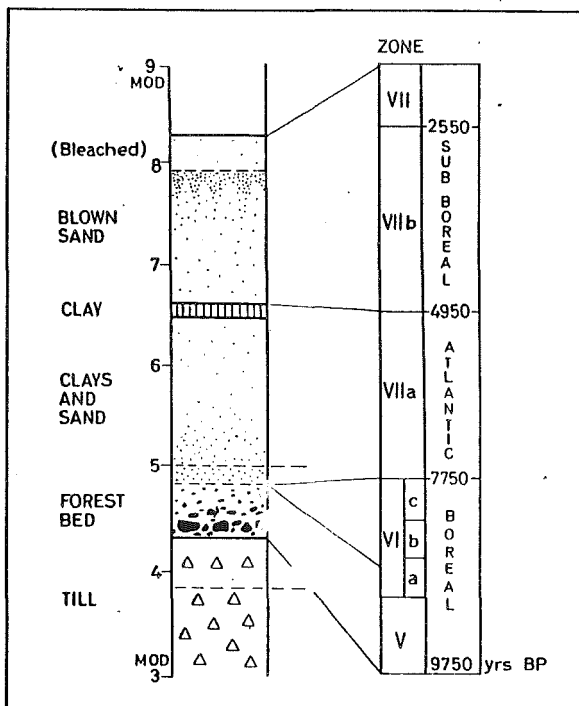


Fig. 42

Stratigraphic section at Phurt (after Phillips 1967).

In the sections exposed above beach-level Ward (1970) identified three basins of fine-grained clastic and organic sediments within the Ayres (Fig. 43b) and it is the southern-most that is exposed at Phurt. It is probable that the physiographic setting of this basin was very similar to the outer parts of Lough Cranstal and the sediments within it represent a similar if not longer time-span. Below normal beach level and only rarely exposed is a further, earlier basin of roughly the same extent as the one above beach level. The outline stratigraphy of these southern basins (Fig. 44) which include the profile described by Phillips shows at the base an irregular surface cut into a reddish brown sandy till (Ballaquark Till?). To the north of the access road the till forms the lower basin, the top of which is at about normal beach level. Where the banks of this basin are exposed a thin patchy veneer of gravel is found and, when fresh surfaces in the till are seen there is evidence of intense cryoturbation in the form of a crude, deeply penetrating polygonal crack pattern and frequent shattered stones. Deeply etched limestone cobbles and bleached granite erratics in the top of the till suggest that these higher parts of the till were once covered with a soil.

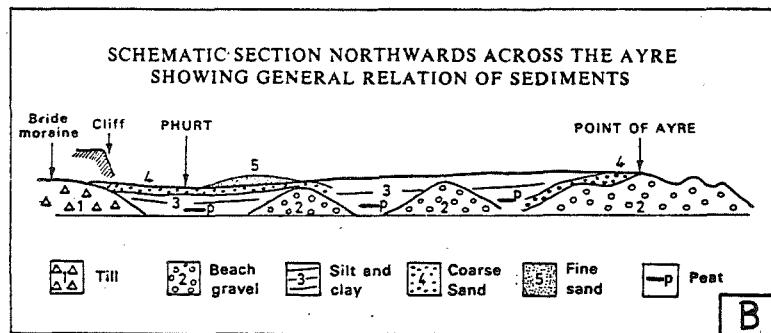
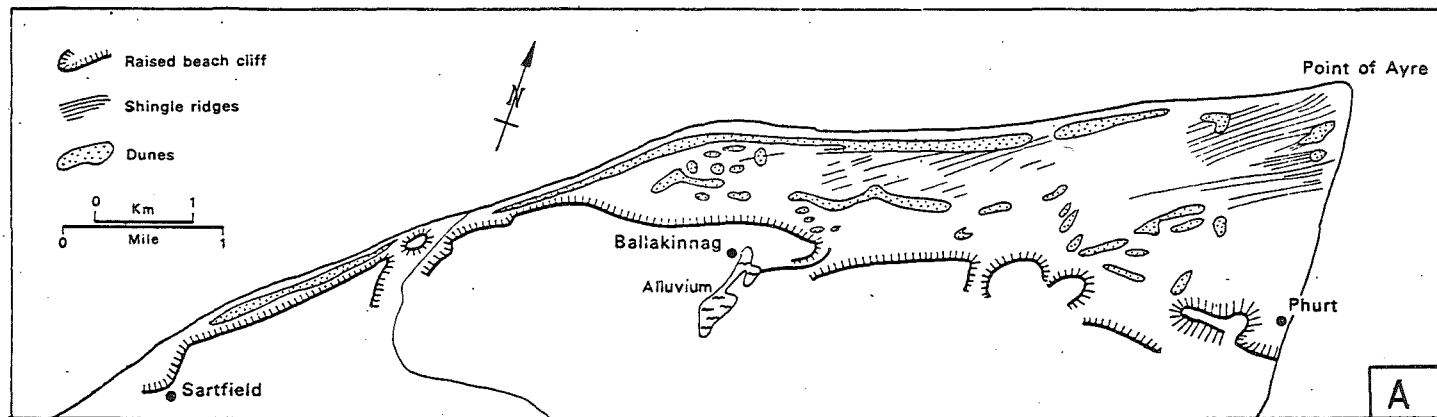


Fig. 43

A. Morphology of the Ayre Raised Beach.  
B. Schematic section across the Ayre raised beach.  
(after Ward 1971).

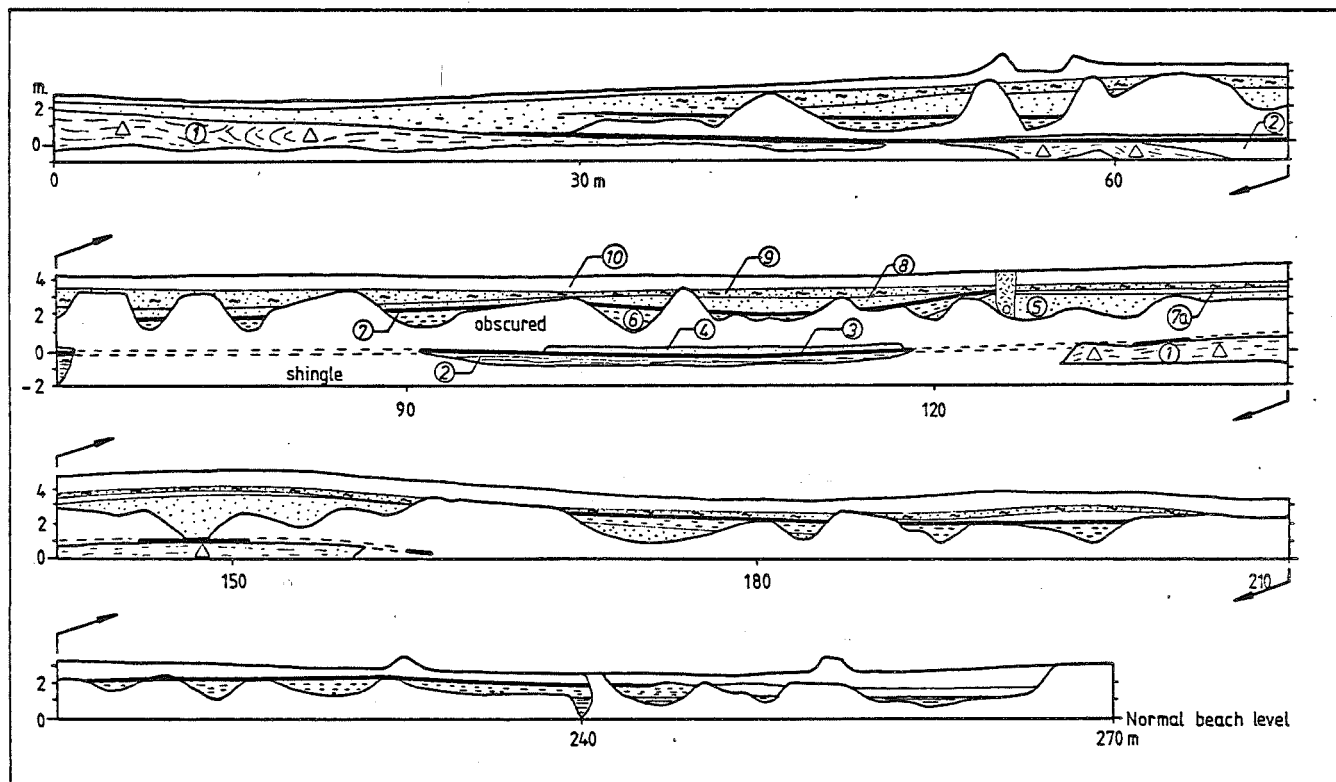


Fig. 44 The stratigraphy of the Phurt section.  
 Key; 1. Till: 2. Laminated silts: 3. 'Forest Bed'  
 4. Grey silts: 5. Blown sands: 6. Laminated  
 silts and sands: 7. Sandy peat.  
 7a. Occupation horizon: 8. Blown sands:  
 9. Ferruginous pan: 10. Recent soil.



The upper surface of the till at the base of Phillips' original section contains a scattering of vegetable remains indicative of colonization of the exposed floor. That the environment at this period was both wet and sandy is shown by the survival of remains of the common reed *Phragmites*, and by pollen of Sea Campion (*Silene maritima*) (Phillips 1967). On both the northern and southern banks of the basin, vegetation remains are seen rooted directly into the till.

The broad basin in the till is filled with a fining upwards sequence from medium and coarse sands with very occasional woody fragments through to well laminated brown clayey silts with an abundance of carbonised wood, Birch being particularly noticeable. Above the clayey silts and overstepping onto the cryoturbated till banks to both the north and south is a thin but extensive biogenic unit, the 'Forest Bed' of Phillips. This unit of peaty clay is packed with vegetable matter and well preserved, but compressed pieces of wood. Also present in this horizon are in-situ stumps and large fallen trunks of Pine, frequent smaller pieces of detrital wood, pine cones and *Typha*.

This horizon seems to represent the in-situ growth of a vegetation assemblage showing a zonation between higher and drier habitats on the till banks and a lower wetter hollow, perhaps an abandoned channel, containing the wet-loving species. Phillips (1967) describes the pollen in the forest bed as indicating a continuation of the "wet and sandy" environment suggested by the vegetation remains on the exposed till surface. He also suggests that the occurrence of pieces of oak wood indicates the age of the bed as being Pollen Zone VIa at the earliest. Birch, Hazel and Willow are also present. A discontinuous woodland environment is suggested (Phillips, 1967) by the assemblage of thistles and dandelions (*Compositae*) and the occurrence of ferns (*Filicales*, *Polypodium*) and wild parsley (*Umbelliferae*). The presence of Horsetail spores (*Equisetum*) and the common water weed (*Potamogeton*) illustrates a fresh water marsh or lake environment close by. That the whole was coastal is shown by the presence of Seablite (*Sueda maritima*) and other *Chenopods* which favour such habitats throughout the post glacial. Water germander (*Teucrium*) also occurs.

The forest bed passes up into a thin layer of crudely laminated silty clay with abundant detrital organic remains and thence up into a thin bed of silty white sand. This is in turn succeeded by about 0.5 metres of slightly sandy, light blue-grey silts. The whole of this sequence above the forest bed is penetrated by stands of *Equisetum* in growth position and ferruginous pipes are well developed around the organic remains. Occasional shells are seen in the grey silt (*Nucella lapillus*) and this suggests the accentuation of an aquatic but maritime environment. The occurrence of Elm suggests a further amelioration of climate and Pine reaches its peak (Phillips, 1967).

Phillips also suggests that there is a truncation of the forest bed in that the following sandy bed is strongly indicative of the Boreal/Atlantic transition (Zone VII/VIIa) with Pine decreasing rapidly at the expense of Alder. Zones VIIb and c would appear to be unrepresented (Phillips, 1967). There is however little sedimentological evidence in the sections currently exposed to suggest anything other than continuous deposition.

The top of the blue-grey silts marks the base of the normally exposed cliff sections as well as the final infilling of the basin cut into the till. Above this level and extending throughout the sections both above the till basin and to the north is a variable thickness of generally well-sorted, bleached coarse to medium sands. These sands form the banks which separate the three basins noted by Ward (1970) and form the substrate beneath them and probably represent the deposits of shifting sand dunes.

Only the southern-most of these basins has been investigated in detail so far but it consists of a suite of silty sands and clayey silts which show pronounced lateral facies change from the basin centre to the margins. The lowest units in the central parts of the basin contain frequent remains of reeds, both upright in life position and as horizontal mats as well as occasional detrital wood and ferruginous mottles. Higher up the sequence the silts and clayey silts are replaced by a thin light blue-grey clay with only very occasional vegetation remains. This is in turn succeeded by a grey silty fine sand with rootlets and ferruginous casts.

According to Phillips (1967) the sandy base to this sequence is strongly saline and the importance of Elm and Alder show that the climatic optimum in this area was attained during its deposition. The approach of a marine environment is indicated by the occurrence of the Alga, *Pediastrum boryanum*, which is characteristic of salt laden sands. The continued existence of fresh-water bodies is shown by the persistence of reeds. These sandy dunes are not true marine clays but probably represent the deposits of shifting lagoons amongst encroaching sand dunes. A salt marsh environment could now be envisaged, though a large amount of Bog Myrtle (*Myrica*) indicates adjacent boggy conditions of the Fen type. No indication of marine transgression is seen, though the water table remained high. These sands and clays mark the greater part of the Atlantic (Zone VIIa) period (Phillips, 1967).

The age of the forest bed is open to some debate in the absence of any absolute dates. The cryoturbation of the till surface suggests that it was exposed in Zone III times and yet according to Phillips it is not until Zone VIa "at the earliest" that the forest bed was deposited. The presence of vegetation rooted into the till banks of the basin suggests that the forest bed followed directly after the primary colonization of the substrate and was not a relatively late event. Phillips' suggested age seems to depend on his identification of oak wood in the forest bed. Bearing in mind the obvious presence of Pine in the forest bed and of Birch in the silts below it, it would seem likely that the whole of the basin fill up to and including

including the forest bed could have accumulated between Zones III and the time of the postglacial maximum sea level which may be responsible for the saline nature of the succeeding sands and silts. High sea level occurred just to the north in Wigtown bay between 7200 and 6600BP (Jardine, 1975) and this corresponds well with the cessation of marine sedimentation in Lough Cranstal at 7370BP.

