Quaternary of Scotland

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Chapter 4

The Orkney Islands

INTRODUCTION

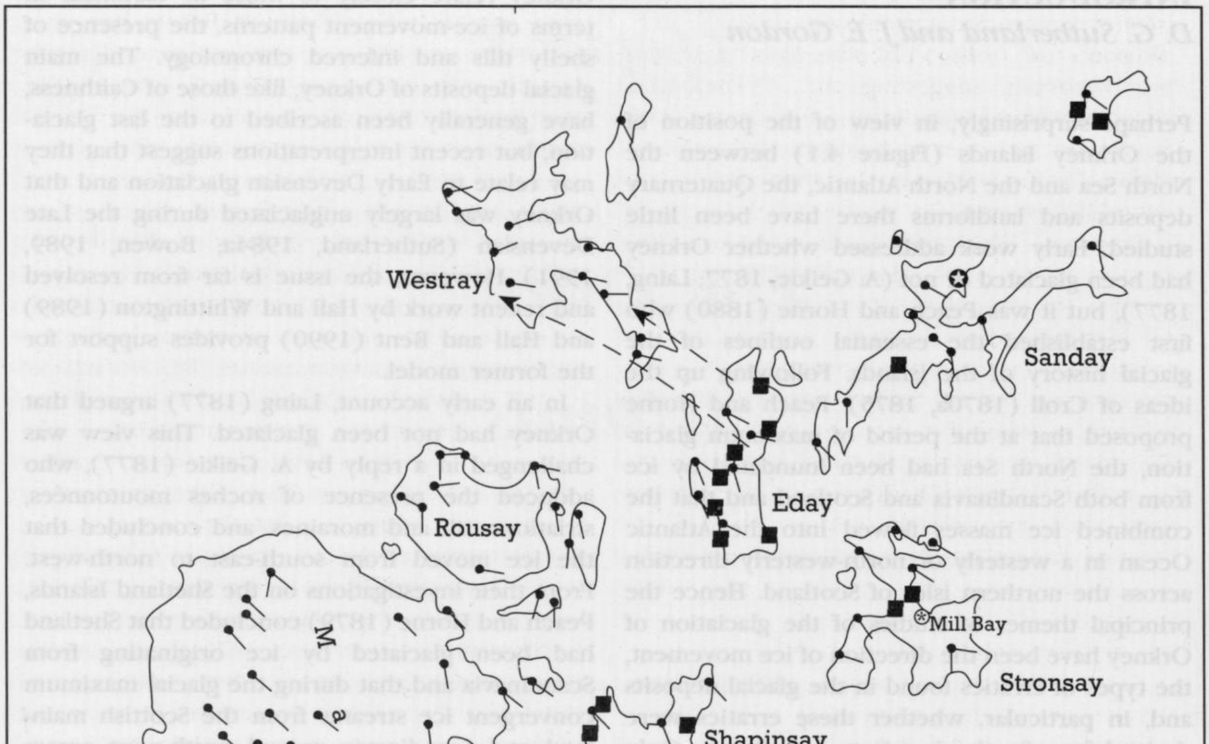
D. G. Sutherland and J. E. Gordon

Perhaps surprisingly, in view of the position of the Orkney Islands (Figure 4.1) between the North Sea and the North Atlantic, the Quaternary deposits and landforms there have been little studied. Early work addressed whether Orkney had been glaciated or not (A. Geikie, 1877; Laing, 1877), but it was Peach and Horne (1880) who first established the essential outlines of the glacial history of the islands. Following up the ideas of Croll (1870a, 1875), Peach and Horne proposed that at the period of maximum glaciation, the North Sea had been inundated by ice from both Scandinavia and Scotland and that the combined ice masses flowed into the Atlantic Ocean in a westerly or north-westerly direction across the northern isles of Scotland. Hence the principal themes of studies of the glaciation of Orkney have been the direction of ice movement, the types of erratics found in the glacial deposits and, in particular, whether these erratics were derived from Scotland or from Scandinavia. Only minor attention was paid to the possibility of local glaciation, and it is only in recent years that a small amount of palynological information has become available on the history of the vegetation of the islands.

