Quaternary of Scotland

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Chapter 12

Outer Hebrides

INTRODUCTION

D. G. Sutherland

The Outer Hebrides (Figure 12.1) occupy a critical position for studies of the extent of the Scottish mainland ice-sheet. In addition, their position on the maritime fringe of the country makes them of particular interest for investigation of past vegetation patterns and of palaeoclimate in general. However, despite an initial period of interest in the Quaternary history of the islands during the last century it has only been within the last fifteen years that this fascinating area has begun to be studied in detail.

The first to attempt a synthesis of the glacial history of the Outer Hebrides was J. Geikie (1873, 1877, 1878, 1894). He argued that the whole island chain had been overridden by the ice-sheet originating in the Scottish Highlands flowing from east or south-east to west or north-west. The apparent absence from many of the islands of erratics deriving from this ice movement was explained by Geikie as the result of the lower, dirtier layers of the ice being diverted to the north and south of the islands, whereas the relatively cleaner upper layers of the ice passed across the main area of the islands. Despite brief reports to the contrary (Bryce, in discussion of Geikie, 1873; Campbell, 1873; Milne Home, 1877), the general pattern of ice movement proposed by Geikie became established in the literature of the next 100 years.

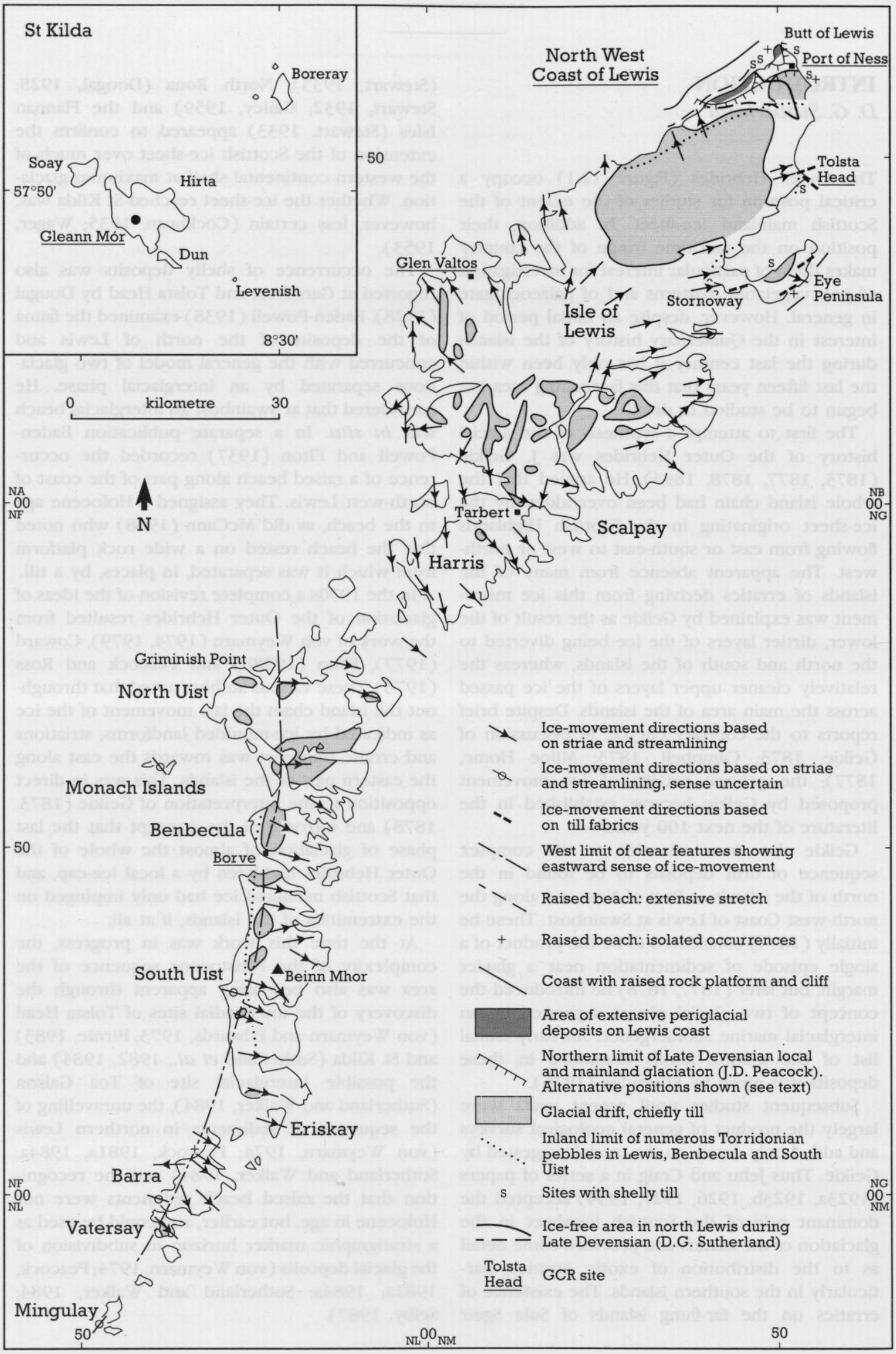
Geikie also drew attention to the complex sequence of drift deposits to be found in the north of the islands at Port of Ness and along the north-west Coast of Lewis at Swainbost. These he initially (1874) considered to be the product of a single episode of sedimentation near a glacier margin, but later (1877, 1878) he introduced the concept of two glacial phases separated by an interglacial marine submergence. An early faunal list of the marine fossils contained in these deposits was given by Etheridge (1876).

Subsequent studies until recent years were largely the product of general geological surveys and added only details to the model suggested by Geikie. Thus Jehu and Craig in a series of papers (1923a, 1923b, 1926, 1927, 1934) accepted the dominant role of the Scottish ice-sheet in the glaciation of the islands and provided some detail as to the distribution of exotic erratics, particularly in the southern islands. The existence of erratics on the far-flung islands of Sula Sgeir (Stewart, 1933), North Rona (Dougal, 1928; Stewart, 1932; Gailey, 1959) and the Flannan Isles (Stewart, 1933) appeared to confirm the extension of the Scottish ice-sheet over much of the western continental shelf at maximum glaciation. Whether the ice-sheet reached St Kilda was, however, less certain (Cockburn, 1935; Wager, 1953).

The occurrence of shelly deposits was also reported at Garrabost and Tolsta Head by Dougal (1928). Baden-Powell (1938) examined the fauna of the deposits of the north of Lewis and concurred with the general model of two glaciations separated by an interglacial phase. He considered that at Swainbost an interglacial beach was *in situ*. In a separate publication Baden-Powell and Elton (1937) recorded the occurrence of a raised beach along part of the coast of north-west Lewis. They assigned a Holocene age to the beach, as did McCann (1968) who noted that the beach rested on a wide rock platform from which it was separated, in places, by a till.

In the 1970s a complete revision of the ideas of glaciation of the Outer Hebrides resulted from the work of von Weymarn (1974, 1979), Coward (1977), Flinn (1978b) and Peacock and Ross (1978). These various authors noted that throughout the island chain the last movement of the ice as indicated by ice-moulded landforms, striations and erratic transport was towards the east along the eastern part of the islands. This was in direct opposition to the interpretation of Geikie (1873, 1878) and introduced the concept that the last phase of glaciation of almost the whole of the Outer Hebrides had been by a local ice-cap, and that Scottish mainland ice had only impinged on the extremities of the islands, if at all.

At the time this work was in progress, the complexity of the Pleistocene sequence of the area was also becoming apparent through the discovery of the interstadial sites of Tolsta Head (von Weymarn and Edwards, 1973; Birnie, 1983) and St Kilda (Sutherland *et al.*, 1982, 1984) and the possible interglacial site of Toa Galson (Sutherland and Walker, 1984), the unravelling of the sequence of sediments in northern Lewis (von Weymarn, 1974; Peacock, 1981a, 1984a; Sutherland and Walker, 1984) and the recognition that the raised beach sediments were not Holocene in age, but earlier, and could be used as a stratigraphic marker horizon in subdivision of the glacial deposits (von Weymarn, 1974; Peacock, 1981a, 1984a; Sutherland and Walker, 1984; Selby, 1987).



St Kilda
Boreray
Soay
Hirta
57°50'
50
Gleann Mór
Dun
Levenish
8°30'
0
kilometre
30
NA
00
NF
N
North West
Coast of Lewis
Butt of Lewis
Port of Ness
Tolsta
Head
Eye
Peninsula
Glen Valtos
Stornoway
Isle of
Lewis
Tarbert
Scalpay
Harris
NB
00
NG
Griminish Point
North Uist
Monach Islands
Benbecula
Borve
50
South Uist
Beinn Mhor
Eriskay
Barra
Vatersay
Mingulay
NF
00
NL
NG
00
NM
50
NL 00 NM
50
Ice-movement directions based on striae and streamlining
Ice-movement directions based on striae and streamlining, sense uncertain
Ice-movement directions based on till fabrics
West limit of clear features showing eastward sense of ice-movement
Raised beach: extensive stretch
Raised beach: isolated occurrences
Coast with raised rock platform and cliff
Area of extensive periglacial deposits on Lewis coast
Northern limit of Late Devensian local and mainland glaciation (J.D. Peacock). Alternative positions shown (see text)
Glacial drift, chiefly till
Inland limit of numerous Torridonian pebbles in Lewis, Benbecula and South Uist
Sites with shelly till
Ice-free area in north Lewis during Late Devensian (D.G. Sutherland)
Tolsta Head
GCR site

The Pleistocene sequence as presently understood in the Outer Hebrides may be summarized as follows. The earliest event known appears to be the erosion of the raised rock platform in northern Lewis. Subsequently there was a glacial event depositing the till on the rock platform, and it is possible that it was at this time that the exotic erratics were emplaced on the outer isles such as North Rona, Sula Sgeir and the Flannan Isles. Traces of similar erratics have been found, reworked in more recent deposits, on St Kilda (Harding *et al.*, 1984; Sutherland *et al.*, 1984), where the emplacement of those erratics has been suggested to pre-date the Devensian. Two sets of moraines have been found on the outer shelf to the north-west and north of Lewis (Stoker and Holmes, 1991) and the glaciation responsible for the earlier of these moraines may have occurred at this time. In north-west Lewis, the Toa Galson peat post-dates this phase of glaciation, and if it is indeed of interglacial origin as suggested by Sutherland and Walker (1984), this too would imply a pre-Devensian age for this glaciation.

Pollen analysis indicates that the Toa Galson peat formed during a period when vegetation changed progressively from a maritime grassland to an acid heath, and the pollen spectra are comparable to those from Sel Ayre, in Shetland (Sutherland and Walker, 1984). They are quite distinct from the spectra from the Tolsta Head and St Kilda interstadial sites, both of these being associated with finite radiocarbon dates implying their attribution to a Middle Devensian interstadial.