Phillips' original section refers to a "persistent band of dark clay" above the silts and sands. The present section shows an organic rich silty sand at about the same level and this unit may be traced from the basin centre to the south where it thins out about 20 metres south of the access road. Traced to the north it passes into a palaeosol which rests directly on the sands which form the foundation to the basin. In the centre of the basin the unit is a silty detritus peat containing woody material, seeds and some sand. Towards the northern margin of the basin the unit becomes more sand rich, thicker and also yields charcoal and a range of artefacts. These include fragments of dark thin walled pottery, very small crumbs of a lighter, thick-walled pottery, flint cores, chippings and occasional flint blades. Most of these artefacts are thought to be Neolithic or Mesolithic (heavy-bladed).

Phillips (1967) suggests that this unit indicates a change in environment with the rise of Alder to dominance marking the late Atlantic. However, he also suggests that it contains no vegetable matter; if this is the same unit he may have been seeing a more basin centre facies, now removed by erosion which is probably of the order of 10-15 metres since his description. The unit probably represents an organic mud of a fresh water lake body that took the place of the former salty lagoons once the salt water table has fallen with lowered sea-level. the presence of Bullrushes (*Typha*) both in the underlying clays and the organic mud confirm this environment. The sands above this horizon in the basin centre are sterile (Phillips, 1967) and were probably laid out rapidly as wind blown deposits followed the retreat of the sea margin. These sands eventually curtailed the growth of the vegetation and once stabilised became bleached in the upper layers by percolation which deposited the concretionary pan below.

Eighty metres north of the access road, above the northern bank of the lowest basin the succession is different to that in the basin centre. The till is seen as a bank rising to about a metre above normal beach level and it is succeeded by patchy thin gravels and then directly by the forest bed. This is in turn succeeded by about 3 metres of crudely bedded fine to medium sands with occasional silty bands near the base. Above these is about 0.5 metres of iron stained and lightly cemented medium to fine sands with occasional organic mottles.

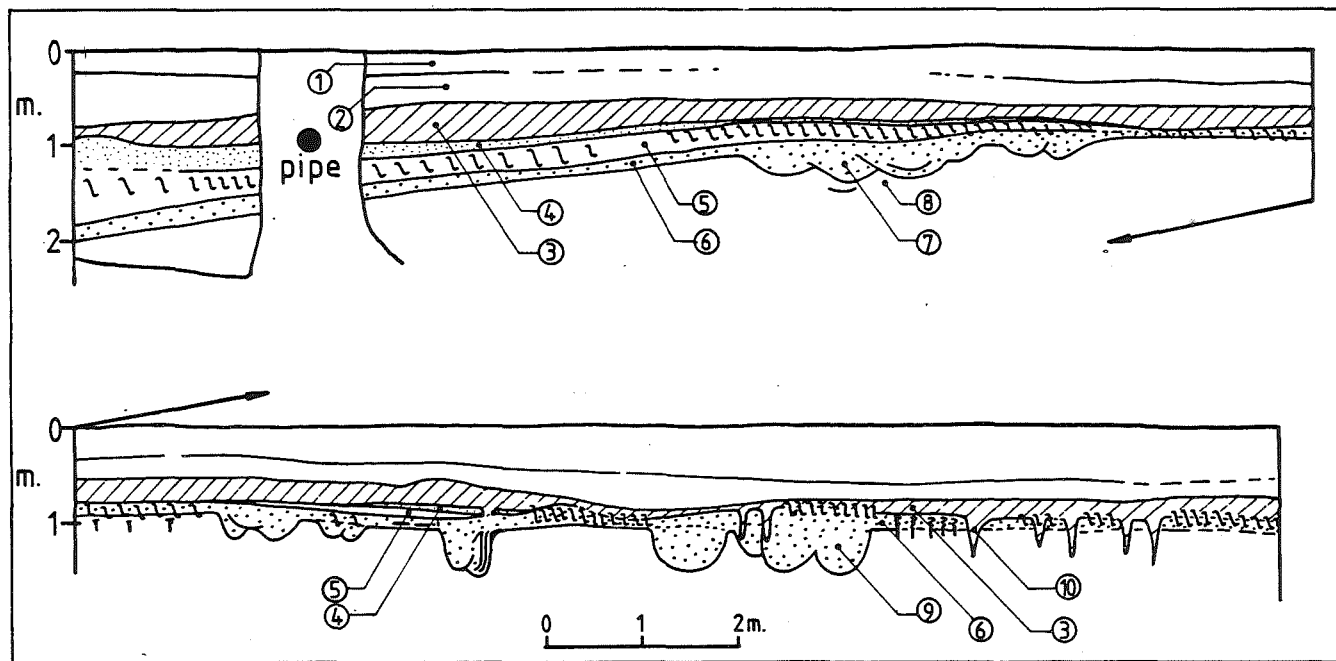


Fig. 45 The stratigraphy of the occupation horizons and palaeosols at Phurt. The top left edge of the sections starts at 122m on fig. 44 and the sections run northward. Key: 1; Present topsoil with marling at base: 2; Buff-orange sand: 3; Palaeosol, medium brown sand with small number of dispersed artefacts at the northern end: 4; Eluviated horizon of buff sand intermittent beneath 3: 5; Light orange sands often with iron pan: 6; Palaeosol, dark grey-green compact sand with artefacts, grading laterally into organic mud at the southern margin of the diagram: 7; Pits containing artefacts dug into and containing 6: 8; Orange sands with iron mottles and stains: 9; Possible grain pit with post holes at each corner: 10; Vertical "post holes" cutting through 6 and containing 3.

There follows a layer of dark grey to black sand of variable thickness, heavily cemented and containing abundant scattered artefacts. This can be traced to the south where it continues into the peaty artefact bearing layer of the southern basin. A number of pits form a downward extension of this horizon (Fig. 45) and contain a range of artefacts similar to those in the peaty horizon to the south together with much charcoal. At the top of one pit a clay 'lid' has been found, the clay being of a similar nature to that beneath the peaty mud to the south. This pit contains pot fragments and an abundance of carbonized pellets and is tentatively interpreted as a grain store. Other pits contain coherent assemblages of flint chippings and cores. These pits extend over a distance of 12 metres along the cliff exposure and are terminated at the north by a series of wedges which penetrate from the next horizon down through the dark sand and into the underlying lightly cemented sands. These wedges are filled with the dark brown fine sand that succeeds the artefact-bearing horizon and may represent post-holes. It is notable that the yield of artefacts is very much lower from the area north of the post-holes. The very heavily indurated nature of the black sands is a purely local phenomenon and is restricted to the area between the 'post-holes' and the margins of the peaty mud in the basin to the south and is probably a response to compaction caused by the repeated trampling of this occupation horizon. To the north this horizon appears as a dark brown sand with what may be ghosts of tree roots, suggesting that the occupation site was a clearing within woodland.

The succession above the occupation horizon is continued with a moderately cemented sand with closely spaced ferruginous pipes and this in turn is succeeded a brownish sand with occasional rootlets. This may represent a grassland soil developed on shifting sand dunes. A further 0.75m of sands completes the succession and consists of a lower yellow sand with modern roots and an intermittent layer of clay 'marling' nodules which marks the base of the modern soil.

#### **AYRE RAISED BEACH (NX 461041, Site 16, GSPT)**

The organic sediments at Phurt dip beneath sea-level to the north and are replaced in cliff section by beach gravels. These form part of the Ayre Raised Beach, a large and complex structure that occupies the northern extremity of the island. The beach extends for some six kilometres westwards from Phurt towards Blue Point and for some three kilometres seaward to the Point of Ayre. The beach is backed by a distinctive fossil cliff-line (Fig. 43a). At Blue Point, in the west, the cliff has slope angles of up to 40 degrees, but eastwards it progressively declines so that towards Lough Cranstal the plane of the beach merges imperceptibly into the slopes of the Bride Moraine. The southern part of the beach, which is now under cultivation, consists of silts and clays deposited in three distinct basins, the largest of which occurs at Phurt itself. Some 500 m of shingle intervenes between this basin and the two smaller ones to the north. Thin organic silts and clays occur in these basins and are sometimes seen to overlie partly cemented beach gravel. The well rounded shingle that separates the basins dips north at 10 degrees but little or no ridge form appears at the surface due to

clearing and cultivation. These gravels probably represent storm ridges forming the seaward boundary of the lagoonal basins.

The most northerly basin is terminated by a large shingle ridge, the first of a series extending to the Point of Ayre, and is accompanied by a change to heathland. The surface of the raised beach is here much diversified by the ridges and swales of the gravels, though sheets of blown sand subdue the morphology in places. Individual beach ridges dip north at angles between 7 and 10 degrees, but in some places an upper, horizontally bedded gravel truncates this and suggests a higher plane of marine erosion cut across the earlier storm ridges. Elsewhere, locally cross-bedded coarse sands overlie the beach ridges.

In the outer part of the beach the alignment of the ridges is plain and some convergence is apparent. Thus a northern group of ridges strike 065 degrees, not quite parallel to the present north coast, and a southern group strikes 075, not quite parallel to the raised cliff. Excellent sections in the more recent beach ridges occur in the gravel pits to the west of the road to Point of Ayre and wind-faceted drierkanter and flint chippings can be found around the periphery. Erosion on the east coast has removed all traces of any recurve of the shingle ridges but these probably once existed as seaward extensions meeting the now abandoned cliff to form completely enclosed lagoonal basins. Air photography comparison indicates that cliff erosion on the eastern coast of the beach is high and at least five metres has occurred since 1944.

Much of the surface of the beach reveals an intricate pattern of dunes and fine to medium sand covers much of the eastern part of the beach and increases in importance westwards. Parabolic dunes, whose tails face largely east or west are common across much of the beach surface, whilst linear forms appear restricted to the mid-beach area. Along the north-west coast a belt of double linear dunes is displayed and sometimes a third line of coalsced dunes occurs to its rear.

#### **SUB-SURFACE SUCCESSION (GSPT)**

The drift deposits of the northern plain overlie a remarkably flat platform (Fig. 46) lying between -41 and -52m OD. Manx Slate underlie the more southerly parts but is replaced northwards by Carboniferous limestones and shales. North of the Bride Hills the bedrock surface dips away to depths of at least -126m at Point of Ayre and is underlain by Permian sandstones and saltiferous marls. From a compilation of borehole records drilled in the areas of Andreas and Point of Ayre, Smith(1930) identified three major sub-surface divisions:

- (1) **Upper Boulder Clay and sands.** This includes all the diamict and clastic sequences exposed in cliff section.
- (2) **Middle Boulder Clay and sands.** Typically developed across the floor of much of the buried rock platform south of the Bride Hills, but nowhere exposed at the surface.
- (3) **Lower Boulder Clay and sands.** Seen only in the deeper boreholes at Point of Ayre at depths between -80 and -126m.

From two of the deepest boreholes at Point of Ayre, Lamplugh(1903, Boreholes I and VI) recorded a supposed marine series at depths between -55 and -69m, immediately below the Middle Boulder Clay. The cores from these boreholes are no longer available, but Lamplugh's description of borehole VI is as follows:

- (1) -60.4m Sandy clay with stones. Small worn shell fragments including *Mytilus* and *Mactra*; angular shell fragments including *Astarte compressa*, *Rhynchonella*, *Nucula* or *Leda*, *Mactra* and *Balanus*.
- (2) -61.4m Silt. Full of crushed shells.
- (3) -62.8m Gravel with shells. *Mytilus edulis* predominant; *Tellina balthica*; *Astarte sulcata* var *elliptica*, *Natica* sp, *Buccinum undatum*. Pebbles encrusted with nullipores and *Serpula*. *Saxicava rugosa* in hollows in pebbles.
- (4) -63.1m Sand. Small shell fragments, foraminifera, *Rhynchonella*, *Balanus*.
- (5) -65.2m Muddy sand with shells. *Mytilus edulis*, *Astarte sulcata*, *Mya truncata*, *Tellina balthica*, *Rhynchonella psittacea*, *Trophon clathratus*, *Turritella terebra*, *Buccinum undatum*, *Natica clausa*, *Lacuna divaricata*, *Balanus hameri*, *Balanus creantus*, *Astarte compressa*, *Astarte borealis*, *Trophon bamffius*, *Astarte* Shell fragments coated with polyzoa.
- (6) -68.9m Reddish sand. Crumbs of shell, few foraminifera. (Base of marine bed)

The age and origin of this possible marine sequence is unknown though Thomas(1977), on the basis of what Bowen(1978) has described as "count from the top" methods, tentatively suggested a pre-Walstonian age. Certainly, this sequence, as part of one of the thickest Pleistocene glacialigenic successions in Britain, remains a high priority for further investigation.

# BOREHOLE INFORMATION FROM THE AYRE PLAIN

( Compiled from SMITH, 1930 and LAMPLUGH, 1903 )

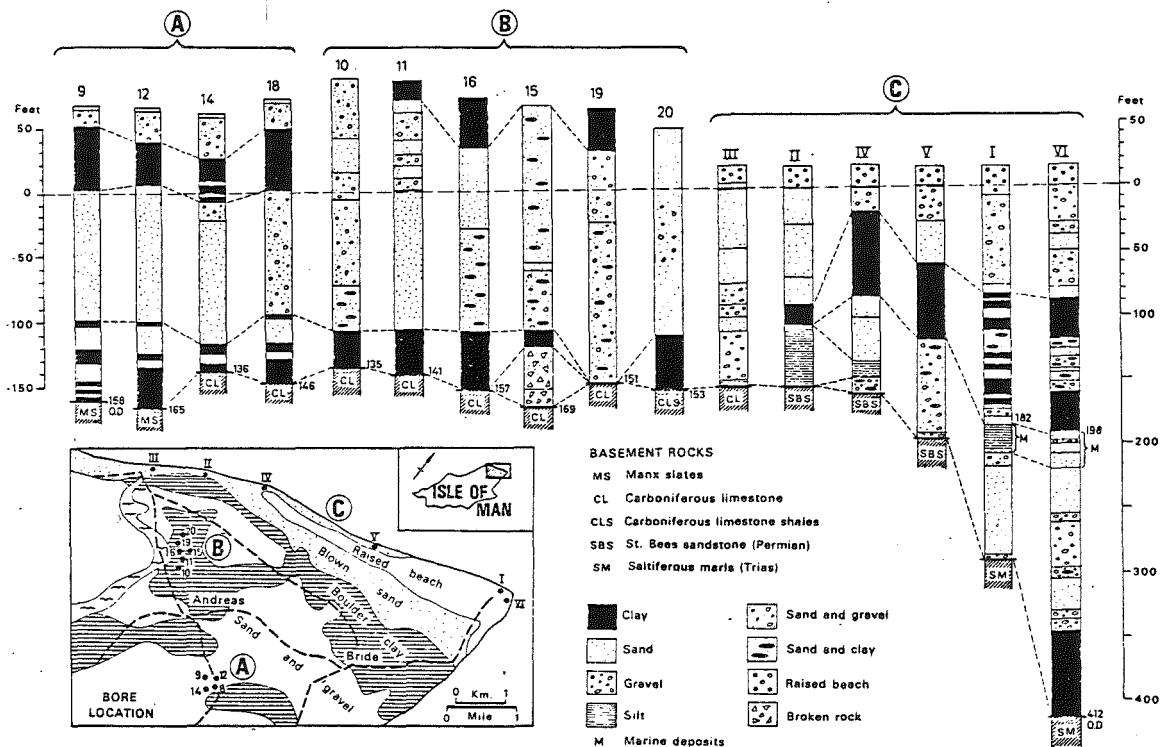


Fig. 45 Borehole data from the northern drift plain, based on Smith(1930) and Lamplugh(1903).