No organic interstadial or interglacial deposits have been reported from Orkney. The stratigraphically earliest Quaternary deposit is a raised cobble beach exposed in the north of Hoy (see Muckle Head and Selwick). The beach occurs at 6–12 m above present sea level and rests on the inner margin of a marine abrasion ramp. No erratic material and no fossils have been observed in the beach, which is overlain by a head deposit and then a till deposited during the last regional glaciation (Wilson *et al.*, 1935; D. G. Sutherland, unpublished data). The age of the beach is unknown.

A fundamental theme in studies of the glaciation of Orkney has been the movement of ice from the floor of the North Sea westwards and north-westwards across the islands. This model derived initially from studies on the Scottish mainland in Caithness (Jamieson, 1866; Peach, 1868 (cited by Croll, 1870a); Croll, 1870a, 1875) and was later substantiated by detailed mapping on the Orkney Islands themselves (Helland, 1879; Peach and Horne, 1880; Wilson *et al.*, 1935; Mykura, 1976; Rae, 1976). The glacial features in Orkney relate closely to those in Caithness in terms of ice-movement patterns, the presence of shelly tills and inferred chronology. The main glacial deposits of Orkney, like those of Caithness, have generally been ascribed to the last glaciation, but recent interpretations suggest that they may relate to Early Devensian glaciation and that Orkney was largely unglaciated during the Late Devensian (Sutherland, 1984a; Bowen, 1989, 1991). However, the issue is far from resolved and recent work by Hall and Whittington (1989) and Hall and Bent (1990) provides support for the former model.

In an early account, Laing (1877) argued that Orkney had not been glaciated. This view was challenged in a reply by A. Geikie (1877), who adduced the presence of roches moutonnées, striations, till and moraines, and concluded that the ice moved from south-east to north-west. From their investigations on the Shetland Islands, Peach and Horne (1879) concluded that Shetland had been glaciated by ice originating from Scandinavia and that during the glacial maximum convergent ice streams from the Scottish mainland and Scandinavia moved north-west across the floor of the North Sea and the Orkney Islands. Subsequently (Peach and Horne, 1880), they elaborated on this model and in support provided detailed field evidence from Orkney for the pattern of ice-sheet and, later, local mountain glaciation; Helland (1879) independently reached similar conclusions. Striations and roches moutonnées showed conclusively that ice moved to the north-west and north-north-west, from the North Sea to the Atlantic. Further evidence of such ice movement was provided by the presence of shell fragments in the till at numerous locations and systematic changes in the lithological composition of the till on several islands. Erratics included a number of rock types foreign to the islands: limestones (including chalk), igneous lithologies, and the famous Saville Boulder, which has been argued to be of Scandinavian origin (Heddle, 1880; Flett, 1898; Wilson *et al.*, 1935). Other supposedly Scandinavian erratics were noted by Saxton and Hopwood (1919), although Rae (1976) considered that they could equally well have been derived from the Scottish mainland. Peach and Horne (1893c) later provided further details of shelly till and erratics on North Ronaldsay. They concluded that some of the material could have been derived from Aberdeenshire, the eastern Highlands and Fife. Peach and Horne's work remained the definitive study of



Striations from Wilson *et al.* (1935).

Transport of erratics recorded in Peach and Horne (1880).

Shelly till localities (after Peach and Horne, 1880; Rae, 1976; Sutherland, unpublished data).

Saville erratic.

Raised beach in north Hoy.

GCR sites.

Orkney for nearly a century and it has provided a basis for most regional syntheses.

Wilson *et al.* (1935) elaborated on Peach and Horne's results, suggesting that Orkney was crossed initially by Scandinavian ice moving from east to west and then by Scottish ice flowing at first towards the north-west and then towards the north. Charlesworth (1956) placed the limit of his Stage A (Highland Glaciation) across the Mainland, based on the distribution of morainic mounds. However, there is no convincing evidence that these are ice-marginal deposits and the current view is that they relate to ice-sheet wastage (Rae, 1976). Godard (1965) followed the interpretation of Wilson *et al.* (1935), but believed that the last ice-sheet movement probably correlated with Charlesworth's Scottish Readvance, a concept that is no longer tenable.