The Toa Galson peat is overlain by a periglacial slope deposit representing a period of cold climate, and that is directly overlain by the sediments of the Galson Beach. There is some dispute as to the precise stratigraphic relations of this beach in north Lewis and whether there were one or two periods of beach formation. However, it is generally accepted that in the Galson/Toa Galson area the beach is only overlain by periglacial slope deposits and its upper horizons are periglacially disturbed. To the south, glacial deposits of the last Outer Hebrides ice-cap overlie the beach. Von Weymarn (1974) and Peacock (1981a, 1984a) consider that, to the north, beach sediments overlie the deposits of the last glaciation, whereas Sutherland and Walker (1984) consider them to underlie the glacial sediments, regarding those gravels that occur within or on the glacial deposits as erratics. Radiocarbon and amino acid dating of the included mollusc shells in the glacial sediments of Lewis allowed Sutherland and Walker (1984) to establish the glacial phase post-dating beach formation as Late Devensian in age. The till overlying the Middle Devensian Tolsta Head interstadial deposits also dates from this episode. It is unclear whether the younger set of moraines on the outer shelf north of Lewis is also of this age (Stoker and Holmes, 1991).

During the Late Devensian, therefore, the Outer Hebrides were glaciated by a local ice-cap, with external ice impinging only on the northern tip of Lewis. A small ice-free area existed along the north-west coast of Lewis. On St Kilda a small local glacier existed at this time (Sutherland *et al.*, 1982, 1984). There has been considerable discussion as to the ability of the Outer Hebrides ice-cap to become established on the low ground of the Uists and Benbecula (Flinn, 1980; Peacock, 1980a; Sissons, 1980c). Sissons (1980c) suggested that it was in fact a remnant of a once more extensive Scottish mainland ice-sheet that had become isolated during ice retreat by calving in the deep waters of the Minches to the east. However, this explanation does not allow for the period of beach formation both in the north and the south of the islands (Peacock, 1980a, 1984a; Selby, 1987) prior to expansion of the local ice-cap. Later, Sissons (1983c) proposed that mainland ice crossed the Outer Hebrides during the Early Devensian and that the ice margin subsequently stabilized to the east of the Outer Hebrides during the Late Devensian, allowing the independent development of an Outer Hebrides ice-cap at this time. On present evidence it therefore seems that during at least part of the Late Devensian the climate was sufficiently severe for the ice-cap to become established on low ground.

Features of deglaciation formed during the decay of the ice-cap have only been discussed in general terms (von Weymarn, 1979; Peacock, 1984a). Particular note has been made of the glaciofluvial deposits in the Uig area of west Lewis (Jehu and Craig, 1934; von Weymarn, 1979; Peacock, 1984a), where eskers, kames, kame terraces, glaciolacustrine deltas and meltwater channels, including the remarkable Glen

Figure 12.1 Location map and principal Quaternary features of the Outer Hebrides (from Peacock, 1984a).

Valtos, were produced. It is notable that the direction of meltwater drainage indicated by these features was from west to east, implying thicker ice immediately offshore at this stage of the glaciation.

Within the hills of Lewis and Harris there are abundant moraines, which have been referred to a period or periods of local glaciation (Geikie, 1878; von Weymarn, 1974, 1979; Peacock, 1984a; D. G. Sutherland, unpublished data). More than one phase of glaciation is apparently represented, the last being the Loch Lomond Readvance.

No studies have been published of the Lateglacial vegetation of the Outer Hebrides, and only a limited amount of information is available on the Holocene vegetational history (Lewis, 1907; Erdtman, 1924; Blackburn, 1946; Heslop Harrison and Blackburn, 1946; McVean, 1961; Ritchie, 1966, 1985; Birks and Madsen, 1979; Walker, 1984a; Wilkins, 1984; Angus, 1987; Bohncke, 1988; Whittington and Ritchie, 1988; Bennett *et al.*, 1990; Birks, 1991). Pollen analyses from Little Loch Roag in Lewis (Birks and Madsen, 1979) suggest that the island was essentially treeless throughout the Holocene. However, the recovery of birch, pine and willow macrofossils from the blanket peats of Lewis (Wilkins, 1984), together with pollen records of *Betula, Corylus, Salix, Sorbus* and *Populus* at Callanish (Bohncke, 1988), implies the presence of scattered pockets of woodland in sheltered locations (Bohncke, 1988; Birks, 1991). By way of contrast, a detailed pollen record from Loch Lang in South Uist (Bennett *et al.*, 1990) indicates the presence there of areas of relatively diverse woodland dominated by *Betula* and *Corylus*, but also including *Quercus, Ulmus, Fraxinus exelsior* and *Alnus glutinosa*. On St Kilda, Walker (1984a) found that the middle to late Holocene vegetational changes reflected the broad climatic variations of this period, Man having an apparently negligible impact on the vegetation in this isolated area.

The history of sea-level changes in the outer islands is quite distinct from that in the Inner Hebrides and the greater part of the Scottish mainland by virtue of the relatively minor glacio-isostatic downwarping of the former area. Eustatic rise in sea level only impinged on the present coastal areas of the Outer Hebrides during the middle Holocene. This has resulted in peat cropping out in the present intertidal zone in many areas. The best documented example is at Borve (Ritchie, 1966, 1985), where at least 5 m of sea-level rise has occurred in the last 5000 years. Contemporaneously with this rising sea level, the coastline has evolved through the development of sand dune and machair systems along lengthy sections of the west coasts of the islands (Ritchie, 1966, 1979) and exceptionally on the eastern coasts (Ritchie, 1986; Whittington and Ritchie, 1988).

NORTH-WEST COAST OF LEWIS

J. E. Gordon

Highlights

The landforms and deposits on the coast of north-west Lewis provide important evidence for interpreting the patterns of sea-level change and glaciation in an area located towards the periphery of the main centres of glaciation. Part of the area remained ice-free throughout the Late Devensian.

Introduction

This site comprises a series of sections and landforms along a 16 km stretch of the north-west coast of Lewis, from Cunndal (NB 512655) to Cladach Lag na Greine (NB 387557). These have long provided some of the most important evidence for interpreting the Pleistocene history of the Outer Hebrides (J. Geikie, 1873, 1874, 1877, 1878; Baden-Powell, 1938; McCann, 1968; von Weymarn, 1974, 1979; Peacock, 1984a, 1991; Sutherland and Walker, 1984). The interest comprises a fossil shore platform, pre-Holocene raised beach deposits, peat (?interglacial), till, complex glacigenic sediment sequences and solifluction deposits. Together these features are of the very highest importance for studying glaciation and sea-level change in an area which has a fundamental bearing on the wider understanding of ice-movement patterns, ice sources, ice extent and climatic conditions in north-west Britain during the Pleistocene.

Description

Early descriptions recognized an essentially tripartite sequence in the area of Swainbost (NB 500635), comprising sands, gravels, clays and silts interbedded between two tills, with shells present in each of the layers (J. Geikie, 1873, 1874, 1877, 1878; Baden-Powell, 1938). However, more recent work has shown a much more complex succession of landforms and deposits represented at a number of localities along the coast (Figure 12.2). The principal features in the currently recognized sequence are as follows:

5. Till in the south and north; head and soliflucted till in the central part; multiple drift deposits at Swainbost.
4. Raised beach deposits with a cryoturbated upper horizon.
3. Head.
2. At different locations the shore platform is overlain by till and by peat; the relationship of the till to the peat is undetermined.
1. A raised shore platform and cliffline.

The oldest marine feature clearly recognizable is a low-level (7–10 m OD) raised shore platform and cliffline (Godard, 1965; McCann, 1968; von Weymarn, 1974). It occurs discontinuously in north-west Lewis and on the Eye peninsula (Figure 12.1) but is best seen between Galson (NB 453603) and Dell (NB 472621) where it attains a width of 150 m (McCann, 1968; von Weymarn, 1974). As described by von Weymarn (1974), the principal features of the platform are:

1. it is cut across the bedrock structure;
2. its seaward margin is sometimes covered in modern sand and shingle;
3. there is often a step down to a lower intertidal shore platform;
4. zones of weathered rock occur on its surface;
5. its landward margin is typically drift covered;
6. it is widest in embayments and narrows towards headlands where the backing cliff is best seen (e.g. at the mouth of the Dibadale Burn at NB 470615 – McCann, 1968);
7. abandoned stacks occur on its surface;
8. its distribution is largely confined to the area outside that of local glaciation in Lewis; a few remnants within the latter area are severely ice-modified.

Resting on the shore platform is a complex succession of deposits. In part, following von Weymarn (1974), these can be grouped into four units:

1. Raised beach deposits associated with till. Raised beach deposits form an important stratigraphic marker and were first identified at Galson, where they appear to overlie till (Baden-Powell and Elton, 1937). Baden-Powell and Elton noted that Torridonian sandstone erratics were present in the beach deposits but absent from the till. The occurrence of the beach has since been identified intermittently along the whole coast (Figure 12.2) (McCann, 1968; von Weymarn, 1974; Peacock, 1984a). From the height of the one beach terrace of any extent at Galson, McCann (1968) inferred a maximum sea level of 32–37 ft (9.8–11.3 m) OD. At several localities the upper layers of the beach deposit are cryoturbated. In addition to Galson, the raised beach deposits overlie till at Cladach na Luinge (NB 465611), Toa Dibadale (NB 469615), Cunndal and Swainbost (McCann, 1968; von Weymarn, 1974; Peacock, 1984a). In contrast, in the southern part of the site, to the south of Breivig (NB 414582), a separate till overlies the raised beach deposits.
2. Raised beach deposits associated with head and soliflucted till. Between North Galson (NB 438595) and Breivig, soliflucted till and head overlie the raised beach deposits; in other places the beach and soliflucted deposits are interbedded, for example at South Galson (NB 431591) and Cunndal.
3. At Toa Galson (NB 453603) an organic deposit interbedded with sand occurs above the shore platform and is overlain in turn by head and raised beach gravels (Figures 12.3 and 12.4). The organic deposit yielded radiocarbon dates greater than 39,100 to 47,150 BP (SRR–2365) (Sutherland and Walker, 1984). The pollen spectra (Figure 12.5) indicate development of the vegetation from treeless, open grassland to grassland with acid heath.
4. Complex successions often referred to as multiple drift deposits. These occur in the Swainbost–Dell area and comprise interbedded till, sand, gravel, laminated clay and silt beds. Historically, they were described by J. Geikie (1873, 1874, 1877, 1878) and Baden-Powell (1938), who both recognized a tripartite sequence comprising sand, gravel, clay and silt interbedded between two till layers. Although more recent references acknowledge the complexity of the sequence (von Weymarn, 1974; Peacock, 1984a), there have been no detailed sedimentological