**Monday April 13th - Foreign deposits (West coast)**

**Route:**

- Site 17: **Sulby Glen** - solifluction terraces, valley asymmetry, alluvial fan.
- Site 18: **Curragh and Ballaugh** - Holocene lowland peat basin, kettle holes (Pingos).
- Site 19: **Killane** - Glacio-lacustrine varve sediments and ice-wedge and involution structures.
- Site 20: **Jurby Head** - Multiple till successions, ice-contact sedimentation, waterlain(?) tills, Late Devensian and Late-Glacial organic sediments.
- Site 21: **Orrisdale** - Moraine ridges, supraglacial landforms, marginal sandur sedimentation, proximal and distal outwash facies variation. Basal or glacio-marine diamict.
- Site 22: **Glen Trunk** - Basal lodgement and flow till facies.
- Site 23: **Glen Ballyre** - Late Devensian and Late Glacial organic sediments.
- Site 24: **Glen Wyllin** - Basal lodgement tills, distal outwash, Late-glacial organic sediments, Late-Glacial alluvial fan sediments. Cryoturbation structures.

## INTRODUCTION

From Glen Mooar, where they were seen to overlie both the local deposits and the Manx Slate, the foreign deposits thicken northwards and are continuously exposed in 10 km of cliff section towards Jurby. Between Glen Mooar and Orrisdale the topography (Fig. 47) consists of irregular mounds and ridges separated by sloping alluvial fans descending from the upland margin to the east. At Orrisdale Head a large ridge, trending NE-SW, intersects the coast but beyond it the ground falls to a low embayment that merges inland into the toe of the alluvial fan issuing from the mouth of Glen Dhoo. To the north, at Jurby, another major ridge intersects the coast and passes eastwards towards the Bride Moraine.

The coastal sections between Glen Mooar and Jurby were first described by Mitchell (1965) and he distinguished two major formations; the Ballateare and Orrisdale. Subsequently, Thomas (1977) remapped the area and provided a revised stratigraphic succession (Fig. 48). The basal stratigraphic member exposed is the Wyllin Till. This is a tectonically disturbed, clay-rich till, similar in all respects to the Shellag Till of the east coast. At Glen Mooar it overlies and intrudes into the Mooar Head and is succeeded by the Wyllin Sands, which contain seams of rich shelly gravel. Both these members are placed in the Shellag Formation by virtue of their lithological similarity, structural deformation and position beneath a major unconformity.

Above the unconformity, which is best displayed around Glen Wyllin, lies the widely exposed Orrisdale Formation, the three west coast members of which dominate the coastal sections. The lowest member, the Orrisdale Till, is extensively exposed across Orrisdale and Jurby Heads and comprises a sandy and stony diamict locally up to 25 m in thickness. It is succeeded by the Orrisdale Sand and Orrisdale Gravel Members. Best exposed at and south of Orrisdale Head, these members show repeated and rapid lateral and vertical passage between coarse and fine lithofacies.

The type-site for the succeeding Jurby Formation occurs at Jurby Head where a complex sequence of alternating diamicts and coarse and fine clastics overlie thick Orrisdale Till. Between Jurby Head and Orrisdale Head a low embayment is underlain by Orrisdale Till and locally succeeded by varved clay and cryoturbated sand. The sand forms the distal part of the alluvial fan issuing from Glen Dhoo. South of Orrisdale Head the Jurby Formation is represented stratigraphically by the Trunk Till Member, a sandy and stony diamict that thickens off the south face of the ridge. This member is deformed into a series of discrete basins within which rich organic infills have developed in the area of Glen Ballyre and Glen Wyllin. These organic sediments are overlain by a series of cryoturbated debris fans derived from the adjacent uplands.

During the day we shall examine all the major elements of the succession and concentrate attention on the interpretation of the diamict and coarse clastic components in the light of recent controversy concerning their origin. We shall also examine the Late-Glacial organic sequences.

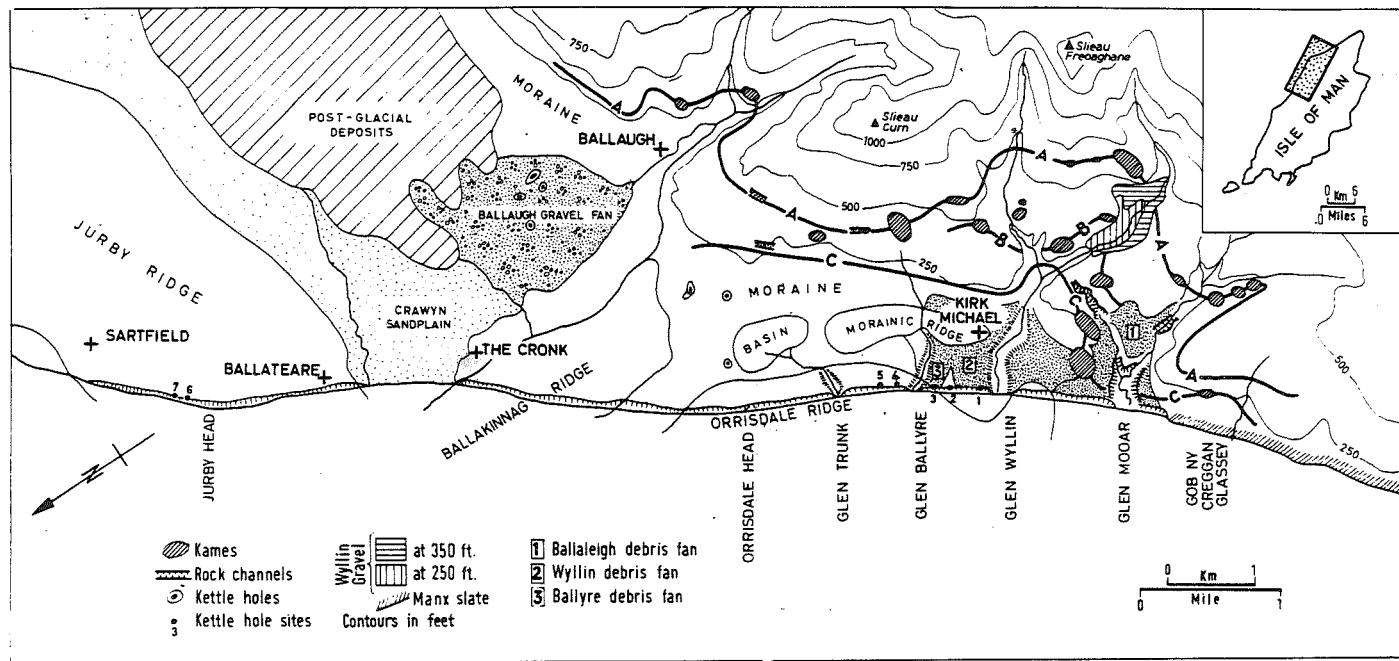


Fig. 47 Quaternary landforms and ice limits in the area of Ballaugh and Kirk Michael (from Mitchell 1965).

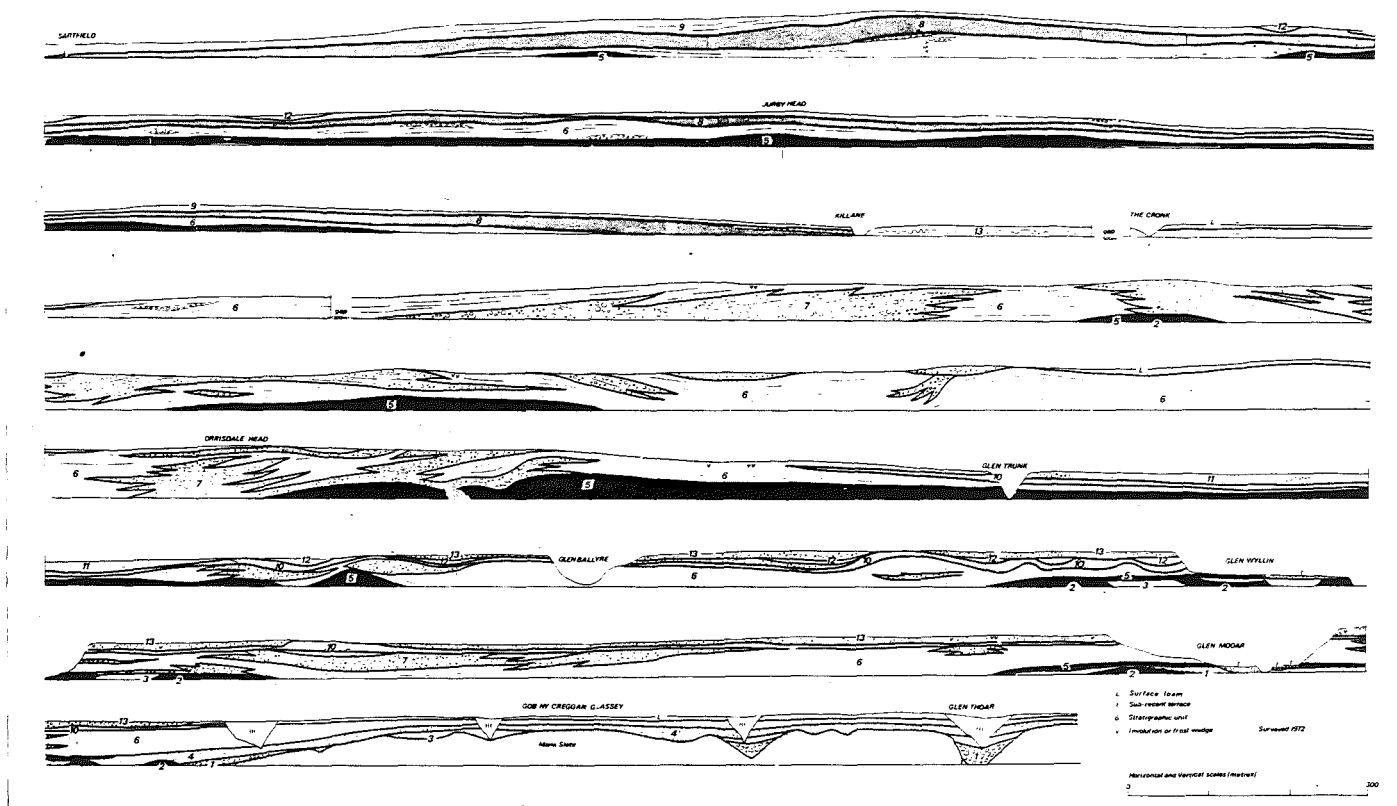


Fig. 48 The stratigraphy between Glen Thoar and Sartfield.

- 4 Mooar Head
- 3 Wyllin Sand
- 2 Wyllin Till
- 1 Mooar Scree

- 8 Jurby Till
- 7 Orrisdale Gravel
- 6 Orrisdale Sand
- 5 Orrisdale Till

- 13 Debris Fans
- 12 Wyllin/Jurby kettles
- 11 Trunk Gravel
- 10 Trunk Till
- 9 Jurby Sand

# **SULBY ALLUVIAL FAN (SC 381944, Site 17, RVD, GH & GSPT)**

Descending from the uplands, we pass down Sulby Glen, a deeply entrenched valley that drains northwards through the Manx Slate escarpment. The valley has a distinctly asymmetric form with a narrow drift terrace on its east side and a steep, rock or scree covered slope on its west. Where the valley breaks through the slate escarpment a large alluvial fan, roughly outlined by the 15m contour, run outwards onto the northern drift plain. Sections in the fan deposits are rare, but the upper parts are composed of muddy gravel of local composition and derived from the reworking of the upland drift. Similar alluvial fans (Fig. 49) issue from the mouths of Glen Auldyn and Ballure Glen to the east, and Glen Dhoo to the west, and coalesce to form a fronting apron to the slate escarpment. In the entrance to Glen Dhoo sections show foreign till underlying local deposits and capped with alluvial gravel, implying that at some early stage foreign ice penetrated a little way into the mouths of the northward draining upland valleys.

# **THE CURRAGH AND BALLAUGH (SC 3694, Site 18, RVD, GSPT, GFM)**

The Sulby fan merges on its western margin with a similar, though much larger, fan issuing from the mouth of Glen Dhoo to the west at Ballaugh. Between them lies an extensive area of water-logged ground called the Curragh. This has provided an ideal environment for the development of Flandrian wood-peat, but little work has been undertaken on the bio-stratigraphy of these thick and extensive deposits. Early maps of the Isle of Man (eg Morden's map of 1695) show the existence of small lakes around the margins of the Curragh, and the discovery of Neolithic implements, including the remains of coracles, beneath peat in the drained parts of the basin (Cumming 1848, Lamplugh 1903) leads to the inviting suggestion that these lakes may have their origins in former glacial lakes.

On the surface of the Ballaugh fan are a series of nine or ten shallow depressions. Most are elongate and have water standing in their lower parts. The direction of elongation is normal to the slope and the group form an arc along the north-east margin of the fan (Fig. 50). Lamplugh suggested that the depressions were the result of the melting of buried ice and Mitchell (1965) termed them kettle-holes. Watson (1971), however, regarded them as the remains of pingos and drew a parallel between them and active pingos on an almost identical fan near Mould Bay, Alaska (Pissant 1967). They do not, however, display raised rims.