The most detailed recent study of the glaciation of Orkney is that of Rae (1976). He concluded that the earliest ice flow originated from between south and south-south-east. Later ice flowed from the south-east and finally from between east-south-east and east. Although he recognized two distinctive till units and cross striations, Rae concluded that there was no substantive evidence for more than one major ice-sheet glaciation on Orkney (see Den Wick). The age of this glaciation was, however, unconfirmed, but on the basis of an infinite radiocarbon date from Mill Bay, Rae believed that it could have occurred during the Early Devensian.

From his work in Shetland, Orkney, Foula and Fair Isle, Flinn (1978a) proposed two possible models for the glaciation of the islands. The first involved Scandinavian ice crossing the North Sea early in the last glaciation and deflecting Scottish ice across Orkney. Later, as both Scottish and Scandinavian ice waned, an independent ice-cap developed in Shetland. The second model, which Flinn considered more acceptable, placed the Scandinavian ice in an unspecified earlier stage.

In the absence of any known organic interglacial or interstadial deposits on Orkney, dating of the glacial sequence has remained conjectural, with most opinions assigning the main glacial features to the last ice-sheet (Late Devensian) or the ice maximum. In recent years, however, the extent of the last glaciation in Britain has been questioned and attention has re-focused on the possible existence of unglaciated areas in the more peripheral parts of the country. A fundamental problem in interpreting the glacial sequence in Orkney centres on explaining the westerly movement of the Scottish ice. This has generally been attributed to its deflection by Scandinavian ice in the central North Sea. However, offshore studies have shown that during the last glaciation the floor of the central North Sea was unglaciated (Cameron *et al.*, 1987; Sejrup *et al.*, 1987). Therefore, unless the deflection of the Scottish ice relates to an alternative, but as yet unidentified, mechanism, the glaciation of Orkney must have been earlier. Thus, although there is no conclusive evidence as yet, the current weight of opinion favours the interpretation that Orkney was last glaciated by an external ice-sheet during the Early Devensian and was not covered by the last Scottish ice-sheet (Rae, 1976; Synge, 1977a; Sissons, 1981b; Sutherland, 1984a; Bowen *et al.*, 1986). Recently, further support for Early Devensian glaciation has come from the preliminary results of amino acid dating of shells from the tills of Caithness and Orkney (Bowen and Sykes, 1988; Bowen, 1989, 1991). If this hypothesis is substantiated, then it places important constraints on wider palaeoclimatic and glacier reconstructions and also on the nature of landscape change and the impact of periglacial processes on Orkney during the Late Devensian. However, Hall and Whittington (1989) have adduced several lines of evidence from Caithness (see below) to support more extensive glaciation during the Late Devensian and a possible ice limit as far north as the Orkney – Shetland Channel (see also Hall and Bent, 1990). Subsequently, Hall and Bent (1990) have suggested that the north-westerly ice movement across Orkney and Caithness might relate to the development of a divergent flow pattern in the Moray Firth, where the ice-sheet moved from a rigid to a deformable bed.

Following A. Geikie (1877), Peach and Horne (1880) recognized a number of moraines on Hoy and the more elevated parts of the Mainland which they inferred to be associated with local valley glaciation. From later work, however, it is apparent that only on Hoy is there clear geomorphological evidence for local glaciation (Wilson *et al.*, 1935; Godard, 1965; Rae, 1976). Rae (1976) concluded that apart from Enegars Corrie, there was no evidence for corrie glaciers in any

Figure 4.1 Location map and principal features of the glaciation of Orkney, including patterns of striations, directions of transport of erratics and shelly till localities (from Sutherland, 1991b).

of the locations suggested by Charlesworth (1956), and in other localities in the valley of South Burn and the Ford of Hoy it was not clear whether the glacial deposits were associated with local ice or with the decay of the ice-sheet.

A number of arcuate end moraines occur, however, for example at Dwarfie Hamars and Enegars Corrie (D. G. Sutherland, unpublished data). Although not directly dated, these possibly relate to the Loch Lomond Readvance and represent the last minor phase of glaciation on Orkney. These small glaciers formed in favoured localities and had equilibrium line altitudes of approximately 150 m OD.