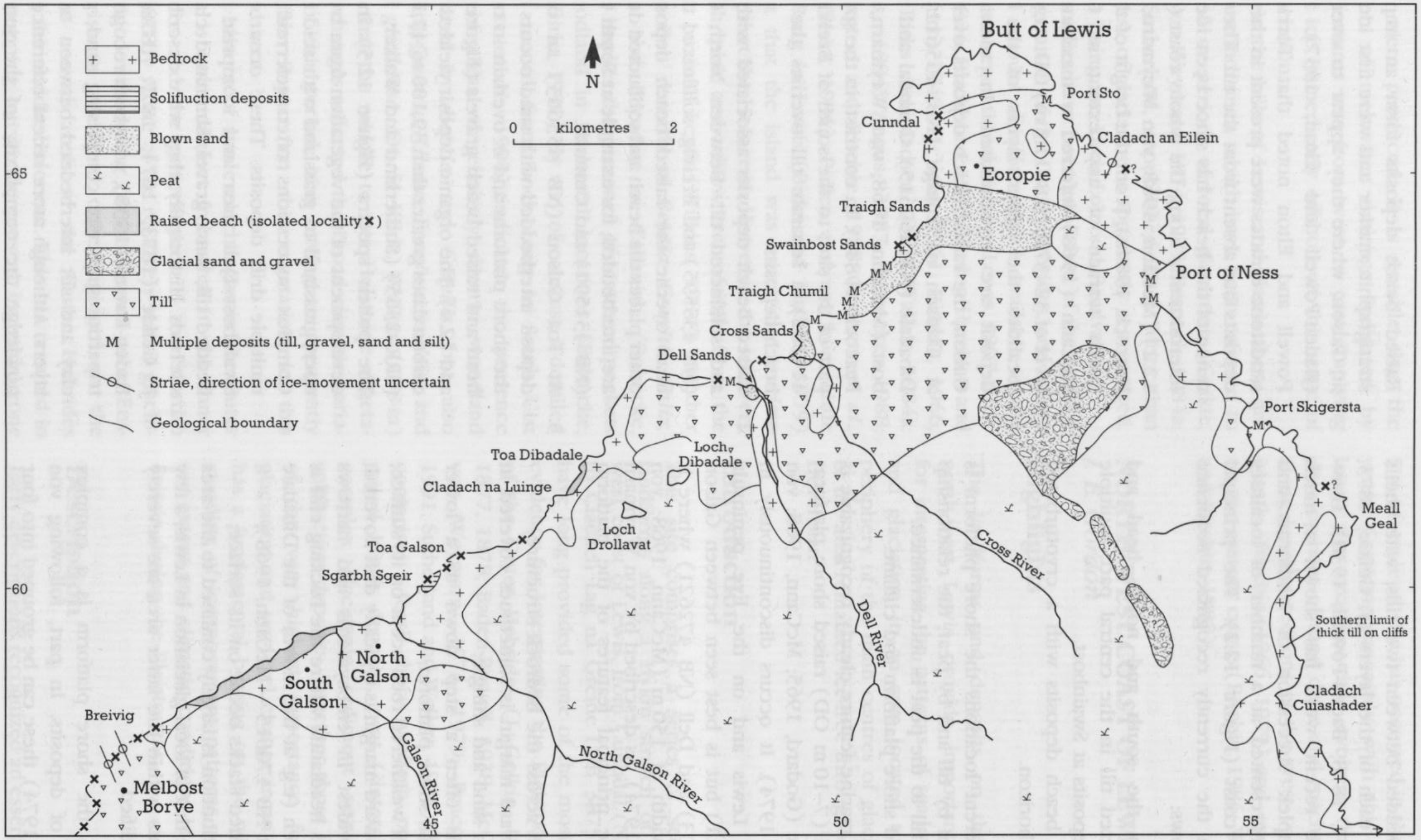


Figure 12.2 Quaternary deposits of north-west Lewis (from Peacock, 1984a).

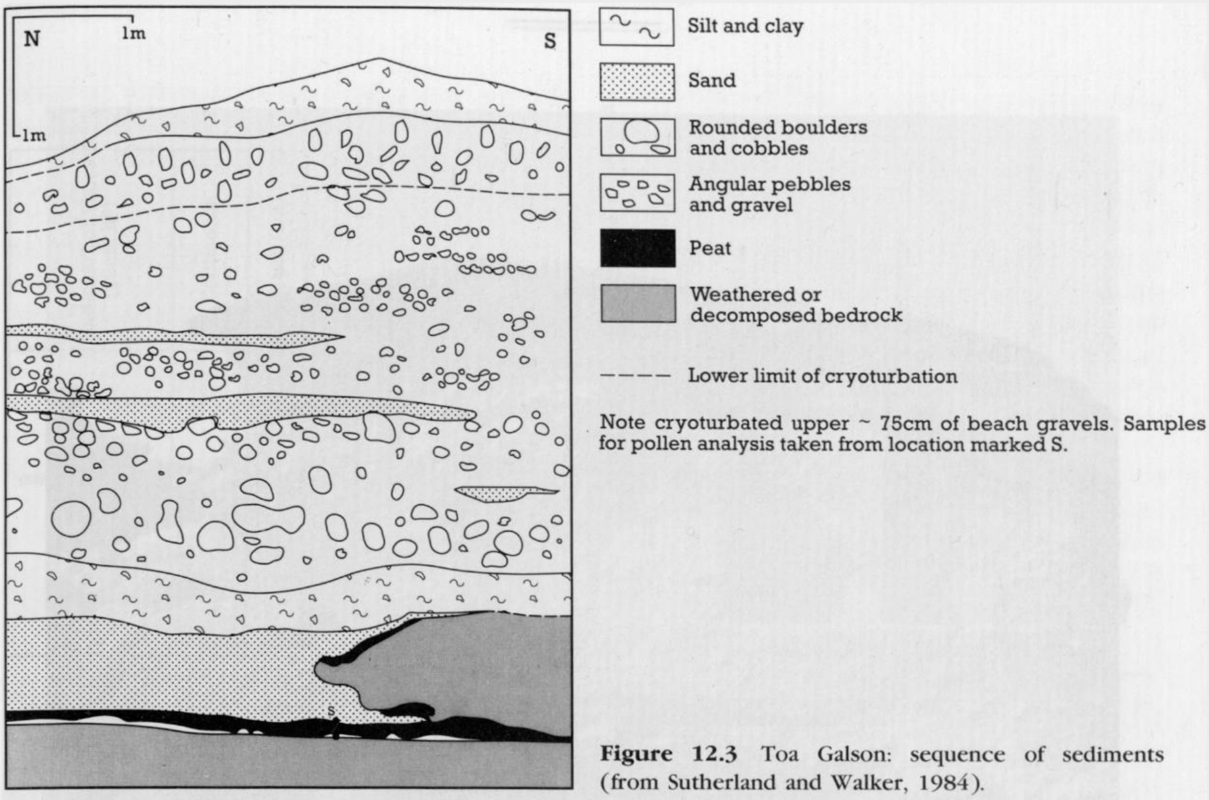


Figure 12.3 Toa Galson: sequence of sediments (from Sutherland and Walker, 1984).

studies. The deposits are glaciotectonically disturbed (J. Geikie, 1877; von Weymarn, 1974; Flinn, 1978b) and are rich in broken shell fragments. A faunal list published by Etheridge (1876) was updated by Baden-Powell (1938). According to Etheridge the faunal assemblage included species of arctic affinity (e.g. *Astarte depressa* (Brown) and *Chlamys islandica* (Müller)) and northern affinity (e.g. *Nuculana pernula* (Müller), *Arctica islandica* (L.), *Saxicava norvegica* (Spengler), *Natica montacuti* (Forbes) and *Fusus gracilis* (Da Costa)); Baden-Powell inferred that only the upper till of the tripartite sequence contained a diagnostic faunal assemblage (e.g. including *Astarte borealis* (Chemnitz), *Mya truncata* (L.), and *Panomya norvegica* (Spengler)), indicating cold-water conditions. Radiocarbon dates on shells from the middle or lower layers of these deposits yielded ages of between 34,470 +720/−660 BP and 39,500 +1270/−1100 BP (inner fractions) (SRR–2368 to SRR–2370) (Sutherland and Walker, 1984).

Amino acid analyses of fragments of *Arctica islandica* from the same beds indicated that the shells were from at least two distinct periods. The older group (6 analyses) had aIle/Ile ratios of 0.114 ± 0.007 and the younger group (9 analyses) had aIle/Ile ratios of 0.079 ± 0.013 (D. G. Sutherland, unpublished data). Ratios from similar analyses on *Arctica islandica* from the last interglacial in the British Isles are 0.15–0.16 (Bowen and Sykes, 1988), indicating that the shells from north-west Lewis are Early and Middle Devensian.

Interpretation

Interpretations of the evidence in north-west Lewis fall into two main groups. The earlier accounts were focused on the drift sequences at Swainbost; later accounts have placed greater emphasis in the wider succession and its spatial variations.

In an early reference to the 'alluvial land' of north Lewis, McCulloch (1819) described superficial accumulations of 'clay and marle, together with a mixture of rolled stones of different kinds'. From their lithological composition he believed they were derived from the gneissic rocks of the mountains but was unable to suggest a mode of derivation.

Initially, from analogies with Greenland glaciers, J. Geikie (1874, p. 215) hinted that sequences such as the multiple drift deposits in north Lewis could have been laid down in a single episode at or near the front of a glacier terminating in the sea (see also J. Geikie, 1877, p. 185 footnote).

Figure 12.4 Section at Toa Galson, north-west Lewis, showing the interglacial peat resting on bedrock and overlain by sand, head and the Galson Beach deposits. The upper part of the beach deposits has been affected by cryoturbation. (Photo: D. G. Sutherland.)

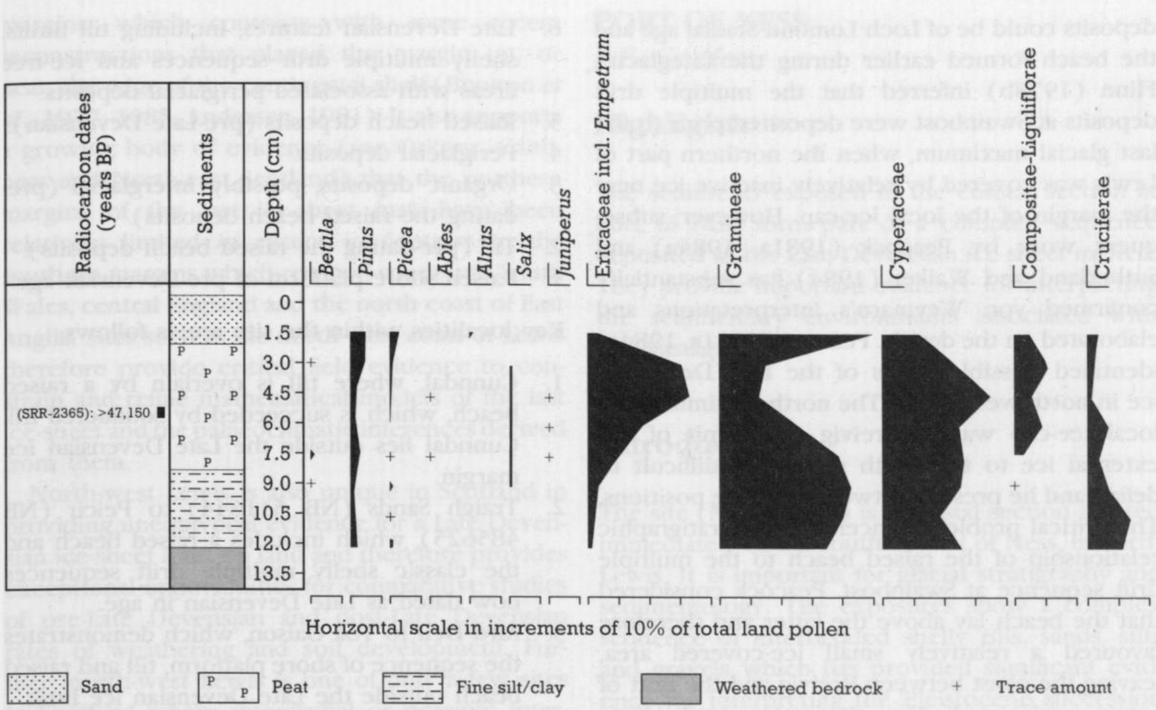


Figure 12.5 Relative pollen diagram for the peat deposit at Toa Galson showing selected taxa as percentages of total land pollen (from Sutherland and Walker, 1984). The location of the sample is shown in Figure 12.3.