Borings through the depressions have shown deposits of Zones II to IV age (Erdtmann 1925; Mitchell 1958 & 1965; Dickson et al 1970) and the following succession (Fig. 51) has been described from one of them (Dickson et al 1970, Ballaugh Site 2):

0.00 - 1.00m	Brown amorphous peat	)
1.00 - 1.50	Brown peat with wood and leaf debris	)
1.50 - 1.80	Brown mud, becoming grey-brown below	) Flandrian
1.80 - 1.97	Grey-green sandy mud with small pebbles; leaf of <i>Salix herbacea</i>	)
1.97 - 2.30	Alternating layers of sandy clay-mud, sand and small pebbles	)
2.30 - 2.65	As before but more muddy	) Late-
2.65 - 2.95	Brown mud with some sand becoming grey-white below	) Glacial
2.95 -	Stones	) Devensian

The base of the organic sequence lay in Zone II and *Betula* was present in some quantity, Gramineae rose strongly and *Rumex* and *Salix* showed low values. Above 2.65 m, where grasses are reduced, Gramineae fell back and *Artemisia* appears. *Lepidurus arcticus* Pallas, a notostracan whose modern distribution is circumpolar between 65 and 80 N, was very common at this level. These changes suggest a break-up of the plant cover as deteriorating climate began to make its influence felt. Zone III opens at 2.45m, where *Artemisia*, *Rumex* and *Salix* rise sharply, and Gramineae and *Betula* are reduced. Zone III ends at 2.05m, where *Artemisia* and *Salix* are cut back, and Gramineae begin their expansion to the IVa maximum; *Empetrum* expands at the same time. Gramineae then give way in IVb to *Betula* and *Salix*, the pollen of which presumably derives from bushes and trees, whereas much of the earlier *Salix* pollen comes from *S. herbacea*. Zone IV comes to an end at 1.05m, because above this level the appearance of *Corylus* pollen marks the opening of Zone V. An adjacent site at Loughan-ruy (Lamplugh 1903) yielded remains of *Cervus giganteus*, the Giant Irish Deer, during British Association excavations in the late nineteenth century. Their account of the stratigraphy makes it clear that the basin held typical Late-Glacial deposits and that as in Ireland the remains of the deer were entombed in mud of Zone II age.

The start of organic sedimentation led Mitchell to suggest that the buried ice that created the depressions did not melt out "until Zone II was well advanced", and Watson that the pingos formed "in Zone I or earlier". Dates from the base of kettle holes on the Jurby ridge indicate that a minimum date for the retreat of glacier ice in this area is c. 15,500 BP. If this is the case then it seems doubtful that dead-ice would have remained unmelted until Zone II and the most likely supposition is that the Ballaugh depressions result from the development of Pingo ice. If so then the Ballaugh, and also most probably the Sulby fan, formed earlier than this.

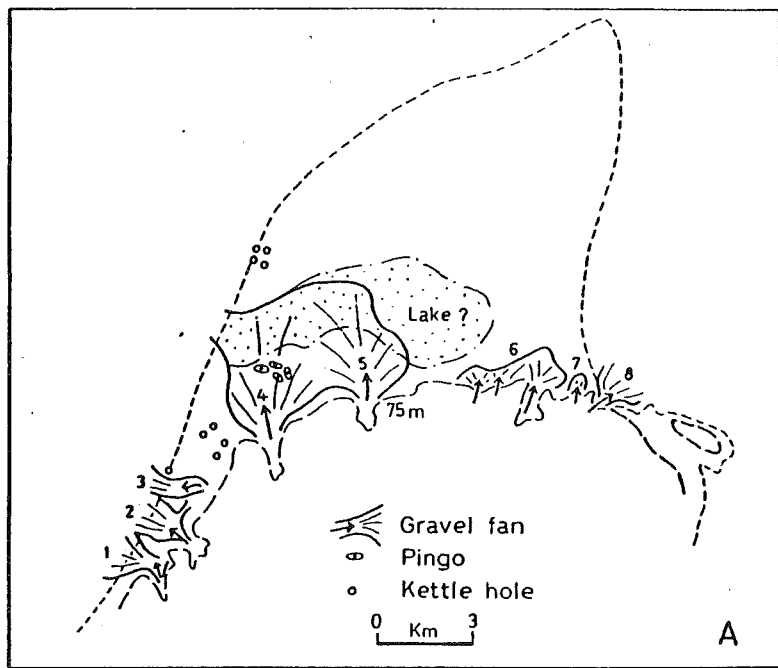


Fig. 49  
Distribution of alluvial fans around northern margin of the uplands of the Isle of Man.

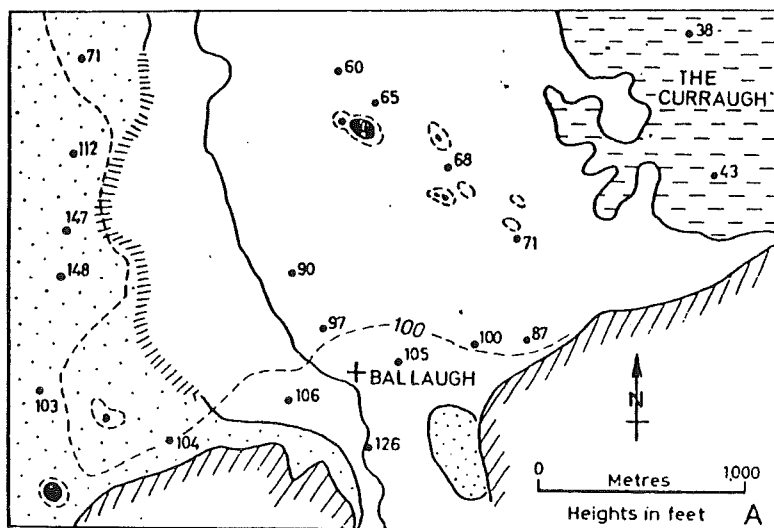


Fig. 50 The Ballaugh alluvial fan showing distribution of supposed pingos (after Watson 1970).

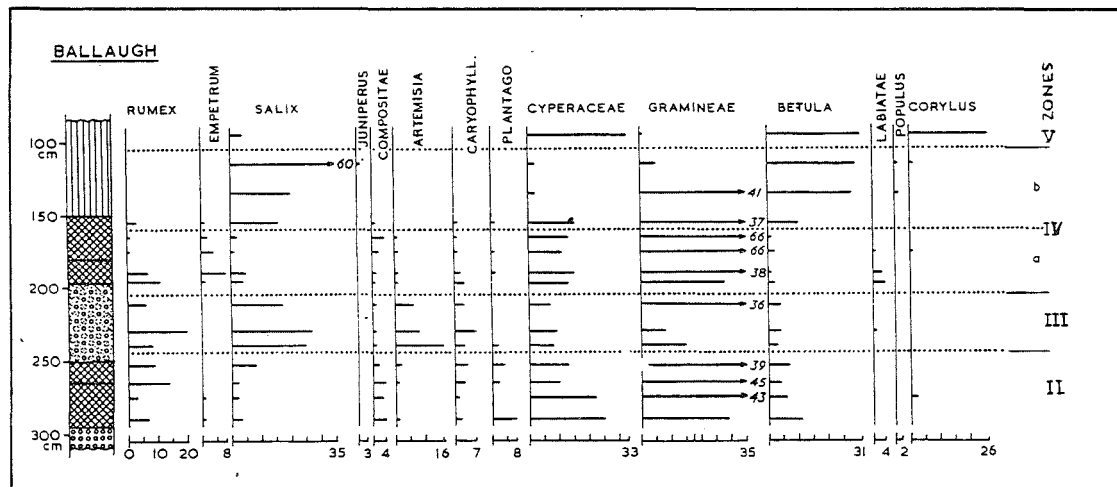


Fig. 51 Pollen diagram from Ballaugh(from Dickson et al 1970).



**KILLANE (SC 340970, Site 19, GSPT)**

From Ballaugh we drive northwest down the sloping fan surface to the coast at Killane. In this area a wide embayment separates the moraine ridge at Orrisdale Head to the south from that at Jurby Head to the north. On the north side of the beach entrance 2m of varved clay is exposed, overlying Orrisdale Till. To the north, the varved clay is overlain by steeply-dipping, coarse gravel foresets. The varve clay displays regular couplets of graded silt and clay often separated by thin intrabeds of fine sand. Individual couplets vary considerably in thickness but the ratio of coarse to fine is maintained laterally for considerable distance. At two persistent horizons in the sequence groups of couplets show slumping and flow folding, and towards the base an intraformational unconformity occurs. Within the sequence numerous small imbricate stones, or concentrically banded calcareous concretions, can be seen.

The varved clay can be traced to the south and reappears south of The Cronk. It is also known to crop out in drainage ditches along the Killane River and this suggests that it represents a lake of some extent.

The clay is progressively overlain by some 3 m of yellow-red, ferruginous sand that forms the floor of the embayment. The sand is heavily cryoturbated and structures range from small, but intense bedding crenulation, up to large, semi-circular involution basins with a vertical amplitude of up to 2 m and a width of more than 3 m. Large and small scale frost wedge casts also occur. Towards the southern limit of the sections the involution structures maintain a regular repetition at intervals between 3 and 5 m horizontally.

Mitchell(1965) termed the cryoturbated sand the Crawyn Sand and considered that it was deposited by glacial melt-water flowing eastwards. Lamplugh(1903), on the other hand, suggested that the sand was a distal facies of the large local gravel fan that issues from the mouth of Glen Dhoo to the south-east.

**JURBY HEAD (SC 343982, Site 20, RVD)**

One kilometre to the north of Killane the sections show a simple four-part sequence which is typical of the sections between the Killane and Jurby Head. At the base the Orrisdale Till rises above beach level and is succeeded by thin Orrisdale Sands. These are in turn succeeded by the Jurby Till and above that the Jurby Sands. North of Jurby Head the upper part of the sequence becomes more complex with a series of thin lenticular diamicts interbedded with stratified sands and gravels and replacing the more massive and uniform Jurby Till. Shallow kettles are developed in the upper till.

The Orrisdale Till is the most extensive diamict unit exposed on the West coast and is characteristically a matrix-rich silty-sand till with a rather variable gravel content. Cobbles and boulders, particularly of Carboniferous Limestone, are heavily striated and striations on deeply embedded boulders agree

with fabric evidence in suggesting ice flow from the north to north-east sector. Typically the Orrisdale Till is massive or crudely bedded into lenticular beds with boundaries than are either slickensided or composed of thin laminae of washed sand. The notable exception to this is at Jurby Head where the lowest part of the exposed section showed (summer 1984) thinly laminated diamict with a higher than average shell content. Intact coiled gastropods and paired bivalves were collected in addition to numerous shell fragments. Amino-acid ratios (D.Q.Bowen, pers. comm.) suggest a Late-Devensian age. The top of the Orrisdale Till is usually eroded although there are sites where it passes up into the succeeding sands via either a series of laminated clays or via a series of thinly interbedded sands and diamicts. At a number of localities in the sections 1 km north of Killane the top of the till is penetrated by vertical fissures containing pebble gravels or by features which, due to their margin-parallel laminated infill, appear to be sand wedges. Also visible in these sections are a series of steeply inclined fissures which appear to be shear planes. Erratic content is variable in composition along the coast and may show local concentrations of different source lithologies. Particularly noticeable are concentrations of Carboniferous Limestone which forms the local bedrock, although it is nowhere seen above sea-level and is proved only from deep borings. Cornwell (1971) reported a positive gravity anomaly in the Jurby Head area and this may suggest that the cover of drift over the solid is relatively thin.

Above the Orrisdale Till the Orrisdale Sands consist of horizontally and ripple laminated sands, trough and planar cross bedded sands and subsidiary gravels. In the southern parts of the section there are abundant soft sediment deformation structures with the succeeding Jurby Till penetrating into the sands. Cross-bedding dips and ripple lamination suggest deposition by currents flowing towards the south-east to south-west quadrant. Large-scale convolutions penetrate and contort the bedding in the sands to a depth of more than 2m.

The Jurby Till is a matrix-rich, clay-rich, silty diamict with a very low proportion of gravel. The gravel component consists of small, usually well rounded, isolated pebbles, many of which are resistant far-travelled species. Typically the Jurby Till is massive and unlaminated although occasional very diffuse lamination may be seen and where this is the case pebbles seem to deform the lamination. The stratigraphic relationship between this unit and the Killane clays to the south is not clear but it seems likely that they are laterally equivalent. Mitchell (in Thomas, 1971) correlated the Jurby Till (his Ballateare Till) with the Wyllin Till in the south around Kirkmichael (his "Ballateare Till"). It is now clear that the Jurby Till complex is considerably younger than the Wyllin Till and is separated from it by the Orrisdale Formation.

The Jurby Sands consist of a variable assemblage of parallel laminated and cross-bedded sands, sandy gravels and clast-supported gravels with subsidiary laminated fine sands, silts and clays, the upper parts of which are often heavily cryoturbated. Cross-bedding dip directions suggest flow towards the south to south-east sector.

At Jurby Head itself the section shows a thick succession of multiple thin diamicts resting on the Orrisdale Till and showing minor thrusting and faulting. To the north the Orrisdale Sands thicken up and the Jurby Till becomes less distinct and is replaced by a series of lenticular sandy diamicts interbedded with the Orrisdale Sands.

North of Jurby Head a number of shallow depressions in the uppermost till contain organic sequences similar to those further south at Glen Ballyre (Site 23). These kettle basins have considerable topographic expression inland. The lower part of the Coleopteran sequence in the northernmost basin (M. Joachim in Tooley, 1977) is similar in most respects to that of Faunal Units I and II in the Glen Ballyre site but shows some difference due to a different local environment. The samples appear to have been taken from near the centre of a much larger pond than those at Glen Ballyre. Evidence of cooler conditions becomes apparent above 60cm with species such as *Arpedium brachypteru* becoming common. There is no abrupt junction between the detritus mud and the overlying sands at this site.

## Discussion

The sequence in the Jurby section can be interpreted in terms of a readvance marginal complex with the Orrisdale Till representing a basal lodgement till and the succeeding complex of sands and diamicts representing the supra-glacial deposits. The relationship between these supraglacial sediments, especially the stone-poor Jurby Till and the Killane laminated clays suggests that the ice margin may have discharged sediment into the margins of a standing water body. High pore-water pressures in the Orrisdale Sands would account for their deformed nature in the southern parts of the section and their relatively undeformed nature to the north around Jurby Head. It is possible that the clay rich silty Jurby Till represents a suspension rain-out deposit as suggested by Eyles and Eyles (1984). To the north of Jurby Head however, the presence of dead-ice collapse structures and kettles containing fresh-water organic deposits would suggest a terrestrial environment throughout the deposition of the glaciogenic sequence. The presence at Jurby Head of laminated Orrisdale Till with a shelly fauna may seem to support the view (Eyles and Eyles, 1984) that the whole of the sequence is marine. There is however little other supporting evidence especially if one regards the fauna as derived.