The hills of northern Hoy are the only ones in Orkney to give rise to significant areas of ground above 350 m OD and they are especially notable for the development of periglacial features (see Ward Hill) (Goodier and Ball, 1975). It seems probable that the periglacially weathered detritus that mantles the summits of these hills was produced during the Late Devensian (and conceivably earlier), but the periglacial features observed today were all apparently produced during the Holocene. The sand sheets ('dunes') on Ward Hill, in particular, seem to preserve a record of changing Holocene environments in the form of buried soil horizons.

Despite the pioneering work of Erdtman (1924), there have been few detailed pollen analytical studies of the vegetational development of Orkney. The only study of Lateglacial profiles is that of Moar (1969a), who indicated that the vegetation at that time was very restricted in its development. During the early to middle Holocene a dwarf-shrub vegetation developed with possibly only isolated patches of birch and hazel scrub (Moar, 1969a; Keatinge and Dickson, 1979). From the middle Holocene onwards there has been considerable human impact on the vegetation (Moar, 1969a; Caseldine and Whittington, 1976; Davidson *et al.*, 1976), and it may be that grazing pressure contributed to the spread of blanket bog in the later Holocene (Keatinge and Dickson, 1979).

MUCKLE HEAD AND SELWICK

D. G. Sutherland

Highlights

Coastal sections at Muckle Head and Selwick provide a rare example in Scotland of raised beach deposits which are overlain by till. These deposits pre-date at least the last glaciation on Orkney, and are important for interpreting the history of sea-level changes and glaciation in the northern isles.

Introduction

Muckle Head (HY 213053) and Selwick (HY 225055) are coastal sections located on the north of Hoy. They provide important exposures in raised beach deposits overlain by till. The raised beach deposits pre-date at least the last glaciation and indicate a former sea level slightly above that at present. They are important not only for interpreting the Pleistocene history of Orkney, but also in the wider context of those parts of Scotland which were peripheral to the centres of glaciation. The only published description of the sites is in Wilson *et al.* (1935).

Description

Wilson *et al.* (1935) recorded a raised beach at Muckle Head and Selwick at between 20 ft (6 m) and 40 ft (12 m) above present sea level and resting on a clear rock notch or platform. They described the beach as being up to 5 m in thickness and consisting of a coarse, rounded gravel with numerous rounded boulders. The beach deposits, which at both localities were cemented by calcite, contained no erratic clasts. Wilson *et al.* (1935) did not specifically record the beach deposits as being overlain by till (and a cross-section of the Selwick beach and rock platform does not show any glacial deposits) but they concluded that the beach was probably 'pre-Glacial' in age, on the grounds of the lack of erratic material.

Recently, the best exposure has been that at Muckle Head (Figure 4.2) (D. G. Sutherland, unpublished data). There, approximately 3.5 m of beach sediments rest in the angle of a rock notch at the back of a ramp cut in conformity with the bedding of the Old Red Sandstone flagstones. The beach consists of a fining upwards sequence of rounded cobbles and pebbles at the base to pebbles at the top, with large subangular flagstone boulders scattered throughout. Immediately overlying the beach is a head deposit, about 1.5 m thick, consisting of angular to very angular platy

Figure 4.2 Section at Muckle Head, Orkney. The raised beach gravel, which rests on a rock platform, incorporates large flagstone blocks and is overlain in turn by a head deposit and till. (Photo: D. G. Sutherland.)

clasts derived from the immediately adjacent bedrock. Resting on this head deposit is approximately 1 m of brown till with a well-developed clayey-sand matrix. The upper 0.3 m of this till has been periglacially disturbed and subject to solifluction, and the section is capped by 0.15–0.3 m of structureless sand with occasional gravel clasts scattered throughout.

The Selwick deposit is less accessible and the stratigraphy less clear than at Muckle Head. Also the beach does not show the fining upward sequence noted at Muckle Head, being composed of rounded cobbles and pebbles, with a scatter of angular boulders throughout. There was no clear contact observed with the overlying deposits, but exposures in slumps revealed a yellow-brown till.

Interpretation

It is apparent from the local stratigraphy that the beach pre-dates the last glaciation of Orkney. The age of this glaciation remains to be established, however. The stratigraphic sequence at Muckle Head can be interpreted as evidence for a period of high sea level, followed, when sea level had fallen, by cold periglacial conditions and then invasion of the area by ice. Subsequent to ice retreat there was a further period of periglaciation. The simplest chronological interpretation would be that this sequence of events represents the last interglacial–glacial cycle, but until direct dating evidence is available such a conclusion is speculative.