Later, however, he interpreted the middle beds of the tripartite sequence as 'interglacial' marine deposits (Geikie, 1878) and postulated a succession of glacial and non-glacial episodes and relative sea-level fluctuations to explain the development of the full sequence over a much longer time-scale (J. Geikie, 1877, 1878).

Geikie (1878) noted the restricted distribution of the shelly till and interbedded deposits. He believed that the latter had once been more extensive but had been removed by the ice which deposited the upper till; the shelly till was confined to the area where basal ice, deflected by the Hebridean land mass, impinged on its northern periphery.

Subsequently, Jehu and Craig (1934) and Baden-Powell (1938) acknowledged Geikie's interpretation of interglacial submergence. Baden-Powell suggested that the submergence was at least 17 m and possibly as much as 60 m, the latter value corresponding with one of the planation surfaces identified by Panzer (1928). Godard (1965) largely concurred, but raised the question as to whether the altitude of the marine deposits might simply reflect older marine material reworked by glacial meltwaters. More recent interpretations, however, are agreed that the multiple drift deposits of north-west Lewis are glacigenic in origin and were formed during a single glacial episode (von Weymarn, 1974; Flinn, 1978b; Peacock, 1984a; Sutherland and Walker, 1984).

Based on what was the first systematic account of the landforms and deposits in north-west Lewis, von Weymarn (1974) inferred a possible sequence of events commencing with formation of the raised shore platform during one or more pre-Devensian interglacials. The platform was overridden by glacier ice from the east and buried by till containing Torridonian sandstone erratics. During the Ipswichian, relative sea level rose by around 7 m and the earlier till was reworked. During the Devensian glacial phases the raised beach gravels were overridden to the south of Borve by a local ice-cap on Lewis, but the coast to the north remained free of ice and subject to intense periglacial activity. The multiple drift deposits probably related to external ice in the north of Lewis during the Late Devensian.

Alternative suggestions were made by Jardine (1977) that the beach deposits could date from the Loch Lomond Stadial rather than the Ipswichian, and by Dawson (1979c) that the solifluction deposits could be of Loch Lomond Stadial age and the beach formed earlier during the Lateglacial. Flinn (1978b) inferred that the multiple drift deposits at Swainbost were deposited prior to the last glacial maximum, when the northern part of Lewis was covered by relatively inactive ice near the margin of the local ice-cap. However, subsequent work by Peacock (1981a, 1984a) and Sutherland and Walker (1984) has substantially confirmed von Weymarn's interpretations and elaborated on the details. Peacock (1981a, 1984a) identified possible limits of the Late Devensian ice in north-west Lewis. The northern limit of the local ice-cap was at Breivig. The limit of the external ice to the north was more difficult to define and he presented two alternative positions. The critical problem concerned the stratigraphic relationship of the raised beach to the multiple drift sequence at Swainbost. Peacock considered that the beach lay above the latter and therefore favoured a relatively small ice-covered area, leaving the coast between Breivig and the Butt of Lewis unglaciated. The alternative explanation that a lobe of ice crossed the coast in the Swainbost area was considered less probable because of the inferred stratigraphic relationship of the raised beach and multiple drift sequence.

Sutherland and Walker (1984) produced a different interpretation of the stratigraphy from that of von Weymarn and Peacock, concluding that the multiple drift sequences on the north-west coast lay stratigraphically above the raised beach. A Late Devensian age for the multiple drift sequence is supported by the radiocarbon dates and amino acid analyses on the shells from the glacial deposits. Therefore the coast between Europie and Dell Sands, where the multiple drift sequences occur, was covered by the last ice-sheet, confirming Peacock's alternative hypothesis.

The radiocarbon dates from the peat beneath the raised beach at Toa Galson confirm the antiquity of the deposit. Sutherland and Walker (1984) tentatively considered it to be of interglacial origin although there is no evidence to assign it to a particular stage. Significantly, the pollen spectra differ from those associated with the interstadial sites at Tolsta Head (see below) and St Kilda (Sutherland *et al.*, 1984), both of which produced finite radiocarbon dates.

North-west Lewis is therefore an area of the highest importance for demonstrating a series of glacial, periglacial and marine events of Devensian and possibly pre-Devensian ages. In sequence, the key elements are as follows:

6. Late Devensian features, including till limits, shelly multiple drift sequences and ice-free areas with associated periglacial deposits.
5. Raised beach deposits (pre-Late Devensian).
4. Periglacial deposits.
3. Organic deposits, possibly interglacial (pre-dating the raised beach deposits).
2. Till (pre-dating the raised beach deposits).
1. Raised shore platform of pre-Devensian age.

Key localities within the site are as follows:

1. Cunndal, where till is overlain by a raised beach, which is succeeded by soliflucted till. Cunndal lies outside the Late Devensian ice margin.
2. Traigh Sands (NB 511644) to Peicir (NB 485625), which includes a raised beach and the classic shelly multiple drift sequences now dated as Late Devensian in age.
3. Aird Dell to Toa Galson, which demonstrates the sequence of shore platform, till and raised beach outside the Late Devensian ice limit.
4. Immediately south of Toa Galson organic deposits occur between the shore platform and the raised beach.
5. Farther south, between North Galson and Breivig, the raised beach terrace is best developed and is overlain by soliflucted till and head.
6. At Breivig the Late Devensian ice limit crosses the coast and till overlies the raised beach here and to the south.
7. At Cladach Lag na Greine the raised beach rests on a shore platform and is overlain by till. Locally, where the platform rises above the beach deposit, it is striated, which provides important evidence that the beach was overridden by glacier ice and is overlain by *in situ* lodgement, rather than soliflucted till.

The assemblage of deposits and landforms represented at these localities is unique in Scotland and has significant bearing on the interpretation of the Pleistocene history and chronology of events in north-west Britain, including sea-level change, glacier reconstruction, palaeoclimatology and vegetational history. For example, as Sutherland and Walker (1984) point out, conventional models of the last Scottish ice-sheet require reassessment in the light of the evidence from north-west Lewis. The presence there of an ice-free area indicates a relatively restricted extent of the last ice-sheet in Britain at its north-west margins, which contrasts with some recent reconstructions that placed the margin on, or near, the edge of the continental shelf (Boulton *et al.*, 1977, 1085; Andersen, 1981). It also supports a growing body of evidence (see Orkney, Caithness and North-east Scotland) that the northern margins of the last ice-sheet may have been relatively limited in extent in contrast to the southern margins which reached south into South Wales, central England and the north coast of East Anglia. Sites such as the north-west coast of Lewis therefore provide critical field evidence to constrain and refine mathematical models of the last ice-sheet and the palaeoclimatic inferences derived from them.

North-west Lewis is also unique in Scotland in providing unequivocal evidence for a Late Devensian ice-sheet limit on land and therefore provides exceptional opportunities for comparative studies of pre-Late Devensian and post-Late Devensian rates of weathering and soil development. Further, north-west Lewis is one of only a few sites in Scotland where interstadial or possibly interglacial organic deposits are represented. As such it is of the very highest importance for palaeoecological and palaeoenvironmental studies. Finally, the multiple drift deposits of north-west Lewis are of significant sedimentological interest for interpreting and reconstructing the depositional environments at the margin of the Late Devensian ice-sheet.

Conclusion

The unique assemblage of landforms and deposits on the north-west coast of Lewis has a long history of research and has provided critical information for interpreting the Pleistocene in Scotland. Among the key features of interest are a pre-Devensian shore platform, a pre-Late Devensian raised beach, organic deposits of possible interglacial origin, solifluction deposits and a complex sequence of fossiliferous sediments deposited by the Late Devensian ice-sheet (approximately 18,000 years ago). This area therefore provides a wealth of evidence for interpreting patterns of sea-level change, palaeoenvironmental conditions and ice-sheet history. One of the key findings to emerge from recent work is that part of the area remained ice-free when the Late Devensian glaciation was at its maximum extent (about 18,000 years ago).

PORT OF NESS

J. E. Gordon

Highlights

The sediments exposed in the coastal section at Port of Ness form part of a complex sequence deposited as the Late Devensian ice-sheet melted. They provide important evidence for interpreting the sedimentary environments associated with ice wastage.

Introduction

The site (NB 537636) is a coastal section located immediately to the south of Port of Ness, in north Lewis. It is important for glacial stratigraphy and sedimentology. The exposures show a complex sequence of interbedded shelly tills, sands, silts and gravels which has provided significant evidence for interpreting the Pleistocene succession in the Outer Hebrides for over one hundred years (Geikie, 1873, 1878; Baden-Powell, 1938; von Weymarn, 1974; Peacock, 1981a, 1984a).

Description

In an early account, MacCulloch (1819) referred briefly to the superficial deposits in north Lewis, which he believed were derived from the 'waste of the gneissic mountains'. Later, J. Geikie (1874) presented a general stratigraphy for the same area based on sections in north-west Lewis and at Port of Ness, which essentially comprised a tripartite succession of two till units with interbedded layers of stratified sand, gravel and clay. At Port of Ness the lower till contained shells and lenses of sand incorporated from the sea floor. The stratified sediments above consisted of coarse gravel with shell fragments. The upper till, which also contained shell fragments, was capped by a further layer of stratified gravels and sands.

Baden-Powell (1938) provided additional details of the Port of Ness succession, in particular noting the lateral variability of the deposits. At the southern end the entire section comprised a massive purple-coloured silt with occasional stony layers. Mollusc shell fragments (e.g. of *Chlamys islandica* (Müller), *Astarte borealis* (Chemnitz), *Macoma calcarea* (Gmelin) and *Mya truncata* (L.)) were taken by him to represent a 'cold'-water marine assemblage, and on this basis Baden-Powell correlated the silt deposit ('Glacial Marine Bed') with the upper till of the tripartite sequence at Swainbost on the north-west coast of Lewis (see above). The stone content of the silt increased northwards, merging into boulders and gravel with a silty matrix. At one locality, a hollow in the underlying bedrock showed a layer of till interbedded with sands and gravel. The sands and gravel were correlated with the 'interglacial' marine deposits (the middle bed of the tripartite sequence) identified by Baden-Powell in north-west Lewis.