# ORRISDALE HEAD (SC 319930, Site 21, GSPT, MC & RVD)

From Jurby Head we retrace our route past Killane and climb up the north side of the Orrisdale morainic ridge. Fine views across the Ballaugh alluvial fan towards the bold escarpment of the Manx uplands can be seen to the east. The Orrisdale ridge forms part of a large tract of hummocky drift terrain that extends in a broken arc north and east towards the Bride Moraine. The topography of the Orrisdale area is irregular and displays a complex assemblage of minor relief forms including conical mounds, flat-topped terraces, enclosed hollows, lake-filled kettle basins, subdued linear ridges and a wide variety of shallow channels (Fig. 52). South of Orrisdale, the ridge falls sharply to a narrow tract of relatively featureless terrain around Bishops Court, where lake sediments underlie the surface, beyond which, around Kirk Michael, is a further arc of mounds, ridges and basins. At the coast north of Orrisdale Head (Fig. 53) the Orrisdale Till forms a series of low ridges striking WSW across the foreshore from the base of the sections. The till is overlain by and partially intercalated with a thick and complex sequence of sands and gravels, collectively termed the Orrisdale Outwash, that show rapid lateral and vertical variation (Fig. 54). Thomas et al (1985) have identified two major litho-facies assemblages

**Assemblage A** is dominant and consists of either multi-storied sets of massive, pebble to boulder gravel separated by thin sheets of parallel laminated sands or thinner alternating co-equal sets of granule to pebble gravel and sand. Facies analysis (Fig. 55) reveals that channel fill processes predominate and the basic sediment cycle is one of scour of a channel into a pre-existing sediment surface, the aggradation of coarse-grained facies by bar migration during high flow stages and subsequent accretion of finer grained facies upon them during waning flow. The cycle starts with a channel sub-environment in which transitions from St to Gt facies types indicate the migration of increasingly larger and coarser dune sets along the channel during rising flood. These pass upwards into a dominant Gm facies indicative of a bar sub-environment. The internal structure of bars shows a crude sub-horizontal stratification and an upward fining from boulder or cobble gravel to pebble and granule gravel, often in multi-storied sets. The low occurrence of related bar facies Gp and Sp indicates no regular down-current bar advance through lee-side avalanching but movement of gravel in sheets across the floor. Diamict units occur frequently within Gm units and suggest regular shifts from debris flow to fluvial flow. Bar gravels pass up into parallel-laminated Sh facies formed in a variety of sub-environments including bar-top, bar-margin and channel floor during falling stage. Some Sh units were also formed at flood peak by avulsion across inactive bars and channels in topographically higher parts of the system to form levees and crevasse splays. Sh units pass upwards into rippled facies Sr and thence into massive or laminated thin mud facies F. This fining-upwards passage indicates a vertical accretion sub-environment formed on cut-off channel floors, in shallow scours or in hollows on bar surfaces, during low flow or by repeated spillage of water across inactive parts of the system.

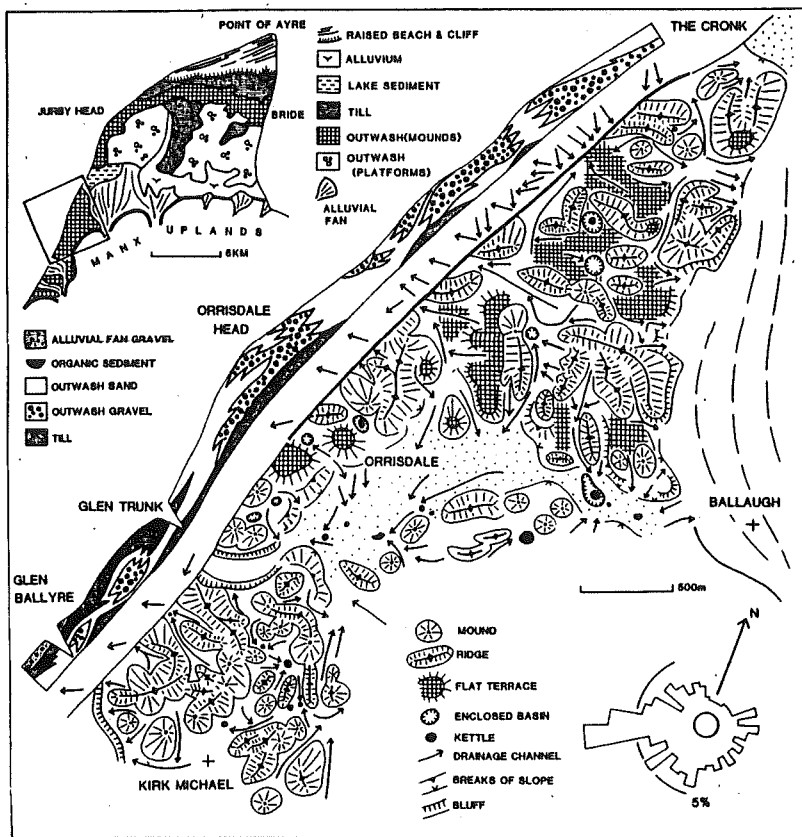


Fig. 52

The geomorphology of the area around Orrisdale showing summary litho-stratigraphic succession (viewed from SE) and spatial distribution of palaeocurrents. Inset shows summary palaeocurrent distribution (from Thomas et al 1985).

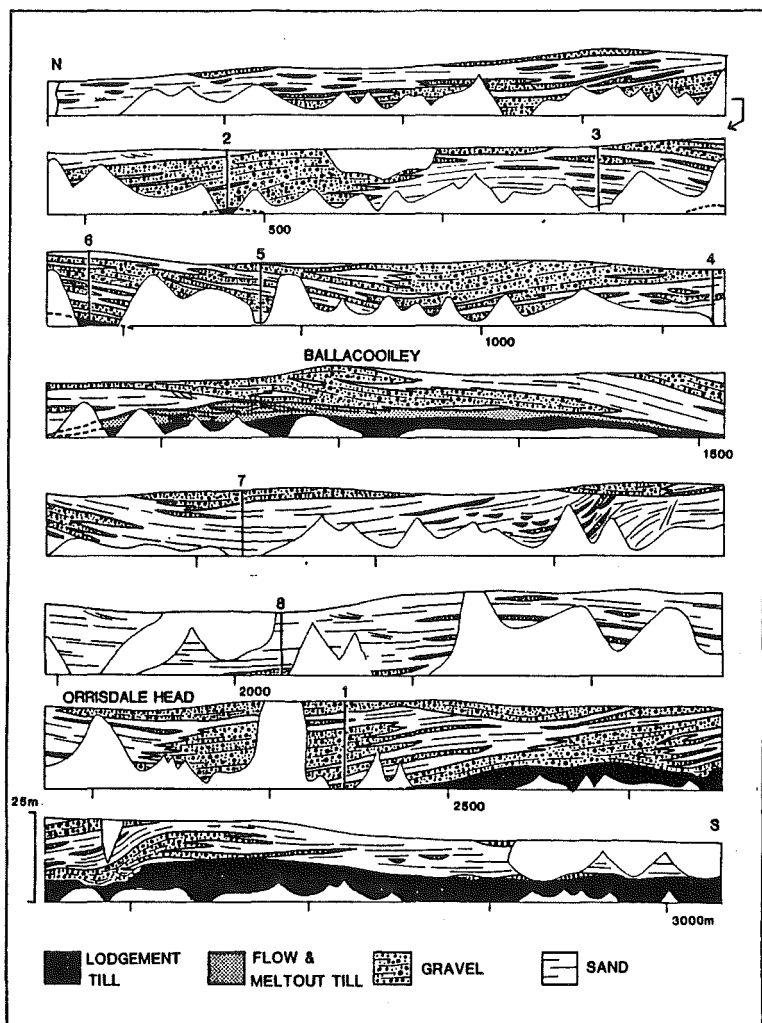


Fig. 53

Cliff sections north of Orrisdale Head and location of log profiles (from Thomas et al 1985).



Fig. 54

Log profiles, arranged in general order coarse to fine (from Thomas et al 1985).

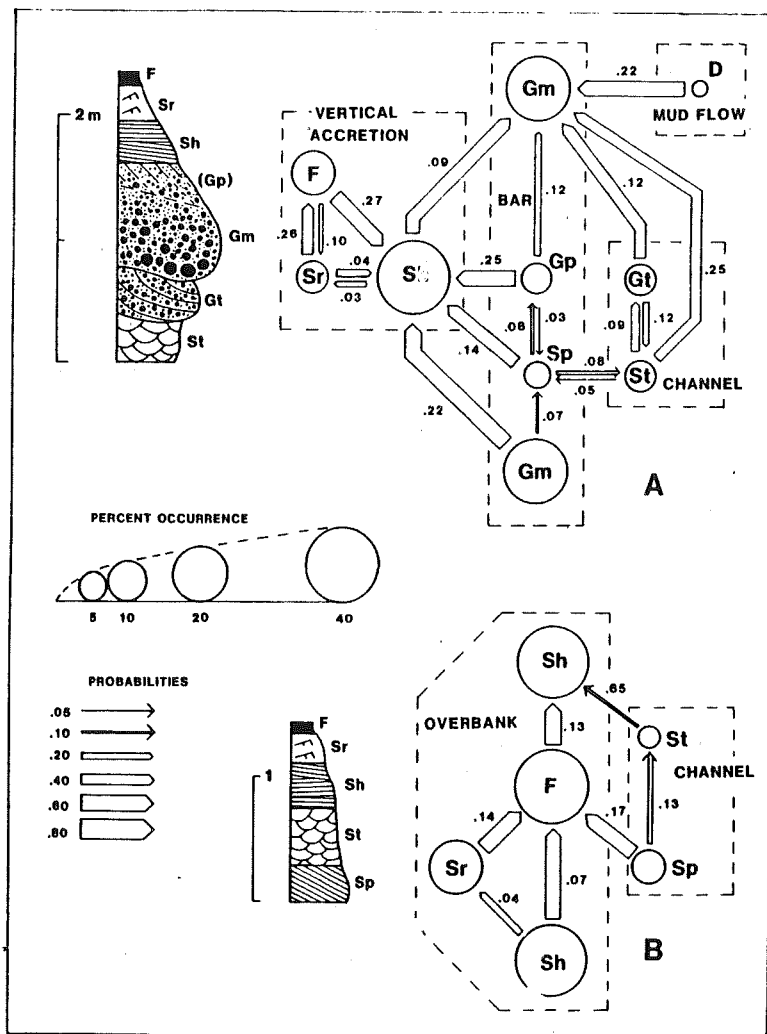


Fig. 55

Facies Relation Diagram for Assemblage Types A and B and idealised facies sequence for each assemblage (from Thomas et al 1985).



This assemblage cycle is transitional between the Scott and Donjek types of Miall(1977) and the GII-GIII facies assemblages of Rust(1978) and is typical of proximal, gravel-dominated braided streams in alluvial fans or the upper reaches of alluvial plains. Cycles, however, are markedly truncated and indicates that in high energy, gravel dominated systems, characterised by frequent sediment reworking, retention of any model cycle will be low. It may also be argued that an ideal cycle is unlikely to arise in the first place because of the operation of different processes at different topographic levels. Thus the dominant  $Sh > Gm > Sh$  shift would develop in the topographically lower parts of the system and the accretion shift  $Sh > Sr > F$  in the upper. Although the ideal cycle here contains both these sub-sequences it is unlikely that they would occur as an upward conjoined cycle.

**Assemblage B** is almost devoid of gravel and consists of parallel laminated medium sand, rippled fine sand and cross-laminated, parallel-laminated or massive mud in thin, but laterally extensive upward-fining sets. Facies analysis (Fig. 55) identifies two major sub-environments. The first is a channel sub-environment in which linguoid sand bars(facies Sp) migrated across channel floors during rising flood and pass up into small dune sets (facies St) formed in shallowing water across stabilised bar fronts during waning flow. This sequence, however, is uncommon and suggests low channel density. The second sub-environment is an overbank sub-environment indicated by the predominant upward transition from Sh to F facies, and to a lesser extent from Sh through Sr to F. These transitions form small-scale upward-fining successions that begin with an erosion surface. This is overlain by a Sh unit the base of which is often marked by small-scale cross-lamination, a slight upward coarsening and ripped-up mud clasts. This is capped by a thin F unit consisting of silty sand or mud with a wide range of small-scale structures including fine parallel lamination, cross-lamination, mud-draped sinusoidal ripples, convolute lamination and flaser bedding. The upper boundary to the next Sh unit is erosional and often marked by load casting, overturned flame and ripple structures and small faults.

This assemblage is similar, in sequence and scale, to the distal flood-generated cycles described by Steel & Asheim (1978) from the Devonian of Norway and the sandy, distal SI assemblage of Rust(1978). The lowermost Sh in the cycle indicates avulsion out of channels towards flood peak and the deposition under high-energy, high sediment concentration upper flow regime sheet flood of extensive parallel laminated sand across the flood plain (Tunbridge 1981). The existence of erosionally stacked Sh sets indicates repeated high-flow events, each truncating underlying units and incorporating ripped-up mud clasts into basal layers. These occurred near channel margins as levees or crevasse splays. Away from channels the upper boundaries to Sh units are transitional into Sr units and indicate a wane in flood flow. Further passage to laterally extensive F units suggests very low flow or suspension sedimentation in pools or very shallow lakes occupying depressions and abandoned channels on the flood plain.