There are relatively few localities in Scotland where raised beach sediments can be observed to be overlain by till. Similar stratigraphic sequences are relatively common in the southern British Isles, where amino acid dating has established that there are several generations of beach deposits, each apparently being correlated with a separate interglacial period (Bowen *et al.*, 1986). In Scotland, beach deposits overlain by till are only known in those areas peripheral to the centres of glaciation, such as in the north of Lewis (see North-west Coast of Lewis), on the islands of Barra (Peacock, 1980a, 1984a; Selby, 1987) and North Rona (Gailey, 1959), and at two localities in the north of Hoy, at Muckle Head and Selwick. In none of these areas have marine shells been recovered from *in situ* beach sediments and hence there has been no opportunity to date the beaches other than with reference to the local stratigraphic sequence. It is therefore not known whether the various exposures of beach deposits are contemporaneous or not.

The raised beach deposits in the north of Hoy are two of the very few similar deposits in Scotland that record a period (or periods) of sea level only slightly above that of the present, but prior to at least the last glaciation. The Muckle Head section, in particular, demonstrates a sequence of sediments which apparently were deposited during a period of climatic cooling and glacial expansion, but the age of these sediments remains to be established. The site is an important element not only in the Pleistocene history of Orkney, but also as part of a pattern of interrelated sea level and glacial events in those areas of Scotland that were peripheral to the areas of build-up of the Scottish ice-sheets.

Conclusion

Muckle Head and Selwick are important in showing raised beach deposits overlain by ice-deposited sediment (till), a succession which indicates that sea level was slightly above that of the present during a period, as yet undated, before the last glaciation. This area of north Hoy is one of only a few locations in Scotland, all located near the periphery of ice-sheet glaciation, where such successions occur. It is therefore critical not only in establishing the history of sea-level change and glaciation in Orkney, but also in helping to reconstruct their wider regional patterns.

DEN WICK

J. E. Gordon

Highlights

The sequence of sediments in the coastal section at Den Wick is representative of the multiple till deposits of Orkney. The lithological contents and clast fabrics of the two tills provide evidence for changing ice-flow patterns during the last glaciation of Orkney.

Introduction

Den Wick (HY 576088) is a coastal section on the Deerness peninsula in the eastern part of the

Mainland; it shows one of the best examples of a multiple till sequence in Orkney. Two tills are present and have been described by Rae (1976). Their lithological characteristics provide significant evidence for reconstructing former ice-flow directions, and they demonstrate important general relationships between till properties and the source bedrock lithologies.

The first suggestion of multiple drift units on Orkney was made by Wilson *et al.* (1935), who noted the occurrence of a grey or yellowish clayey rubble below the more usual grey, red or purple till of sandy-clay composition, but they concluded that the former was little more than fractured and locally transported bedrock. Subsequently, Rae (1976) formally established and defined the existence of more than one till on the basis of colour, lithology and sedimentological properties. He argued that the till characteristics at a site reflect the bedrock composition up-ice and that contrasts between individual till units at a site relate to changing ice-movement patterns. Rae (1976) recorded twenty multiple till sections in Orkney.

Description

At Den Wick, Rae (1976) noted the following sequence:

3.	Red till	1.5–>3 m
2.	Brown till	>5.5 m
1.	Striated bedrock	

The contact between the two tills was sharp and undulating, and locally a thin sand and gravel horizon, 0.1–0.15 m thick, intervened between the tills. However, Rae considered that at this and all the other sites, there was no significant evidence to support more than one glacial episode, and therefore the multiple tills were deposited by a single ice-sheet.

From the orientations of striae on the bedrock beneath the brown till, the lithological composition of the till (a relatively high percentage of Lower Eday Sandstones) and clast fabric measurements, Rae concluded that the ice movement associated with the lower till was from between south and south-east. Ice following such a flow pattern would have traversed the Lower Eday Sandstone most of the way across the Deerness peninsula and avoided the Middle Eday Sandstones.