At Port of Ness, von Weymarn (1974) recorded the following sequence:

5.	sand and silt	*c.* 0.8 m
4.	till	*c.* 5.4 m
3.	sand, silt and gravel	*c.* 1.9 m
2.	till	*c.* 1.8 m
1.	gravel	up to *c.* 1.6 m

Later Peacock (1981a, 1984a) provided further details of the complexity of the sequence and its lateral variability. At the north end of the section, he recorded about 8 m of crudely-bedded, bouldery gravel in which clast imbrication suggested deposition towards the north-west. The gravel is overlain by a brown diamicton, possibly a till. Southwards, the gravel passes laterally into an interbedded sequence, about 10 m thick, of tills or debris-flow deposits and sands and gravels.

Until recently the age of the Port of Ness deposits was unconfirmed. However, the work of Sutherland and Walker (1984), together with unpublished results of amino acid analysis of shells in the glacial deposits of north-west Lewis (see above), suggests that the multiple drift sequence at Port of Ness may be correlated with that on the north-west coast of Lewis and therefore is of Late Devensian age.

Interpretation

J. Geikie (1874) interpreted the stratified deposits at Port of Ness as representing an interglacial marine submergence. This idea was also developed by Baden-Powell (1938). According to von Weymarn (1974), however, the sand, silt and gravel (bed 3 of his succession) could not be correlated with the raised beach gravels on the north-west coast of Lewis, and their characteristics suggested that they might be part of a complex depositional sequence. This suggestion was later supported by Peacock and Ross (1978). Neither von Weymarn nor Peacock and Ross ascribed specific origins to the individual beds or the succession as a whole. Subsequently, however, Peacock (1981a, 1984a) tentatively identified the succession as representing a complex proglacial debris fan from an ice source lying to seaward. Therefore, although the sequence of deposits appears to be established in outline, the site has significant potential for sedimentological study to clarify in detail the lateral variability of the different beds and to provide the basis for a better understanding of their depositional environments.

Port of Ness is important in several respects. It is of historical interest, having been recognized for over one hundred years as a key section providing evidence for the Pleistocene history of northern Lewis, and complementing the interest of the sections on the north-west coast of the island. Formerly it was thought to show both interglacial and glacial marine deposits, but recent studies suggest that the sequence of sediments represents a complex ice-marginal depositional environment. By virtue of its location, the Port of Ness succession also has a direct bearing on interpreting the pattern of the last glaciation and deglaciation in the northern part of the Outer Hebrides. The conventional view, as set out by J. Geikie (1873, 1874, 1877, 1878), that during the last glaciation the whole of the Outer Hebrides was covered by ice moving across the Minch from the Scottish mainland, has now been reassessed and the concept of an extensive local ice-cap firmly established (von Weymarn, 1974, 1979; Flinn, 1978b; Peacock and Ross, 1978; Peacock, 1984a; Sutherland and Walker, 1984). However, a key question, still not fully resolved, is whether ice from the mainland reached and crossed northern Lewis (see Peacock, 1984a; Sutherland and Walker, 1984). Evidence of onshore movement of ice is suggested by the drift deposits in northern Lewis. As first noted by Geikie and later by Baden-Powell (1938) these deposits are distinguished from the drift of the rest of Lewis by their complex stratigraphy, glaciotectonic deformation and their sandstone (ascribed to the Torridonian) erratic and shell content. However, the erratics could possibly have been derived from the Mesozoic sedimentary rocks that underlie the floor of the North Minch close offshore and then transported on land by local Hebridean ice recurving onshore on to north Lewis (Sutherland and Walker, 1984).

Further research on the Port of Ness succession, together with other sites in north Lewis, should help to clarify this issue, which has potentially significant implications for the extent of the Late Devensian ice-sheet, the ice sources and ice-movement patterns and therefore the associated palaeoclimatic conditions in north-west Britain (see also North-west coast of Lewis).

Conclusion

Like the deposits in north-west Lewis, those at Port of Ness have been much studied, featuring in early interpretations of the glacial history of the Outer Hebrides. Recent investigation suggests that they form part of a complex fan of sediments deposited from the margin of an ice-sheet lying to the east. The site has significant research potential for achieving a better understanding both of the pattern of development and melting (deglaciation) of the last ice-sheet in the Outer Hebrides, and of the depositional processes that accompanied ice wastage (about 18,000 years ago).

TOLSTA HEAD

J. E. Gordon and D. G. Sutherland

Highlights

Deposits exposed in the coastal section at Tolsta Head include organic lake detritus formed during a Middle Devensian interstadial around 27,000 years ago. Pollen and diatoms preserved in these sediments provide an exceptionally detailed record of the vegetational and environmental conditions at that time.

Introduction

This site (NB 557468) comprises a cliff-top section located on the south side of Tolsta Head in north Lewis. It shows a sequence of organic interstadial deposits underlying till deposited by Late Devensian ice. Although organic sediments containing marine shells were reported from near Tolsta Head by Dougal (1928), the present site was first described by von Weymarn and Edwards (1973) and further details of both the organic and glacial sediments have subsequently been given by Flinn (1978b), Edwards (1979a) and Birnie (1983).

Description

The section was described by von Weymarn and Edwards (1973), with further details being added by Birnie (1983) (Figure 12.6). At the base, resting on Lewisian gneiss bedrock, is approximately 0.6 m of bedded silts and sands with organic lake detritus. Overlying these is 2.5 m of reddish-brown till notable for a relatively high content of Torridonian sandstone erratics. The top of the organic sediments has been truncated and material from it incorporated as clasts into the base of the till (D. G. Sutherland, unpublished data). The uppermost 1 m of the till has been frost-disturbed.

Palynological, plant macrofossil and diatom studies have been carried out on the organic sediments (von Weymarn and Edwards, 1973; Edwards, 1979a; Birnie, 1983). Von Weymarn and Edwards (1973) reported grass–sedge-dominated pollen spectra (Figure 12.6), with a consistent increase in the percentage of juniper pollen towards the top of the profile. Birnie (1983) provided further details, subdividing the organic deposits into a lower, sandier unit and an upper, more organic unit. The lower unit was considered to have been deposited in more variable flow conditions than the upper one, and it is possible that there may have been a hiatus in deposition between the two. The diatom record indicates that alkaline water conditions were present throughout the upper zone and a succession developed from epipelic and planktonic communities to epiphytic communities. With the notable exception of *Juniperus*, Birnie (1983) confirmed the pollen spectra as reported by von Weymarn and Edwards (1973) and she also recorded *Salix herbacaea* macrofossils. A radiocarbon date of 27,333 ± 240 BP (SRR–87) was obtained from the uppermost 0.15 m of the organic sediments (von Weymarn and Edwards, 1973).

Interpretation

The radiocarbon date confirms that the deposits preserve evidence of a Middle Devensian interstadial. Von Weymarn and Edwards (1973) considered that the pollen spectra indicated a

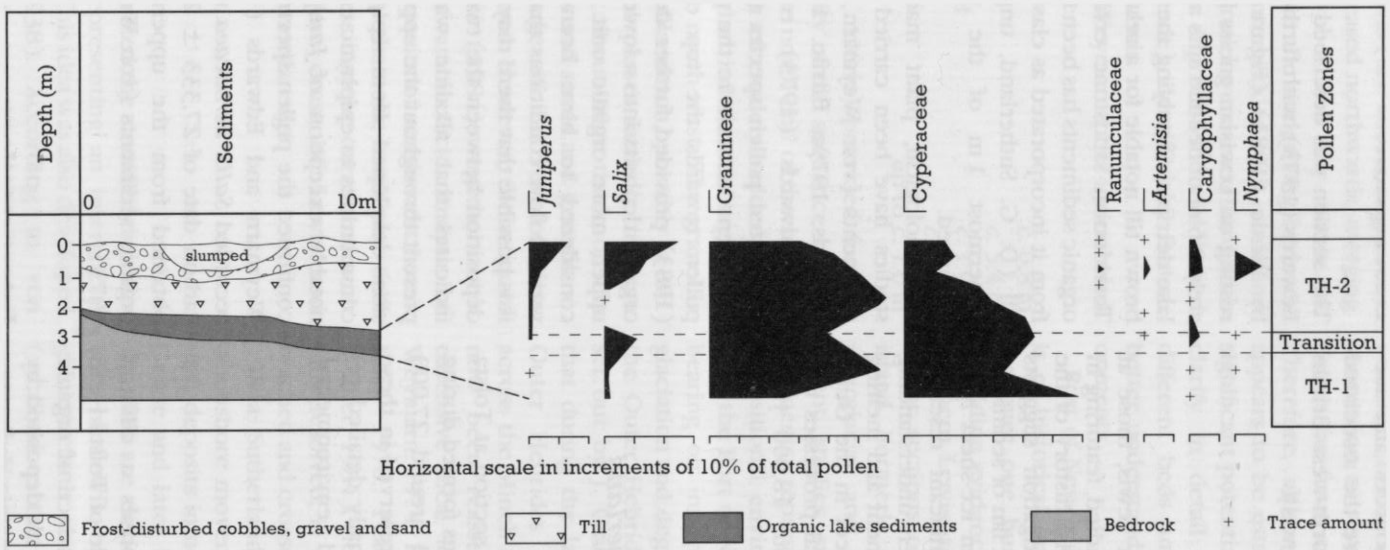


Figure 12.6 Tolsta Head: sediments and relative pollen diagram showing selected taxa as percentages of total pollen (from von Weymarn and Edwards, 1973; Birnie, 1983; Lowe, 1984).

flora not inconsistent with a cool maritime climate. Birnie (1983) considered that the alkaline water, the inwash of minerogenic sediment and the occurrence of both pollen and macrofossils of open-ground herbs suggested soil instability, probably solifluction, throughout the period represented by the organic sediments. However, the degree of severity of the climate is uncertain, as the presence of *Nymphaea* in the uppermost 0.10 m and certain diatoms are compatible with temperatures not necessarily any lower than those of today. The radiocarbon date also indicates that the overlying till is Late Devensian in age, in agreement with the conclusions of Sutherland and Walker (1984) based on radiocarbon dating and amino acid analyses of shells from till in the north of Lewis (see North-west coast of Lewis).

Von Weymarn and Edwards (1973) reported that till fabric measurements showed a predominant N50°W clast orientation and they inferred ice movement from the south-east. However, in the till Flinn (1978b) found fragments of a phyllonite, which crops out at the south-west corner of Tolsta Head, and he concluded that the direction of movement of the ice that deposited the till was towards the north-east. Von Weymarn (1979) suggested that during the Late Devensian, Tolsta Head was close to the junction of the Scottish ice-sheet (ice flow from the south-east) and the Outer Hebrides ice-cap (ice flow from the south-west), which may explain the apparently conflicting evidence (see also Sutherland, 1984a).