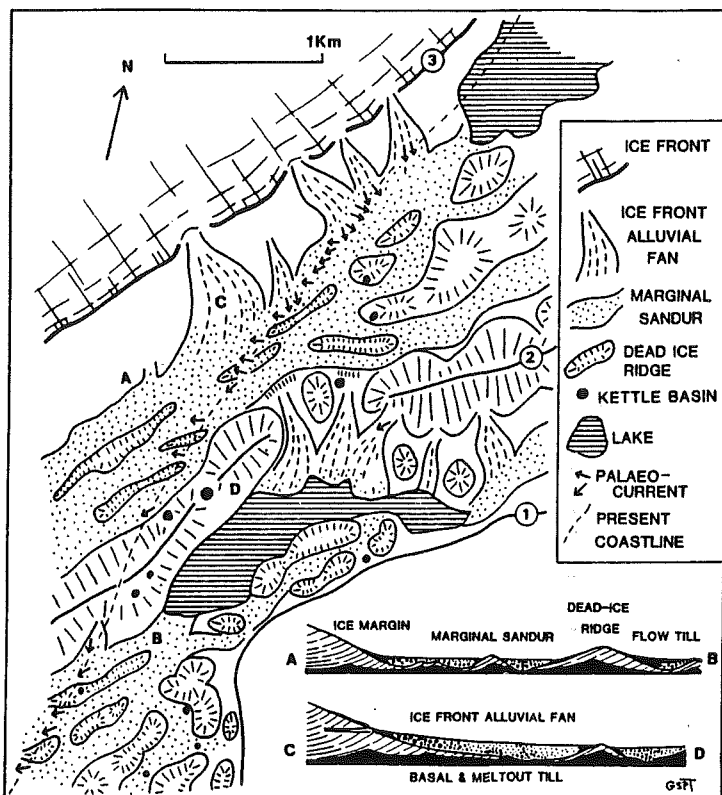


Fig. 56

Palaeogeographic reconstruction of the environments of deposition of the Orrisdale Outwash Member (from Thomas et al 1985).

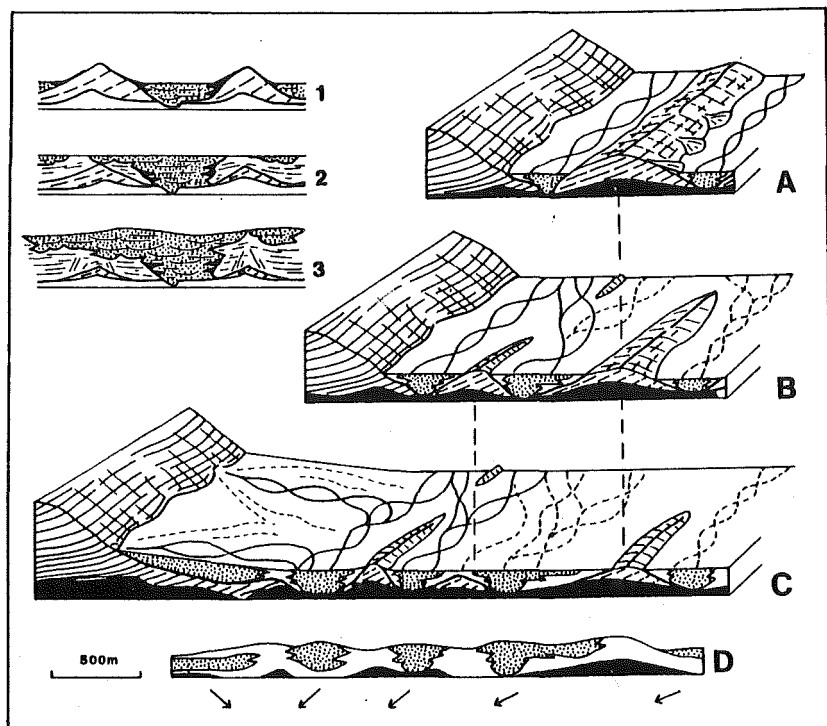


Fig. 57 Stages in the deposition of the Orrisdale Outwash Member. Inset shows stages of development of one marginal sandur (from Thomas et al 1985).

In the sections across and north of Orrisdale Head these two assemblages show repeated lateral transition but the coarser, gravel-dominated assemblage maintain a relatively fixed position through a considerable thickness of sediment accumulation. Palaeo-current indicators show a strong maximum running southwest, but when plotted spatially two regional patterns emerge (Fig. 56). In the northern part of the sections, towards The Cronk, directions are southeast; in the south, around Orrisdale Head, they are to the west and southwest.

Between Orrisdale Head and The Cronk the Orrisdale Till rises in the cliff sections to form the Ballacooiley till ridge (1100-1500m, Fig. 53). The Orrisdale Till at this site passes up into the Orrisdale outwash via a series of thin interbedded diamicts, rippled and horizontally laminated sands, massive silty clays and laminated clays. This series shows considerable lateral facies variation, particularly at the northern end of the section where some of the thin diamicts pass laterally into coarse stratified gravels containing large reworked diamict clasts up to 1.5m in size. Stratification within the thin diamicts is draped over the underlying Orrisdale Till and interdigitates with the adjacent and succeeding Orrisdale Sands. These thin diamicts contain abundant evidence of flowage with 'hook' (Evenson et al, 1977) and recumbent flow overfolds and fine rippled and washed lamination being present. This complex is interpreted as a localised development of supraglacial sedimentation within the Orrisdale Outwash and is seen by Thomas et al. (1985) as representing the position of a dead-ice ridge.

Thomas et al (1985) consider the outwash to have been deposited in a series of diachronous marginal sandur troughs formed on an unstable, ice-cored supraglacial topography and controlled by dead-ice ridges running parallel to the ice-margin (Fig. 57). In the initial stages, channels directed SW by the confining flanks of dead-ice ridges locally cut down into the upper surface of the Orrisdale Till and deposited coarse facies assemblages during successive flood events. As sediment accumulated it abutted against the margins of the ice-cored ridges and sheets of flow till were introduced. Few of these diamicts were preserved though sequences on the flanks of the Ballacooiley ridge show alternation of diamict and coarse clastic equivalent to Paul's (1983) Type 1 sediment assemblage. As sedimentation continued and as the ice-cored ridges melted down the sandur system widened. At this stage only a portion of the trough was active except in flood. Consequently, peripheral areas accumulated fine-grained flood basin facies assemblages which only formed at high flood. With the decline of these floods, sedimentation reverted to the lower parts of the troughs where sediment accumulation was slower due to regular and repeated in-channel erosion. Thus, through much of the history of filling of individual troughs the position of major sandur systems remained relatively stable. As the sequence built up, however, the importance of dead-ice ridge control declined and in a number of troughs abrupt upward fining in facies assemblage is indicative of the sudden abandonment of the channel system and its subsequent occupation only during peak flood. In other cases coarse facies assemblages shift laterally upwards to transgress adjacent basins. This resulted from the elimination of

topographic constraints and the consequent coalescence of sandur surfaces.

Moving south towards Orrisdale Head, a major ridge of Orrisdale Till rises to dominate the cliff sections. At least 22m thickness of the till is exposed in the cliff sections and it is seen to crop out on the beach at low water mark giving a total minimum thickness of the order of 28 m. The top of the till is eroded and distinct channels are cut deeply into the northern flanks of the ridge. To the south of Orrisdale Head the top of the till is more mixed in nature with some deep scours but in other areas there appears to be a continual passage up into the overlying Orrisdale Outwash. Although only infrequently exposed the lower boundary is invariably unconformable and sharp.

At this, its type-site, the Orrisdale Till is an homogeneous, very hard, massive, compact, matrix-rich sandy diamict. Typically there is about 17 - 23% gravel and about 8 - 10% clay although there is a systematic reduction in silt and clay upwards through the section. A subtle colour change occurs within the section with the upper parts being of a more reddish-brown and the lower part being more grey. Examination of the matrix and clasts suggests that this may be due to the lower layers containing reworked material from the Wyllin Till. Lamination and bedding is generally only poorly developed and the latter usually consists of rather thick, lenticular beds separated from each other by thin laminae of very fine sand, silt or clay. These features are interpreted (Dackombe, 1978) as shear lenses indicative of spasmodic sub-glacial deposition and erosion. In the lower parts of the section lamination is apparent along with the presence of some pockets of stratified material. Both the lamination and the stratified sediments show evidence of deformation with occasional attenuated recumbent folds being present. Clast fabrics show a strong maximum aligned north-east to south-west, a direction which mirrors that of deformation structure in the underlying Wyllin Till and Sands.

Dackombe (1978) interprets the Orrisdale Till as being the product of two main mechanisms of deposition with the lower, lenticular bedded and rather heterogenous facies being the product of thrust stacking, shearing and subglacial melt-out. Above this is the massive, occasionally laminated and homogeneous facies which is interpreted as the product of particle-by-particle subglacial lodgement. Eyles and Eyles (1984) interpret the Orrisdale Till, part of their coarse-grained diamict assemblage, as glacio-marine in origin and the product of deposition on an open marine shelf under the influence of ice-rafting, deposition from suspension and reworking by variable bottom currents.

# GLEN TRUNK (SC 317923, Site 22, RVD)

At Glen Trunk the Orrisdale Till has declined to form a steep lower facet of the cliff about 4 - 5m high. It is succeeded by a succession of Orrisdale Outwash that includes the Trunk Till. This unit, here at its type-site, is some 6m thick and consists of a lower facies of 0.45m of mildly contorted laminated sandy diamict and laminated silts and clays grading downwards into horizontally bedded and laminated sands. This is succeeded by 4.5m of matrix-rich, brown sandy diamict with generally <5% gravel and up to 15% clay. This unit contains occasional pockets of well-sorted sand and is transected by a series of well defined sand laminae 1 - 2 cm thick which divide the diamict into "pseudo-cross-beds". These features probably represent successive diamict flows and indicate a flow direction towards 260 degrees. In the main body of the diamict the "top-set" lamination is indistinct, but as it is traced down the dip the lamination becomes better defined and passes as "bottom-set" lamination into the lower laminated facies. Clast fabrics from the main body of the diamict show a strong maximum aligned parallel to the inferred palaeoslope and this corresponds to the type of fabric reported by Boulton (1971) from around the lobate nose of a flow till where movement takes place in a liquid or semi-plastic state. This lower laminated unit may therefore represent the distal fines-enriched facies of a flow-till. Above this main body of the till there is a 25 cm thick bed of laminated medium to coarse sands with occasional lenses of fine gravel. This separates the main body of the unit from a further much more gravel rich upper diamict which contains abundant lenses and pockets of sorted and washed sands and gravels. The top of the diamict here is sharp and is succeeded by the thinly bedded informally defined Trunk Gravels, part of the Orrisdale Outwash.

Traced to the north the Trunk Till rises above the Orrisdale Till to near the crest of the Orrisdale Ridge before declining to become superimposed on the Orrisdale Till and indistinguishable from it. Traced to the south the unit shows rapid and substantial local changes in both thickness and lithology. The greatest thicknesses are found in topographic lows and between the major gravel plugs within the Orrisdale Outwash. Hook folds, recumbent flow overfolds and starved ripples attest to the fluid nature of the material at the time of deposition. Locally variable fabrics and palaeocurrent indicators, as well as considerable faulting around the major gravels and in the vicinity of the kettles suggests collapse due to the melting of buried dead ice and consequent secondary redistribution of material (Fig. 58).

Dackombe (1978) interpreted the Trunk Till as a flow till deposited from the reactivated margin of the Orrisdale Ice during retreat. It probably represents an early phase of withdrawal of ice from the area and pre-dates the operation of the supra-glacial sandur systems to the north of Orrisdale Head which partly bury it. Eyles and Eyles (1984) consider the Trunk Till as part of their coarse-grained diamict association and the presence within it of abundant flow and dewatering structures is central to their interpretation of the Manx glacigenic sequence.

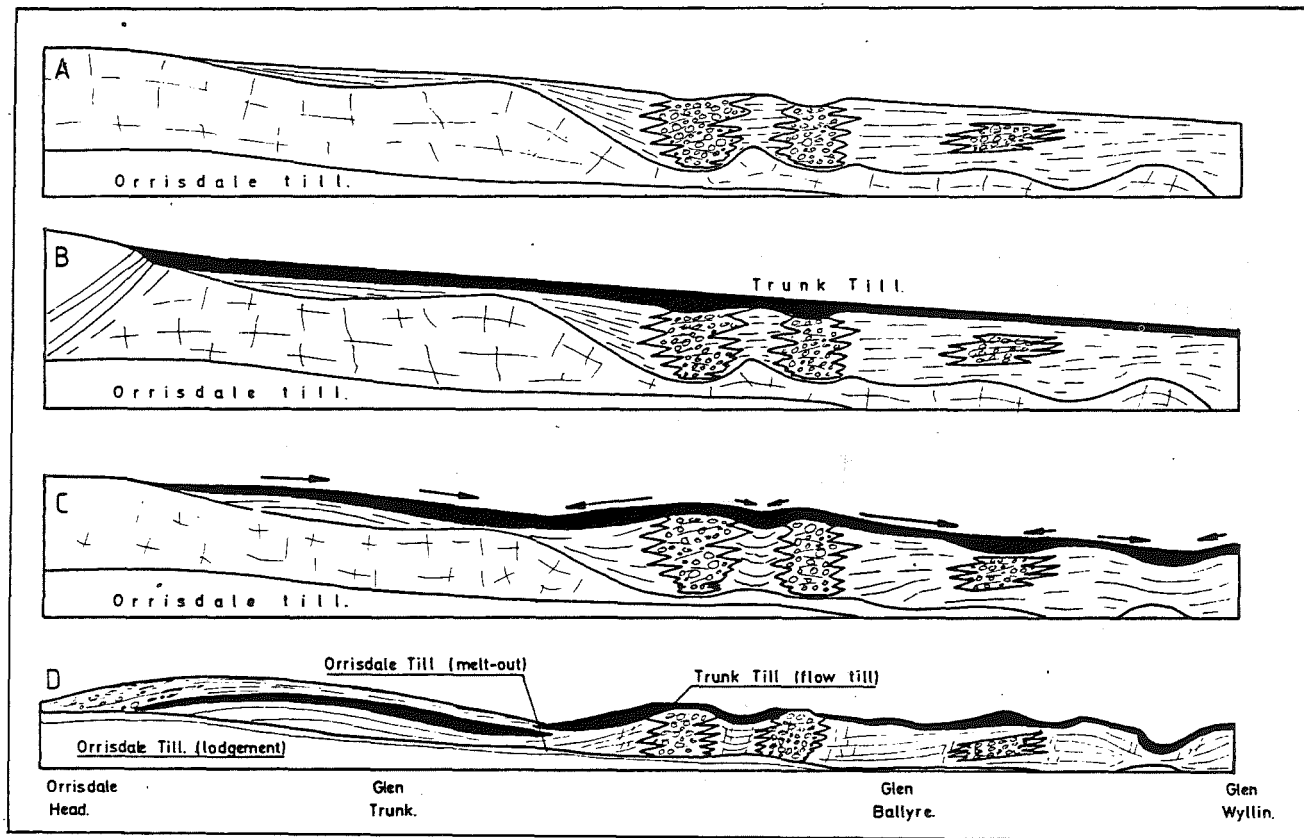


Fig. 58 Stages in the deposition of the Trunk Till. A; The form of the pre-existing ice margin and outwash topography. B; Deposition of the Trunk Till as a blanket flow till. C; Redeposition of the till as a result of the melting of buried ice and differential compaction. D; Final kettled topography.