The overlying red till has a relatively higher content of red sandstone clasts similar to the Middle Eday Sandstone. Since no onshore outcrop of this lithology appeared to fit with the pattern of striations observed beneath the red till elsewhere in Deerness where it rests directly on bedrock, Rae postulated an offshore outcrop, an interpretation supported by the presence of chalk erratics in the red till but not in the brown till. The red till was therefore associated with ice flow from a more easterly azimuth than the underlying brown till. Shell fragments have been recovered from both till units (A. M. Hall, unpublished data).

Interpretation

Den Wick is an important section representing one of the key elements of the till stratigraphy of Orkney. The multiple till sequences, of which Den Wick is a particularly good example, are important in several respects. First, their lithological and sedimentological characteristics demonstrate close relationships with the source bedrock traversed by the ice. Second, the superimposition of the different till units indicates changes in ice-flow direction, thus supporting the inferences based on striation patterns. Third, the contacts between the different units at individual sites provide no conclusive evidence for deposition during more than one glacial period. Fourth, the superimposition of the multiple till units in a consistent fashion (Rae, 1976) and the inferred shifts in the direction of ice flow provide important evidence for significant changes in the wider regional dynamics of the ice-sheet and its driving forces. Further study at both regional and national scales, coupled with ice-sheet modelling, is required to elaborate the origins of these changes and the extent to which they may relate to climatic factors and other variables that determine ice-sheet flow patterns. Multiple till sequences, like that at Den Wick, will be an important source of field evidence to provide constraints on the appropriate mathematical models.

Conclusion

The sediments at Den Wick are representative of the multiple till deposits of Orkney. They comprise two superimposed tills, each containing distinctive rock fragments derived from the bedrock over which the ice that deposited the tills had flowed. The tills provide evidence, in the form of their stone orientations and rock and shell contents, for former ice-flow directions. The till succession indicates a change in the flow pattern during the course of a single glaciation, suggesting a significant change in ice-sheet dynamics.

MILL BAY

J. E. Gordon

Highlights

The coastal section at Mill Bay is the best locality for demonstrating the shelly till that is characteristic of the eastern part of Orkney. This deposit shows that the ice moved across the sea floor and then onshore in a west-north-west direction. The presence of the shells also provides an important opportunity to date the last main glaciation of the islands.

Introduction

A coastal section at Mill Bay (HY 665256), on Stronsay, provides the best available exposures of the shelly till of Orkney and has been described by Peach and Horne (1880) and Rae (1976). As well as demonstrating the characteristics of this important till unit, Mill Bay is particularly significant for the dating potential of the shells in the till.

Description

The section at Mill Bay forms a continuous cliff 6–10 m high over a distance of nearly 1 km. Peach and Horne (1880) recorded a reddish-brown, gritty clay containing striated stones. In composition the till mostly includes material from the adjacent flagstones and siltstones, but a range of exotic rock types is also present, including igneous and metamorphic lithologies, fossiliferous limestones, chalk, flints and fossil wood. Peach and Horne inferred that the erratics were derived from the Scottish mainland. Numerous fragments of shells, including *Arctica islandica* (L.), *Mytilus* and *Mya truncata* (L.), are also present in the till, and according to Peach and Horne they appear smoothed and striated. Striations on bedrock at Mill Bay are aligned W15°–35°N. Peach and Horne also recorded large blocks of what appeared to be petrified wood in the till. Rae (1976) has provided additional sedimentological and lithological details of the till at Mill Bay, and noted the presence of a lens of grey till incorporated in the red till. Rae (1976) also obtained an infinite radiocarbon date of >44,300 BP (T–1152) from shell fragments in the till.

Interpretation

The lithological composition and the erratic and shell content of the Mill Bay till clearly indicate that ice moved onshore from an easterly direction (Peach and Horne, 1880; Rae, 1976) in accordance with the general pattern established for the Orkney Islands. Although, strictly, the radiocarbon date is inconclusive, Rae argued that on the basis of probability it suggests an Early Devensian age for the till. More recently, preliminary results from amino acid epimerization analyses suggest that shells in the till are no younger than the last interglacial, which again lends support to the hypothesis that the maximum age of the till is Early Devensian (see Bowen and Sykes, 1988; Bowen, 1989, 1991).