There are relatively few sites in Scotland, in addition to Tolsta Head, at which evidence for a Middle Devensian interstadial has been discovered and dated: Bishopbriggs (Rolfe, 1966), Hirta (St Kilda) (Sutherland *et al.*, 1984), Crossbrae (Hall, 1984b), Sourlie (Jardine *et al.*, 1988), Creag nan Uamh (Lawson, 1984), and possibly Teindland (Fitzpatrick, 1965; Edwards *et al.*, 1976). Of these, Tolsta Head is the site which has been studied in most detail and which has provided most information about the environment of that period. Three of the sites (Bishopbriggs, Crossbrae and Sourlie) were temporary exposures and as there is doubt as to whether Teindland does indeed date from the Middle Devensian, Tolsta Head remains the most important interstadial site of this age in Scotland.

Conclusion

Tolsta Head is important for showing one of the few deposits in Scotland that may be dated to a Middle Devensian interstadial (a warmer climatic phase during an otherwise intensely cold glaciation). It has provided the most detailed evidence for environmental conditions during the phase (approximately 27,000 years ago) immediately before the last glacial maximum, indicating a cool maritime climate and unstable soils. Tolsta Head is a key reference site for palaeoenvironmental reconstruction in Scotland.

GLEN VALTOS

D. G. Sutherland

Highlights

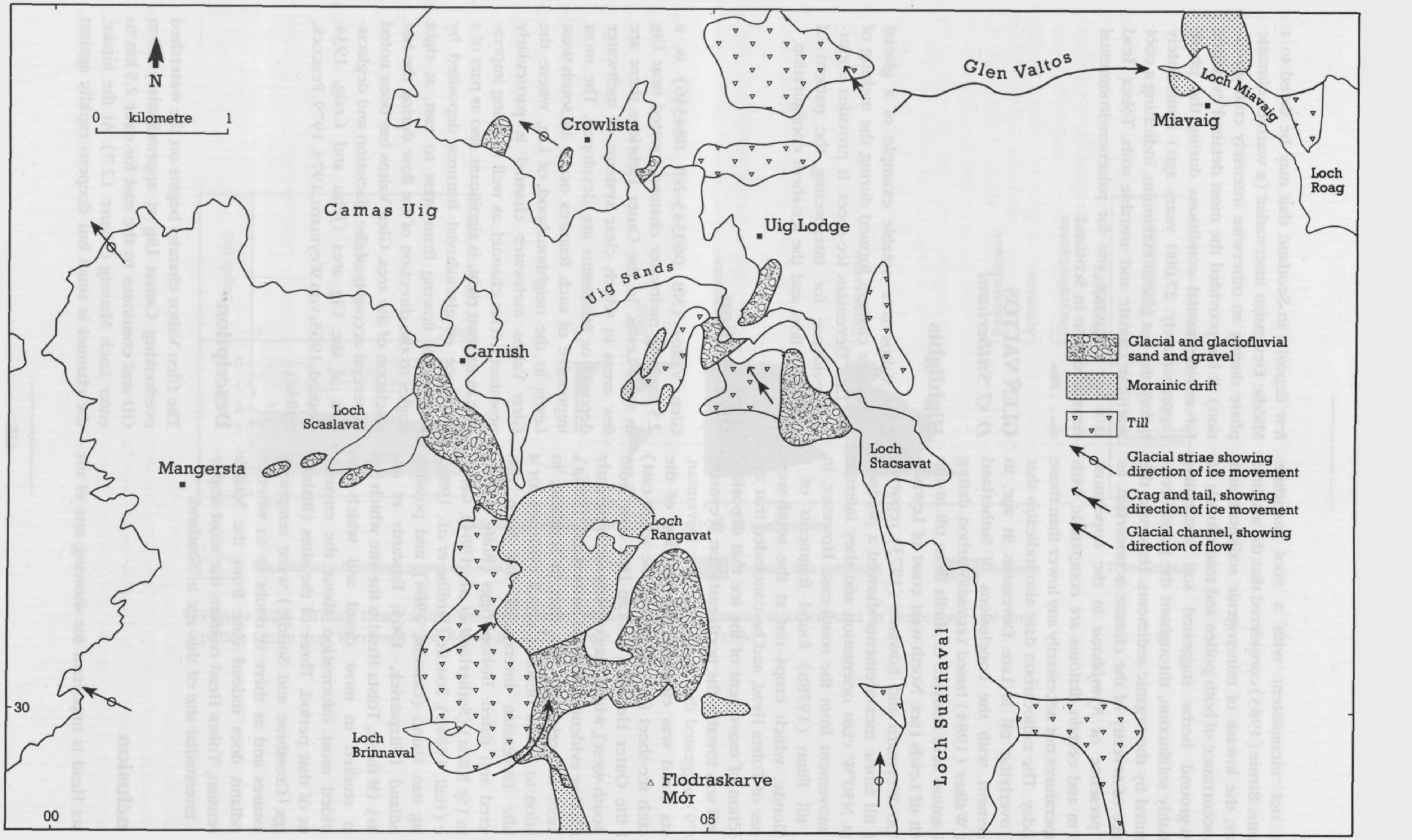
Glen Valtos is a notable example of a glacial meltwater channel formed during the melting of the Late Devensian ice-sheet. It provides important evidence for interpreting the pattern of meltwater flow and the ice-sheet configuration.

Introduction

Glen Valtos (NB 060343–NB 084346) is a 2.5 km long meltwater channel located near Uig in west Lewis. In the Outer Hebrides there are few areas in which clear systems of meltwater deposits or landforms are developed. The most impressive of such features occur in south-west Lewis in the neighbourhood of Uig, where the Glen Valtos meltwater channel is particularly prominent. This channel, as well as being impressive in its own right, is significant also as part of a sequence of glaciofluvial features deposited by meltwaters flowing from west to east, at right angles to the direction of ice flow during the last glaciation of the area. Glen Valtos has been noted in several accounts of the glaciation and deglaciation of the Uig area (Jehu and Craig, 1934; Godard, 1965; von Weymarn, 1974, 1979; Peacock, 1984a).

Description

The Glen Valtos channel begins on the watershed overlooking Camas Uig at approximately 40 m OD and continues to the east for over 2.5 km to enter Loch Miavaig (Figure 12.7). At the intake, the channel is small but deepens rapidly against



Glen Valtos
Loch Miavaig
Miavaig
Loch Roag
Crowlista
Camas Uig
Uig Lodge
Uig Sands
Carnish
Loch Scaslavat
Mangersta
Loch Stacsavat
Loch Rangavat
Loch Brinnaval
Flodraskarve Mór
Loch Suainaval
N
0 kilometre 1
30
00
05
Glacial and glaciofluvial sand and gravel
Morainic drift
Till
Glacial striae showing direction of ice movement
Crag and tail, showing direction of ice movement
Glacial channel, showing direction of flow

the general slope of the land, and at its eastern end is over 45 m deep (Figure 12.8). Its western portion is sinuous but the eastern, most deeply incised section is linear, suggesting fault control. At its head there are three 'blind' intakes in addition to the main one. Two of these blind ends are continued at the top of the slope by a peat-filled channel system, which extends for approximately 800 m to the south-west where it too has an intake above Camas Uig, at an altitude of about 50 m OD.

There are no glaciofluvial deposits contained within the channel, but at its mouth by Miavaig (Figure 12.7) there is a group of small mounds composed of bouldery, poorly sorted fluvial gravels. In the upper part of the northern channel side (near NB 074346) up to 1 m of grey till is exposed. The implication of these deposits together with the discordant nature of the channel intakes is that the channel was probably formed, or at least initiated, subglacially.

The cliffed bedrock slopes of the channel have weathered to produce angular debris that has formed stratified screes several metres thick, but these deposits have not been investigated.

The various intakes to the channel system occur on bare rocky slopes. However, to the west, around Camas Uig, there are major glaciofluvial accumulations (Figure 12.7) (Peacock, 1984a, figure 3). The principal ones are, first, a major arcuate ridge trending approximately south-west to north-east and terminating by Uig Lodge (NB 055333); second, a large glaciofluvial delta at Carnish (NB 030323) deposited to an altitude of about 53 m OD; third, a large area of dead-ice terrain south of Loch Rangavat (NB 042311); and fourth, a large mound of stratified sand and gravel to the west of Crowlista (NB 041339). All of these deposits relate to meltwater flow from west-south-west to east-north-east.

Interpretation

The glaciofluvial deposits and landforms in the Uig area have been described in a number of publications. Jehu and Craig (1934) considered the Glen Valtos channel to have been eroded by waters overflowing from an ice-dammed lake in the area of Camas Uig, the Carnish delta having been deposited in the same lake. The large arcuate drift mound south-west of Uig Lodge was interpreted by both Godard (1965) and von Weymarn (1974) as an end moraine. The former thought the ice from which it was deposited had occupied Camas Uig, whereas the latter suggested the moraine was related to a glacier emerging northwards from the valley of Loch Suainaval (NB 068290), on the opposite side from Camas Uig. In contrast, Ritchie and Mather (1970) interpreted the ridge as an esker, and Peacock (1984a) argued that it was one of a series of kames, eskers and morainic mounds that were possibly associated with subglacial drainage towards the channel. The topographic situation of the glaciofluvial deposits in the Uig area is such that at the time of their formation, drainage north-westwards to the sea via Camas Uig must have been blocked by ice and it is most probable that it was at this time that Glen Valtos was eroded. Such an interpretation is supported by the only slight difference in altitude between the highest intake to the Glen Valtos channel system (about 50 m OD) and the altitude of the top of the Carnish delta (53 m OD).

Striations, crag-and-tail landforms and ice-moulded bedrock indicate that the last ice movement in the Uig area was to the west of north. Both von Weymarn (1974, 1979) and Peacock (1984a) noted that the west to east direction of flow of the meltwaters draining through the Glen Valtos channel was almost at right angles to that direction of ice flow. Furthermore, the disposition of the features apparently requires ice lying off the west coast of south-west Lewis to have been thicker or to have melted later than ice in the Loch Roag area to the east. This pattern of ice decay is anomalous in terms of the present knowledge of glaciation of the Outer Hebrides and awaits further research to be fully understood.

The Glen Valtos channel is a particularly impressive example of a subglacial meltwater channel. In contrast to the majority of similar channels found elsewhere in Scotland, it has been eroded by waters flowing almost at right angles to the last direction of ice flow in the area. The channel is part of a wider assemblage of glaciofluvial deposits and landforms which were deposited during the same period of ice decay, but the reasons for the apparently anomalous direction of meltwater flow are as yet poorly understood.

Figure 12.7 Landforms and deposits of the Glen Valtos–Uig area (from Peacock, 1984a).

Figure 12.8 Glen Valtos meltwater channel. The channel has the form of a single, narrow gorge. (Photo: D. G. Sutherland.)

They seem to imply thicker ice immediately off the west coast of south-west Lewis than in the area close to the mountains that were one of the sources of the ice.

Conclusion

Glen Valtos is important for glacial geomorphology, in particular for the most impressive meltwater channel in the Outer Hebrides. It forms part of an assemblage of landforms and deposits that together provide important evidence for interpreting the pattern of decay of the last ice-sheet (approximately 18,000–14,000 years ago). In particular, the direction of meltwater flow indicated by Glen Valtos implies the presence of thicker ice off the west coast of Lewis than onshore; this apparent anomaly (thicker ice would be expected nearer the mountain sources inland) remains to be explained in terms of what is known of the configuration of the last ice-sheet.