GLEN BALLYRE (SC 314914, Site 23, MJ, GFM & GSPT)

Between Glen Trunk and Glen Ballyre the cliff sections show thick Orrisdale Till slowly passing beneath beach-level. It is succeeded by a complex sequence of outwash sands and thin diamicts, forming part of the Trunk Till. These are in turn succeeded by thick foreign gravels. Towards Glen Ballyre the Orrisdale Till reappears at the base of the sections as a series of sharp-crested ridges between which are thick plugs of gravel. Intercalated lenses of Trunk Till fill the upper parts of these troughs, which are lined in two places by organic sediment. These troughs probably represent former marginal sandur similar to those seen north of Orrisdale Head. At the entrance to Glen Ballyre the Orrisdale Till has dipped beneath sea-level and the sections are dominated by fine-grained sand facies of the Orrisdale Outwash overlain by thick local gravels of the Ballyre Debris Fan. Further organic basins are exposed in the walls of the glen but due to the thick cover of alluvial gravel they have no surface expression.

Mitchell (1965) and Dickson et al (1970) have described the succession in the organic kettle basin (site 1) 110m north of the entrance to Glen Ballyre (Fig. 59). The basin, some 30m wide at time of study, lies above Orrisdale outwash sand and is not overlain by the Ballyre debris fan which wedges in a little way to the south. Consequently it can be traced as a hollow in the ground surface above and within its perimeter there is a rich growth of *Equisetum*.

Mitchell and his co-workers did not record the basal moss band subsequently sampled by Joachim, and describe the basin as lined with sandy clay. Above this was a layer of detritus mud, the base of which was sandy and contained leaves of *Dryas octopetala*. A sample of the upper part of this mud had a 14C age of 12,150 (GRO-1616). The mud was buried by a metre of stratified sand with seams of fine gravel and clay; the upper part of which was feebly cryoturbated. This sand was probably Zone III in age. There then followed a layer of sand rich in brown organic material, and a further 1.15m of sand interrupted at a depth of 0.8m by an old soil line. Pollen analysis (Fig. 61) indicated that below 2.50m *Dryas*, *Rumex* and *Salix* are prominent and this part of the sequence was assigned to Zone I. Above 2.50m *Dryas* disappears, *Rumex* and *Salix* are reduced, and *Betula*, Gramineae and *Plantago maritima/media* type increase. *Betula* values remained extremely low and there cannot have been substantial stands of it in the vicinity. Zone II is not shown in full, having been truncated by the overlying blown-sand.

In Joachim's description the base of the organic sequence here is marked by a bed of blue-grey clay with moss bands (*Drepanocladus revolvens* Hedw. Warnst.). The clay passed upwards into a greyish silt, which gradually became browner and more organic, grading into a detritus peat with large plant fragments. The peat was abruptly truncated by windblown sand at the surface. The basal moss band was dated between 18,900 (Birm 213) and 18,400 BP (Birm-270C) (Shotton & Williams 1971 & 1973), but much doubt has been expressed concerning the reliability of these dates due to incorporation of older carbon into the organic cycle and the



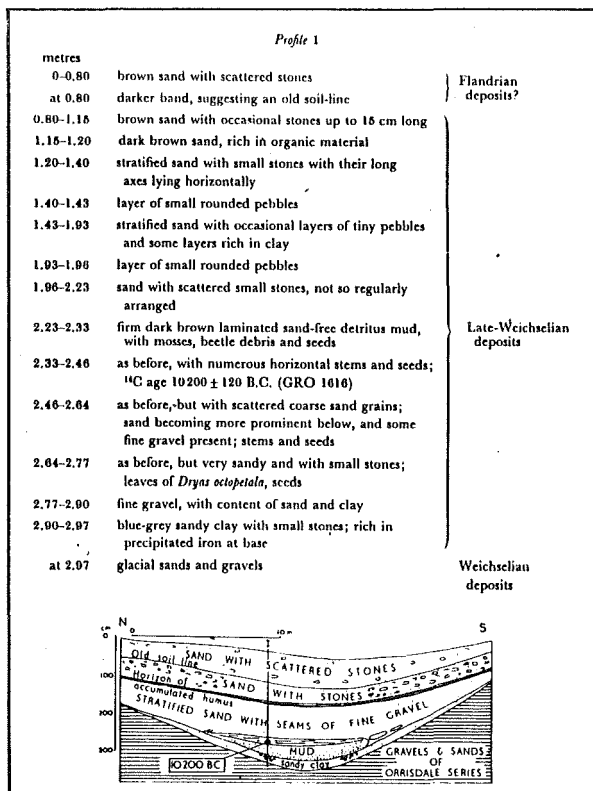


Fig. 59

Measured profile and sketch of kettle basin at Glen Ballyre (from Dickson et al 1970).

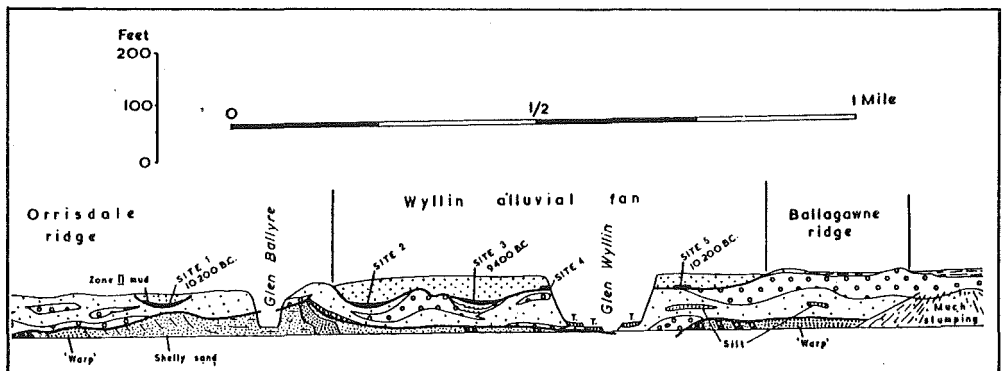


Fig. 60

Outline stratigraphic section between Glen Wyllin and Orrisdale Head, showing location and stratigraphic relations of kettle basins (from Dickson et al 1970).

possibility of fractionation of carbon isotopes during photosynthesis in *Drepanocladus*. Further dates from an organic silt 30-35 cm from the base have been dated at 12,645 BP (Birm 214) (Shotton & Williams 1971).

The Coleopteran fauna of the Ballyre site includes 194 species, of which 24 are not now native to Britain. Ground and water beetles predominate in the lower part of the deposit and suggest a pond surrounded by almost bare, damp sand. The number of phytophagous species gradually increases as the vegetation develops and the detritus peat contains large numbers of staphylinids which preyed on small invertebrates inhabiting the organic debris. The upper part of the peat is characterised by many individuals of a restricted number of species. At no time does the fauna suggest the presence of extensive woodland.

When the present day distributions of the fossils are compared, marked contrasts become apparent. The lower 35 cm of sediment contain a fauna of a predominantly northern aspect and many of the species occur today only on high ground or in Northern Britain. Of the non-British species, *Bembidion hasti* Sahlberg, *B. lapponicum* Zetterstedt and *B. repandum* J. Sahlberg occur in arctic Europe and Asia, and *Syncalypta cyclolepidia* Munster and *B. fulvipes* Sturm are found in high mountains further south in Europe. All these beetles are now found above the tree-line and the general character of the fauna is compatible with an average July temperature of some 10 C. This period, represented by the lower 35 cm of sediment, has been designated Glen Ballyre Faunal unit I.

From 35 to 65 cm above the base the fauna is noticeably different. No northern species are found and the distribution of many includes only the south of England. The change in water beetle species is less well marked than those of the terrestrial habitat but this is explained by the wider range of temperatures normally experienced on land. *Bembidion octomaculatum* Goetz has not been recorded, even from Kent and Sussex for many years and may now be restricted to southern Europe. *Asaphidion cyanicorne* Pandelle, *Metablatus parallelus* Ballion and *Coelambus marklini* Gyllenhal are all now confined to southern, central or eastern Europe and central Asia. An unidentified *Xyletinus*, which resembles *X. saraptanus* Kiesenwetter, is probably also markedly southern in distribution. Such a fauna existing today would probably require an average July temperature of at least 17 C. The sediment from 35 to 65 cm is referred to as Faunal Unit II, and is equivalent to the lower part of the Windemere Interstadial.

From 65 cm upwards the fauna changes and northerly species again make an appearance. Whereas the Unit I fauna was characteristic of bare ground and an open pond, the fauna here is largely phytophagous and is indicative of well-developed terrestrial and aquatic vegetation. From 65 to 85 cm there appears to have been a gradual cooling, and species such as *Amara torrida* Illiger and *Arpedium brachypterum* Gravenhorst are common. Above 85 cm there are far fewer species present and the proportions of beetles with marked northern distributions increases rapidly. These include *Agonum consimile* Gyllenhal,

*Diacheila arctica* Gyllenhal and *Boreaphilus henningianus* Sahlberg, all of which occur north of the Arctic Circle or above the present treeline. The fauna now suggests very acid conditions with a severe climate; the average July temperature must have been about 10 C again. The upper part of the sequence, from 65 to 120 cm, is described as Faunal Unit II and may be correlated with the upper part of the Windermere Interstadial. Above this point the sequence is interrupted and the overlying sands are virtually barren.

The presence of the basal moss band was not recorded by Mitchell (1965) or Dickson et al (1970) and there are considerable differences both in stratigraphy and interpretation of the faunal and floral evidence which are summarized below.

FAUNA		FLORA (Dickson et al 1970)	
Interpretation	Faunal Unit	Pollen Zone	Interpretation
Very cold, acid bog	III	II (part)	Thermal maximum extensive vegetation
Cool, abundant vegetation			
Warm (17 C), meadow with occasional trees	II	I	Gradual climatic amelioration, establishment of vegetation
Very cold (10 C), glaciers nearby, gradual establish- ment of vegetation	I	barren	Glacial conditions, little or no vegetation

The beetles give consistently earlier indications of climatic change than the flora and they also demonstrate that these changes took place very rapidly for beetles are far more mobile than plants, they can transport themselves rapidly across areas totally unsuited to colonisation and their life cycles are much shorter. For these reasons it is felt that the beetles provide a more accurate picture of the climatic changes during brief interstadial fluctuations; during the longer interstadials the flora and fauna records agree much more closely.

#### **GLEN WYLLIN (SC 310908, Site 24, GSPT & GFM)**

Between Glen Ballyre and Glen Wyllin sand facies of the Orrisdale outwash at first dominate the lower parts of the cliff sections. Palaeocurrent indicators trend to the south-west and the sequence is indicative of a large and complex marginal outwash sandur system, some 800m wide, operating between ice-cored diamict ridges to the north and south. Towards Glen Wyllin the outwash thins and a sheet of Orrisdale Till rises from beneath beach level to unconformably overlie sheared and contorted strips

of Wyllin Till and Sand. The Wyllin Till is a dark-red or brown massive clay containing occasional far-travelled erratics, and is very similar to the Shellag Till of the east coast. Structural measurements indicate that this till was deformed by ice moving from the northwest. Gravel horizons within the Wyllin Sand here have yielded a rich molluscan fauna dominated by the small gastropod *Turritella communis* (Lamplugh 1903, Mitchell 1965).

In the upper parts of the cliff sections the Orrisdale Sand is succeeded by discontinuous, and often lenticular units of the Trunk Till. For some 200 m south of Glen Ballyre this till is draped across the surface of the outwash but further to the south it forms the lining to a series of deep basins, each filled with thick organic sediment. A further basin occurs on the south side of Glen Wyllin. The organic fill varies between the basins and includes thick sequences of peat, organic silt and calcareous marl which has yielded the remains of the Irish Elk species *Cervus giganteus*. These basins are sealed by thick successions of local slaty gravel, similar to that seen at Glen Mooar to the south (Day 1), and formed by alluvial fans draining from upland valleys to the east. Two major alluvial fans are exposed, draining from Glens Ballyre and Wyllin respectively, and are separated by a low morainic ridge that runs inland towards Kirk Michael. According to Mitchell (1965) both these fans are early Flandrian in age but the occurrence of weak cryoturbation structures within them suggests that they are earlier. At Glen Wyllin itself a series of recent river terrace gravels in the floor of the glen unconformably overlies sections in the Wyllin Till. To the south of the glen, towards Glen Mooar (Day 1), the sections are very similar to those to the north except that gravel sheets diversify the Orrisdale outwash and a further low morainic ridge separates the southern margin of the Glen Wyllin alluvial fan from the northern margin of the Ballaleigh.

The rich organic sediments exposed between Glens Ballyre and Wyllin have been thoroughly investigated by Mitchell (1965) and Dickson et al (1970) using analysis of pollen and macrofossils and by radiocarbon dating. Assemblages totalling over 114 taxa of flowering plants, one gymnosperm, nine pteridophytes and 35 mosses were recorded from strata referred to Late Glacial Zones I, II and III; one of the richest floras from this period in the British Isles. Amongst the most noteworthy species are 46 not now living on the island; including *Dianthus deltoideus*, *Juncus balticus*, *Lychnis viscaria*, *Ranunculus hyperboreus*, *Sibbaldia procumbens*, *Mesisia tristicha*, *Helodium blandowii* and *Polytrichum norvegicum*. The vegetation comprised a great diversity of communities of open, largely calcareous grassland, snow beds, mires both base-rich and base-poor, flushes, freshwater, inundated flats and calcareous dunes. Saline conditions are indicated by *Glaux maritima* and *Triglochin maritima*. Trees were represented only by *Betula* and the taller shrubs by *Juniperus* and *Salix*. A summary pollen diagram for all the sites is given in Fig. 61.