Mill Bay is an important reference site for the shelly till of Orkney, and it represents the best exposure of its type on the islands. Although shelly till is exposed at several other localities (see Peach and Horne, 1880; Rae, 1976), predominantly in the eastern half of the Orkney Islands (Figure 4.1), Mill Bay is one of the few sites where shell fragments are relatively abundant and it has also yielded a relatively wide range of erratic types. Mill Bay therefore demonstrates particularly well the general direction of ice movement onshore and towards the west-north-west. In a wider context, the Mill Bay till forms part of a lithostratigraphic unit that extends across Caithness and Orkney. This formation is thought to be the product of a single glacial episode in which ice from the Scottish mainland moved north-west from the Moray Firth Basin and adjacent North Sea Basin. As yet the age of the glaciation is not securely established, but Mill Bay provides significant dating potential. Preliminary results from amino acid analyses, taken in conjunction with those from Caithness and with other evidence from the central North Sea, provide some support for glaciation during the Early Devensian. If substantiated, this would be

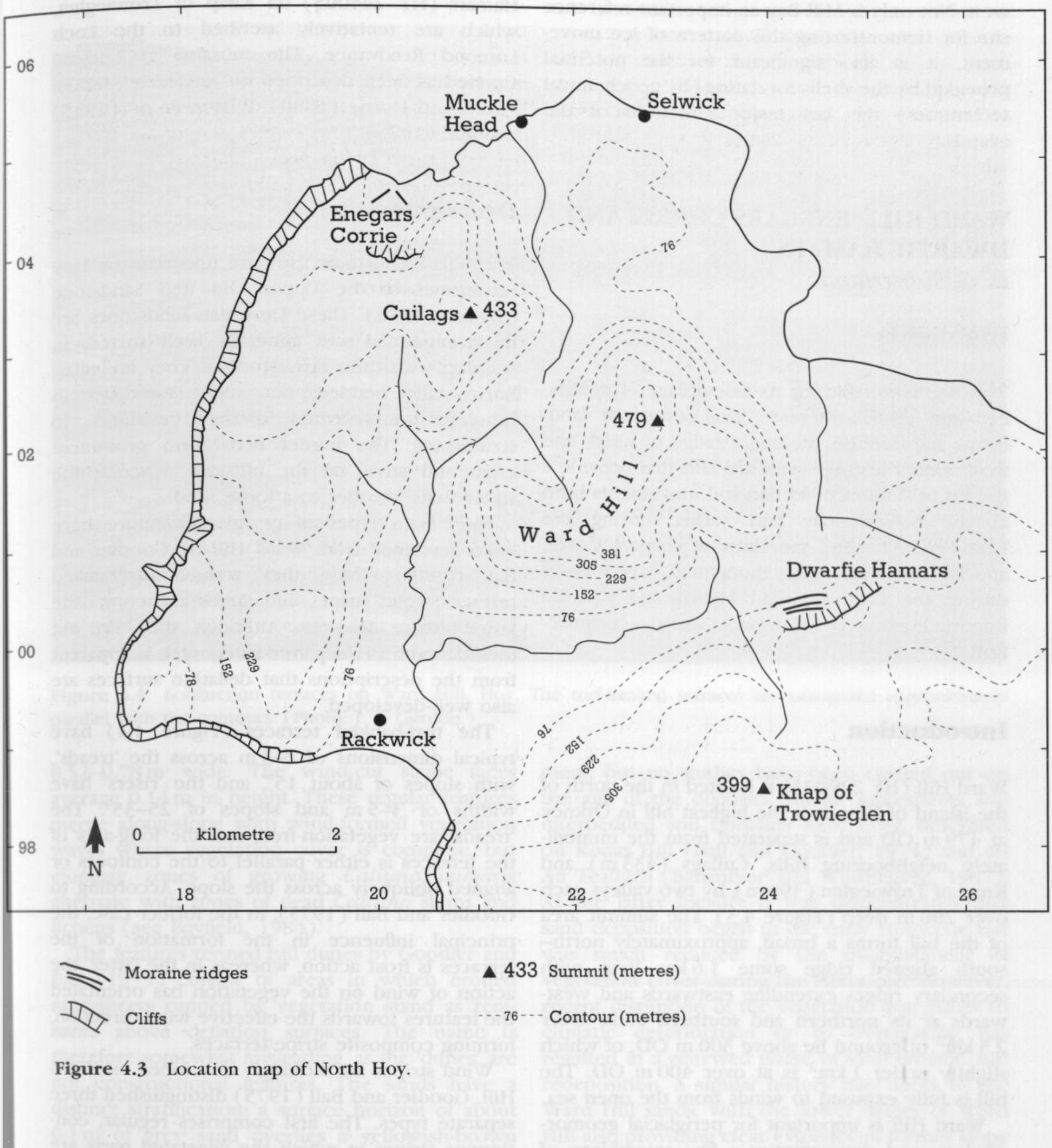


Figure 4.3 Location map of North Hoy.