BORVE

W. Ritchie

Highlights

The coastal sediments in the inter-tidal and sub-tidal areas at Borve comprise a sequence of interbedded sands and organic materials which accumulated in a former freshwater lake. Analysis and radiocarbon dating of these sediments has provided important evidence for interpreting sea-level changes and coastline evolution during the Holocene in the Western Isles.

Introduction

The site (NF 769499) is located on the south coast of North Uist facing the entrance to the South Ford, which separates Benbecula from South Uist. The interest lies in organic deposits preserved in the inter- and sub-tidal zones. Organic deposits, usually described as peat, have been recorded at intertidal locations in the Uists since the 18th century (Macleod, 1794; McRae, 1845; Martin, 1884; Beveridge, 1911; Jehu and Craig, 1927; Elton, 1938). Although the materials at these sites resemble peat, they consist of a variety of compressed organic layers, normally with a high sand content. Some layers contain wood fragments and others reed stems: some layers have a high silt content and a few contain terrestrial gastropods. Investigations in recent years (Ritchie, 1966, 1979, 1985) have demonstrated the importance of these organic horizons in understanding both sea-level change and the accompanying development of the dune and machair landscapes of the western coasts of the Outer Hebrides. The most extensive and best documented site is that at Borve on the south-west coast of Benbecula (Ritchie, 1985).

Description

The deposits occur in a shallow rock basin, now covered by a thin sand beach, between low, irregular rock platforms. At high tide level there is a small shingle storm beach which lies at the base of a sand cliff 1–4 m high. There are no dunes and the coastline is backed by a mature, flat machair plain which stretches inland for up to 2 km. The deposits have been investigated in a series of pits and boreholes and comprise, principally, a succession of interbedded sand and organic layers (Figure 12.9). Some organic layers include wood fragments and reed stems. Pollen analysis and study of macrofossils indicate that the entire site was at one time a freshwater lake which progressively infilled to form a marshy grassland. Later, massive quantities of sand were carried across these deposits to form the existing machair landforms. The complexity of the stratigraphy, however, indicates many changes in local conditions. Throughout the period of accumulation of the organic deposits there was considerable sand-blowing, the episodic nature of which is reflected in some individual sand layers up to 0.2 m in thickness; other beds are mainly organic material with only a few discrete sand particles in the matrix.

Three radiocarbon dates indicate the approximate period of deposition of the organic deposits and phases of sand influx. A fragment of wood from 0.6 m below present mean tide level was dated to 5700 ± 170 BP (I–1543) (Figure 12.9, pit J), and peat-like material, obtained from offshore and 3.7 m below the same datum, gave an age of 5160 ± 45 BP (SRR–1222). These two dates imply that the freshwater lake existed between a time prior to 5700 BP until after 5200 BP. In the machair sands backing the beach, a peaty layer at 2 m above present high water

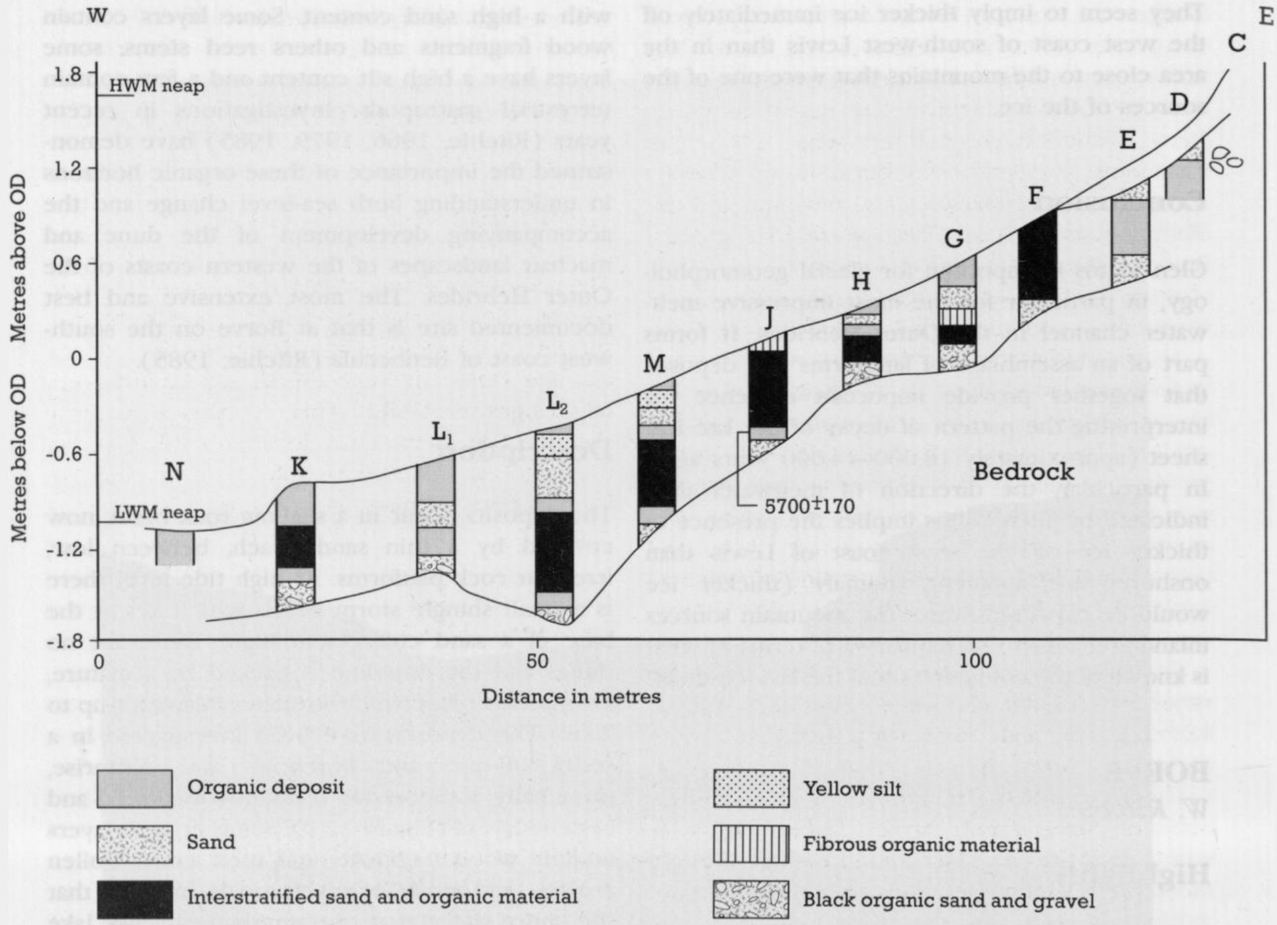


Figure 12.9 Profile across the intertidal deposits at Borve, showing the sediment sequence and its variations (from Ritchie, 1985).

mark has been radiocarbon dated to 3370 ± 60 BP (GU–1096); this layer represents a machair slack similar to those found in most low-lying machair plains today.

Interpretation

The freshwater lake in which the organic remains accumulated is interpreted as being similar to the lochs and marshlands that usually form the landward margins of modern machairs, the water level of which rarely exceeds 2 m above mean sea level (Ritchie, 1985). It seems likely that there has been a sea-level rise of at least 5 m as well as an accompanying landward movement of the shoreline in the last 5200 years. Radiocarbon dates on similar subtidal and intertidal peats of 8330 ± 65 BP (SRR–1223) from Pabbay (Ritchie, 1985) and 8802 ± 70 BP (SRR–396) from Holm in Lewis (von Weymarn, 1974) suggest sea levels at least 3–5 m lower between about 8800 BP and 5200 BP (Ritchie, 1985). The lacustrine origin of these dated organic materials makes it difficult to provide exact values for both the amount and rate of sea-level rise, but all such deposits provide unambiguous evidence of coastline recession.

The radiocarbon date of 3370 ± 60 BP from the machair sands indicates a locally stable land surface at that time, with phases of sand accumulation both before and after. Elsewhere, radiocarbon dates associated with machair coastlines suggest significant sand accumulation after 4366 ± 40 BP (SRR–1225) on Pabbay (Ritchie, 1985), 4550 ± 70 BP (SRR–2988) on Grimsay (Whittington and Ritchie, 1988) and 7810 ± 140 BP (GU–1762) at Claddach More (Balelone) (G. Whittington and W. Ritchie, unpublished data). Thus more evidence is accumulating from a variety of sites to demonstrate a long period of sand drifting both from primary and secondary sources. Unpublished evidence from a variety of

Bronze and Iron Age archaeological sites, located in machair areas, also indicates that there were many episodes of sand drifting which alternate with periods of stability. The extent to which these changes were anthropogenic is open to discussion. Similarly, the question of whether these periods of massive sand movements were synchronous in South Uist, North Uist and the Sound of Harris remains unanswered.

Inter- and sub-tidal organic remains occur at thirteen sites in the Uists (Ritchie, 1985). However, those at Borve are the most extensive and best documented deposits of their type in the Outer Hebrides. They are important for the evidence they provide both for sea-level change in the middle to late Holocene and for the accompanying development of the dune and machair landscapes that occupy 10% of the land area of the Uists. Unlike the coastline of mainland Scotland (see Western Forth Valley, Silver Moss and Philorth Valley) and the Inner Herbrides, sea-level change around the outer isles during the latter part of the Holocene resulted in coastal submergence and landward migration of the shoreline. Borve is one of the few sites in Scotland at which this type of sea-level movement has been dated. The evidence from there and related sites provides a fundamental, if as yet incomplete, stratigraphic and chronological framework that underpins the interpretation of the development and evolution of the beach and machair systems in the Outer Hebrides (see Ritchie, 1966, 1979, 1986; Whittington and Ritchie, 1988, unpublished data).

Conclusion

Borve is important for a sequence of deposits that provides a detailed and dated record of sea-level changes and coastline development in the Outer Hebrides during Holocene times. In particular, the deposits show that the coastline has moved landwards as relative sea level rose by at least 5 m during the last 5200 years. Phases of sand erosion and accumulation occurred both before and after about 3400 years ago. This evidence is important not only for understanding the development of the dune and machair landscapes of the Western Isles, but it also allows valuable comparisons with results from sites elsewhere in Scotland where the pattern has been one of coastal emergence rather than submergence. Borve is therefore a valuable reference site for sea-level studies in Scotland.

GLEANN MÓR, HIRTA

M. J. C. Walker

Highlights

The sediments which infill a topographic basin in Gleann Mór contain a valuable pollen record, supported by radiocarbon dating, of the Lateglacial and Holocene vegetational and environmental changes on St Kilda. This record is particularly significant in view of the location of the site on the extreme Atlantic periphery of the British Isles, where human modifications have been minimal.