At Site 2 (300 m south of Glen Ballyre) the organic sequence rests on Orrisdale outwash sands and is overlain by thick gravels of the Ballyre debris fan. The following section was recorded:

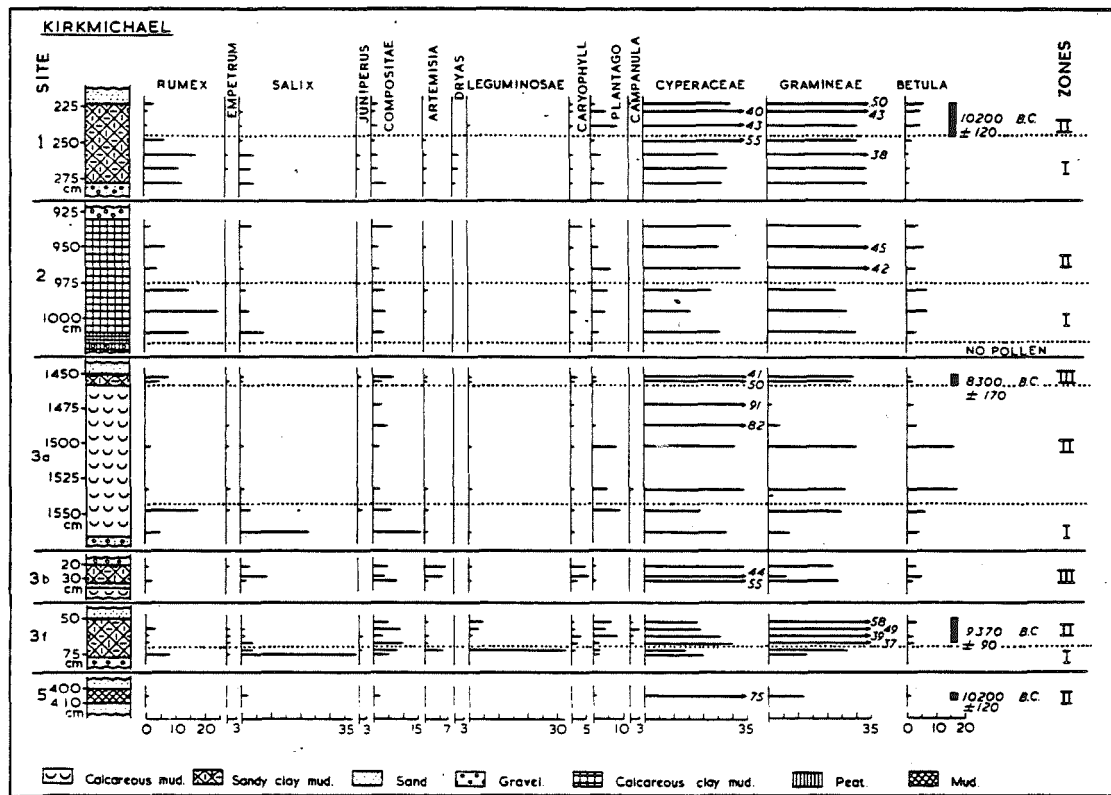


Fig. 61 Pollen diagrams from Kirkmichael sites 1,2,3 and 5(from Dickson et al 1970).

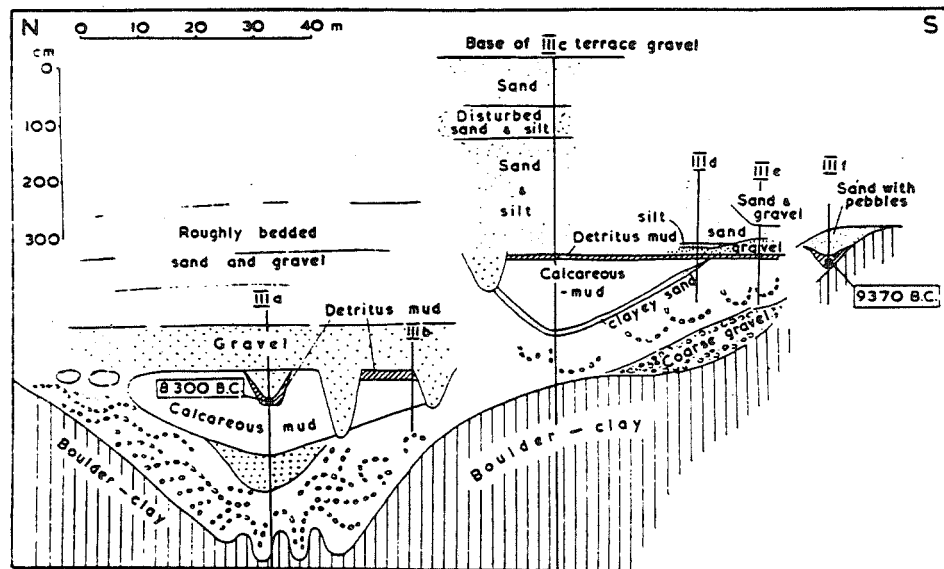


Fig. 62 Outline section through composite kettle basin, site 3 (from Dickson et al 1970).

- m (Ballyre debris fan deposits)
- 0.00-1.20 Silty sands with lenses of gravel.
  - 1.20-4.90 Bedded slaty gravel with sand.
  - 4.90-5.30 Clayey sand.
  - 5.30-7.60 Bedded slaty gravel.
  - 7.60-8.20 Clayey sand with gravel.
  - 8.20-8.80 Fine Gravel.
  - 8.80-8.90 Silt with mud and clay.
  - 8.80-9.30 Fine gravel.
- (Late Glacial deposits)
- 9.30-9.45 Dark grey calcareous clay-mud with **Chara**. Disturbed, and tongues of mud protrude into overlying gravel.
  - 9.45-10.10 Grey calcareous clay-mud with **Chara**, streaked with light horizontal bands.
  - 10.10-10.15 Very dark grey calcareous clay-mud with moss and ostracods.
  - 10.15-10.30 Dark grey clay-mud with scattered pebbles.
  - 10.30-10.50 Grey clay with bands of sand and clay-mud.
- (Devensian Orrisdale outwash deposits)
- 10.50-11.70 Bedded slaty gravel.
  - 11.70 > Sand and gravel.

Below 10.20m pollen was not present in countable numbers and only occasional grains of **Betula**, **Pinus**, **Salix herbacea**, **Artemisia**, **Calluna**, Cyperaceae, Gramineae, **Rumex** and **Lycopodium** cf/ **selago** were noted. The basal clay-mud with pebbles (10.20-10.30m) and the underlying deposits are regarded as pre-Zone I in age. Between 9.75 and 10.20m **Rumex** and **Salix** are prominent and a wide range of herbs are represented by small numbers of pollen. This part of the diagram is assigned to Zone I. Above 9.75m **Rumex** falls markedly and Gramineae rise and Zone II begins, though **Betula** again remains at a very low level. Zone II is not shown in full having been truncated by the overlying alluvial gravels.

At Site 3 (150m north of Glen Wyllin) extensive deposits of calcareous mud and detritus mud are intermittently exposed in the cliff for some 150m (Fig. 62). These deposits lie above Orrisdale outwash sands and Trunk Till and below thick alluvial gravels of the Wyllin debris fan, which cut channels into the organic sediments. Two Late Glacial ponds may be represented here, or there may have been one large pond with a floor which either varied considerably in level or was later displaced. Remains of **Cervus Giganteus** were found in this basin in 1974.

Mitchell(1965) and Dickson et al(1970) analysed a number of profiles from this complex basin; one of which(profile 3a) is listed below:

m	(Wyllin alluvial fan deposits)
0.00-0.60	Disturbed soil
0.60-0.70	Well-stratified gravel.
0.70-1.10	Much altered sandy mud, almost free of stones.
1.10-1.30	Well stratified gravel.
1.30-1.60	Brown to grey-brown sandy clay with few stones.
1.60-2.60	Well stratified coarse gravel.
2.60-2.80	Sand with some clay content.
2.80-3.10	Blue-grey sandy clay.
3.10-3.40	Stratified sand with some layers rich in clay.
3.40-3.65	Blue-grey sandy clay.
3.65-5.75	Well-stratified coarse gravel.
5.75-14.00	Roughly bedded layers of sand and gravel.
	(Late Glacial deposits)
14.00-14.50	Brown sand with small stones filling centre of channel cut in calcareous mud.
14.50-14.58	Thin alternating seams of sandy clay and sandy detritus mud, rich in moss remains. 14C age 10,350 BP(Q-673) - Late Zone III.
14.58-15.65	Sandy calcareous mud, yellow-white , with brown seams throughout. Faulted and tilted.
15.65-15.67	Green sandy mud with less calcium carbonate.
	(Devensian glacial deposits)
15.67-16.90	Rounded gravel, not disturbed.
16.90-17.05	Sand.
17.05-17.95	Frost-heaved gravel, with many fragments of slate.
17.95-18.85	Frost-heaved Trunk Till, with gravel as above in hollows.
18.85-20.10	Trunk Till.
20.10-36.00	Orrisdale outwash sands and gravels.
	(Unconformity)
36.00-41.00	Wyllin Till. Contorted.
41.00	Modern beach.

Before the freshwater muds accumulated, a slaty layer of gravel was deposited on a layer of till. Cryoturbation followed with the result that the surface of the till was drawn into peaks and hollows, the hollows becoming filled with slaty gravel. Below 15.40m *Rumex* and *Salix* are prominent, and below this level the deposits must belong to Zone I. Above this level *Betula* and *Gramineae* rise and all the upper parts of the calcareous mud probably belongs to Zone II, even though the top sample, due to the presence of anther fragments of *Cyperaceae*, show 90% of this type of pollen. At this site *Betula* values rise to 15% of all non-aquatic pollen, and there may have been some development of birch copses in the immediate vicinity. Though the calcareous mud has some sand content, its white color showed that it was essentially clay-free and the surrounding plant cover must have been virtually complete at the time of deposition. The overlying



sandy detritus mud was in a channel cut into the calcareous mud and rested unconformably upon it. In addition to high values for Cyperceae it also had some content of *Rumex* and low values of *Betula*. It must be later than Zone II, but the relatively low values for Gramineae suggest that it cannot be as young as the opening of sub-Zone IVa. Radiocarbon gave an age of 10,550 BP(Q-673), and it may be placed in a late stage of Zone III.

#### MINERAL MAGNETIC STUDIES OF THE MANX TILLS (JW, JPS & RVD)

Despite the fairly wide use of NRM and susceptibility anisotropy in studies of till fabrics and structures, little attention has been paid to the characterisation of the magnetic mineral assemblages present in tills. Vonder Haar and Johnson (1973) used mean susceptibility as an additional tool in stratigraphic differentiation and correlation. Recently, Thompson et. al. (1980) have shown that the use of parameters dependant upon magnetic mineralogy (i.e.  $\chi$ , SIRM, ARM etc.) are a sensitive, reliable, quick and non-destructive means of sediment characterisation. Such mineral magnetic assemblages can remain stable in a range of detrital depositional environments and reflect in part erosion source.

Studies are currently being carried out to evaluate the usefulness of such an approach to studies of provenance and stratigraphic correlation of the Manx tills and selected tills around the Irish Sea Basin. Although this work is still in the developmental stage, preliminary results on both the matrix and clast components of the Manx tills indicate ordered similarities and differences in their make up. Fig. 63 shows a summary of the the mineral magnetic linkages between four of the major till members.

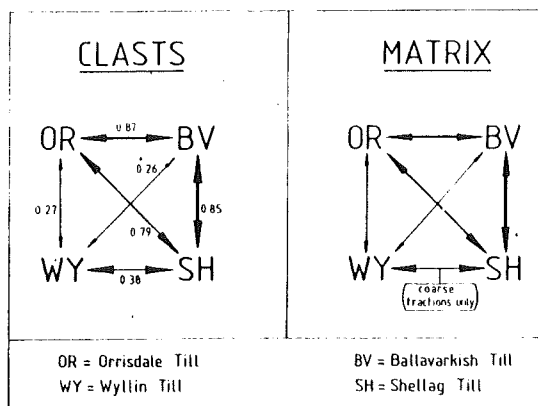


Fig. 63 Mineral magnetic relationships between Manx tills. (Line thickness indicates "strength" of linkage.)

Tentatively, interpretation of results to date suggest:-

1. Mineral magnetic methods appear to reliably and consistently characterise the four Manx tills so far investigated in terms of both clasts and matrix samples.
2. Amongst the clast samples the strongest similarity is between the Orrisdale and Ballavarkish members, and then between the Shellag and Ballavarkish and Shellag and Orrisdale members. Relatively little similarity exists between the Wyllin member and the other three members. The most notable difference between the Wyllin and the Shellag members for example lies in a distinctly greater percentage of stones with higher  $\chi$  and low coercivity of remnance (cf Basalts) in the Wyllin and a greater percentage of stones with high SIRM/ $\chi$  ratio and high coercivity of remnance (cf Red Sandstones) in the Shellag. Such a distinction seems consistent with possible likely differences in provenance of the coarse grade material of these tills.

The linkage between the magnetic character of the Shellag, Ballavarkish and Orrisdale suggests that they are derived from material of similar provenance to the Shellag, or the Shellag itself.

3. The matrix values reflect, at least in part, linkages between terminal grade material which may have travelled far and may have been subjected to several episodes of reworking or mixing. Generally, as with the clasts, the strongest linkages are between Shellag, Ballavarkish and Orrisdale members. In particular the finer than 8 phi samples of matrix from these three tills are magnetically almost identical.

It appears possible to identify two trends in the matrix samples as far as gross magnetic mineral assemblage is concerned.

- a) The presence of 'hard' (cf hematite) magnetic minerals in the Shellag, Ballavarkish and Orrisdale tills that are not present in the Wyllin.
- b) A well developed 'Magnetite' signal in all size fractions of the Wyllin matrix that shows some similarity to the coarser fractions of the Shellag in terms of the style of assemblage but with a greater concentration of magnetic minerals.
4. Therefore similar linkages seem to be indicated when either clasts or matrix are used. The lack of any overall relationship between the Wyllin and Shellag tills in magnetic mineral terms seems to suggest different provenances. The provenance of the Ballavarkish and Orrisdale seem strongly related to each other and to the Shellag.

The method seems promising because mineral magnetic characterisation of stones of varying lithology is very rapidly carried out and large numbers of stones, collected with rigorous sampling procedures, can therefore be measured.

Measurements of till matrix on a size fraction basis, and separate clasts is currently being undertaken on all the Manx till members currently identified and from selected sites around the Irish Sea Basin where reasonable stratigraphic relations are established. The magnitude of mineral magnetic variation within and between till members is actively being established.

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