Introduction

The site (NF 086997) is a small peat bog located at an altitude of approximately 90 m OD on the lower slopes of Gleann Mór, in the north-west part of the island of Hirta. The islands of St Kilda have long been a focus of ecological interest because of their remote position on the Atlantic fringes of the British Isles. The archipelago, consisting of the islands of Hirta, Dun, Soay and Boreray, lies near the edge of the continental shelf 180 km west of the Scottish mainland and 64 km west-north-west of the westernmost headland of the Outer Hebrides. Although a considerable amount of research has been carried out on the present vegetation (Turrill, 1927; Petch, 1933; Poore and Robertson, 1948; McVean, 1961; Gwynne *et al.*, 1974), until recently only limited palynological investigations (McVean, 1961) had been made and hence the vegetational history of the island group was virtually unknown. Following the discovery of an interstadial polleniferous sand (Sutherland *et al.*, 1984), the publication (Walker, 1984a) of a detailed pollen diagram from Hirta covering much of the Holocene has given important insights into the vegetational development of the islands.

Description

A little over 2 m of sediment, comprising principally sand, organic muds and peat, have accumulated in the peat bog (Figure 12.10).

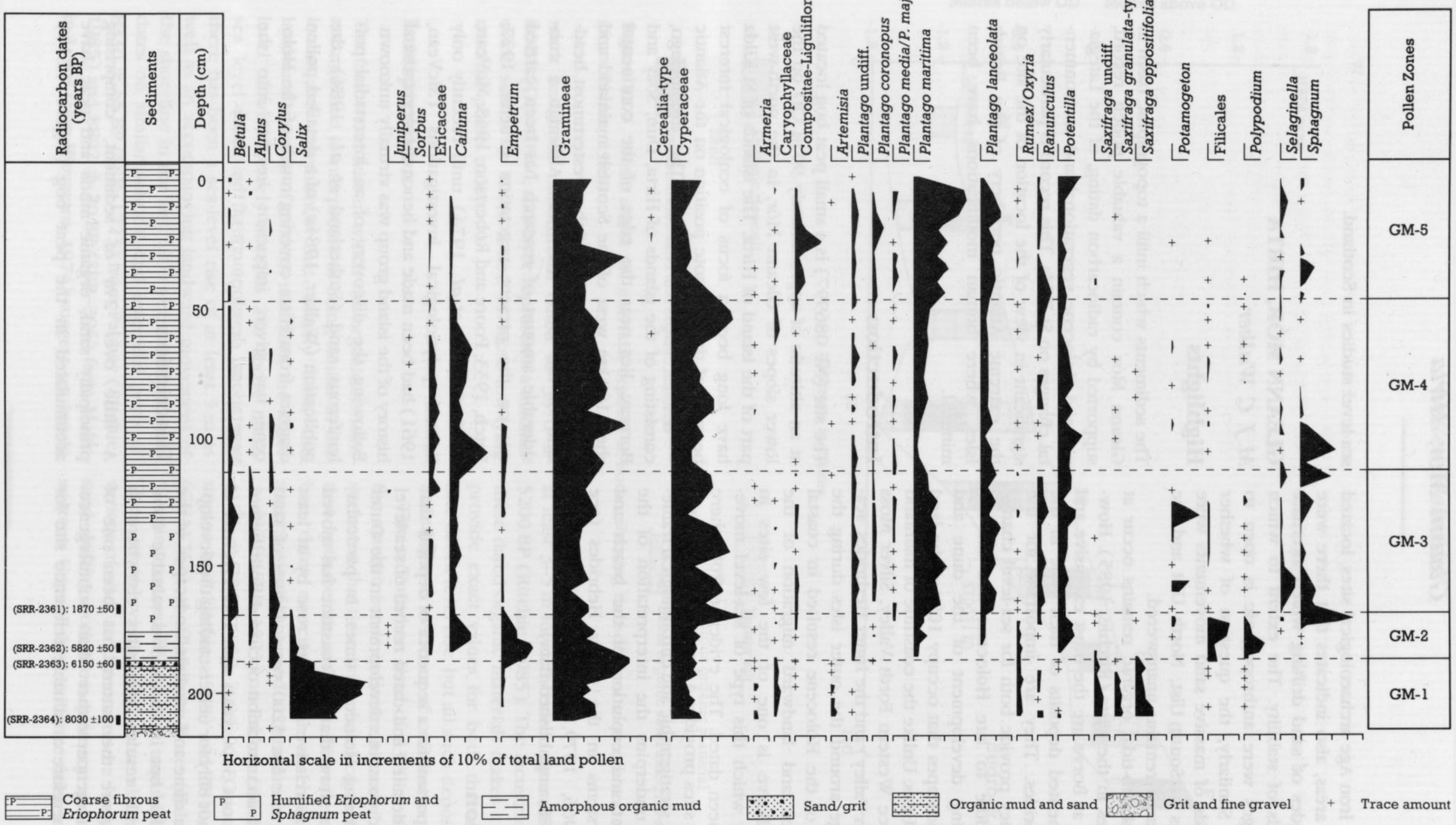


Figure 12.10 Gleann Mór, Hirta: relative pollen diagram showing selected taxa as percentages of total land pollen (from Walker, 1984a).

The lowermost sediments in the profile, comprising beds of grit and fine gravel, and brown organic mud are of probable Loch Lomond Stadial age; the remainder are Holocene deposits. Five pollen assemblage zones have been identified and four radiocarbon dates (SRR–2361 to SRR–2364) have been obtained from the sediments (Figure 12.10).

Interpretation

The earliest pollen zone (GM–1) is dominated by *Salix*, and is characterized by pollen from taxa indicative of bare and disturbed ground such as *Saxifraga oppositifolia*, *Oxyria digyna*, *Artemisia* and species of Caryophyllaceae. An open tundra landscape is indicated and hence the *Salix* pollen indicates the presence of either the least willow (*Salix herbacea*), or such northern or arctic willows as *Salix polaris*, *Salix reticulata* or *Salix glauca*. The basal minerogenic sediments that contain this pollen assemblage are indicative of periglacial conditions, and a Loch Lomond Stadial age (11,000–10,000 BP) is suggested. The radiocarbon date of 8030 ± 100 BP (SRR–2364) obtained from the base of the profile is considered to be in error by around 2000 years as a consequence of groundwater contamination.

The boundary between pollen assemblage zones GM–1 and GM–2 has been dated to 6150 ± 60 BP (SRR–2363) which, if correct, indicates a gap in the sediment record of the Gleann Mór profile spanning over 4000 years during the early and middle Holocene. The pollen spectra in GM–2 reflect a floristically diverse grassland with *Plantago maritima*, *Plantago lanceolata*, *Potentilla*, *Rumex*, Compositae (Liguliflorae) and *Polypodium*, interspersed with heathland communities dominated by *Empetrum*, *Calluna vulgaris* and, probably, *Erica cinerea*. Pollen of *Betula*, *Alnus* and *Corylus* is also present. While it is possible that small numbers of birch, hazel and alder managed to gain a foothold on Hirta, the fact that frequencies for these genera never exceed 6–7% of total land pollen means that the possibility of long-distance transfer from the Scottish mainland cannot be discounted (see Birks and Madsen, 1979). Certainly, there is no unequivocal evidence to support the view (McVean, 1961) that St Kilda once possessed a cover of birch–hazel scrub.

The renewed accumulation of sediment at Gleann Mór a little before 6000 BP is almost certainly a reflection of a regional climatic shift to more oceanic conditions in north-west Europe following the Holocene rise in sea level. The first traces of *Alnus* which are recorded in the Gleann Mór profile around 5800 BP may be a further indication of a general trend towards increasing climatic wetness (Godwin, 1975).

Pollen zone GM–3, the base of which has been dated to 1870 ± 50 BP (SRR–2361), reflects a change from a mixed heath and grassland landscape to a *Plantago*-dominated sward, the principal elements of which were *Plantago maritima* and *P. lanceolata*, along with *P. media*/*P. major* and *P. coronopus*. Many of these species are found in the halophyte swards that have developed on St Kilda at the present day in areas where the sea-spray effect is considerable (Gwynne *et al.*, 1974). The decline in heathland and expansion of the *Plantago* grassland may therefore be indicative of an increase in storm frequency and intensity around St Kilda, with salt spray being blown across large areas of Hirta. Wetter conditions are also indicated by the occurrence of *Potamogeton* and *Littorella* which suggest pools of standing water, by the appearance of *Selaginella* reflecting the expansion of moist and damp habitats, and by the higher counts for *Sphagnum* and Cyperaceae. These records probably reflect the marked deterioration in climate that occurred throughout north-west Europe around 2500 BP (Lamb, 1977, 1982a).

The pollen spectra in zone GM–4, by contrast, appear to indicate a change to drier and less stormy conditions. The decline in *Plantago maritima* frequencies and the increased values for *Empetrum* imply an expansion of heathland at the expense of *Plantago* sward. Some areas of marshy and boggy ground remained but, in general, the extensive maritime communities that had previously been a feature of the Hirta landscape were significantly reduced. No radiocarbon dates were obtained from this level of the profile, and hence dating is speculative, but pollen zone GM–4 may span the first millennium AD, a period of generally more equable climate in the North Atlantic region (Lamb, 1977, 1982a, 1982b).

The uppermost pollen assemblage zone (GM–5) is comparable in a number of respects to GM–3, with the expansion of *Plantago*-dominated plant communities at the expense of heathland. Again, an episode of wetter and more stormy conditions is implied, most probably corresponding with the Little Ice Age, the climatic deterioration experienced throughout north-west Europe and the

North Atlantic region during the second millennium AD.

Anthropogenic effects on the vegetation of Hirta are difficult to establish. The appearance of *Plantago lanceolata* pollen shortly after 5800 BP is a feature that has frequently been associated with human activity (for example, Johansen, 1978), but in the context of St Kilda, the pollen record for this species is more probably a reflection of the growth of ribwort plantain in natural maritime grassland communities. Similarly, although it is possible that some of the fluctuations in the *Calluna* pollen curves may be due to prehistoric grazing activity, there is little independent archaeological evidence, and hence the pollen record is more likely to reflect climatic rather than anthropogenic influences. Only in the uppermost 0.2 m of the profile, where low frequencies of cereal-type pollen are encountered, is there clear evidence of human activity.

The pollen site in Gleann Mór on the island of Hirta is of considerable significance. It provides valuable data on the vegetational history of St Kilda during the Loch Lomond Stadial, and it contains detailed pollen evidence of vegetational changes in this remote area of the British Isles throughout the middle and late Holocene. Of particular importance, however, is the fact that, by contrast with other areas of the British Isles and north-west Europe, human influence on the vegetation of the islands appears to have been minimal and hence the pollen sequence provides a rare proxy record of climatic changes in the North Atlantic province spanning the past 6000 years. Relatively few records of this nature are available because the effects of climatic change are frequently masked in late Holocene pollen records by anthropogenic influences (Birks, 1986).

Conclusion

Gleann Mór is important for its record of vegetation history and environmental change on St Kilda during the Lateglacial and Holocene (approximately the last 11,000 years). The site provides valuable palaeoecological data from a remote and inaccessible part of Britain, and the pollen evidence from Gleann Mór is of particular significance for the insights it allows into the patterns of climatic change during the later part of the Holocene.