the first positive evidence for Early Devensian glaciation in Scotland. On the other hand, there is evidence from Caithness (see below) that the shelly till may in fact date from the Late Devensian. Sites such as Mill Bay therefore have a major role to play in resolving this key issue of the limits of the last ice-sheet in northern Scotland and the adjacent shelf.

Conclusion

Mill Bay provides the best available exposures in the shelly till (sediments deposited by ice) of Orkney. The presence of the shells of marine molluscs in the till, together with other evidence, indicates the movement of ice across the sea bed and then onshore and towards the west-north-west. Not only is Mill Bay an important reference site for demonstrating this pattern of ice movement, it is also significant for the potential provided by the shells for dating (by geochemical techniques) the last major glaciation of the islands.

WARD HILL, ENEGARS CORRIE AND DWARFIE HAMARS

D. G. Sutherland

Highlights

This site is notable for its assemblage of periglacial and glacial interests. The periglacial landforms and deposits include a range of wind- and frost-related features on Ward Hill that provide a record of slope activity and soil movements both at the present day and earlier during the Holocene. The end moraines at Enegars Corrie and Dwarfie Hamars are thought to have formed during the Loch Lomond Stadial and provide important evidence for palaeoclimatic reconstruction.

Introduction

Ward Hill (HY 229023) is located in the north of the island of Hoy. It is the highest hill in Orkney at 479 m OD and is separated from the immediately neighbouring hills, Cuilags (433 m) and Knap of Trowieglen (399 m), by two valleys each over 200 m deep (Figure 4.3). The summit area of the hill forms a broad, approximately north–south aligned ridge some 1.6 km long with secondary ridges extending eastwards and westwards at its northern and southern ends. Over 2.5 km^2 of ground lie above 300 m OD, of which slightly under 1 km^2 is at over 400 m OD. The hill is fully exposed to winds from the open sea.

Ward Hill is important for periglacial geomorphology and demonstrates a fine assemblage of active and fossil landforms. By virtue of its northern location, it is a prime site in a network of mountain summits for studying the distribution of upland periglacial features in Scotland. It is particularly noted for landforms associated with wind activity, described by Goodier and Ball (1975). Additional interest in the hills of North Hoy is provided by end moraines at Enegars Corrie (HY 200043) on Cuilags and at Dwarfie Hamars (HY 245005) on Knap of Trowieglen, which are tentatively ascribed to the Loch Lomond Readvance. The moraine at Enegars Corrie has been described by A. Geikie (1877), Peach and Horne (1880), Wilson *et al.* (1935) and Rae (1976).

Description

The hills of northern Hoy are underlain by Hoy Sandstones of the Upper Old Red Sandstone (Mykura, 1976). These Devonian sandstones are medium-grained and generally well sorted, in keeping with their fluvial origin. They are near-horizontally bedded, but slight variations in lithology are reflected in their resistance to weathering. The harder beds form prominent crags and steps on the hillsides, whereas the softer beds weather to a loose sand.

Four main types of periglacial feature have been described from Ward Hill by Goodier and Ball (1975). These they termed turf-banked terraces, wind stripes, hill dunes and composite stripe/terrace features. Although they do not include them as a separate category, it is apparent from the descriptions that deflation surfaces are also well-developed.

The turf-banked terraces (Figure 4.4) have typical dimensions of 2–3 m across the 'treads', with slopes of about 15°, and the 'risers' have widths of 3–5 m and slopes of 25–35°. The 'treads' are vegetation-free, and the long-axis of the terraces is either parallel to the contours or aligned obliquely across the slope. According to Goodier and Ball (1975), in the former case, the principal influence in the formation of the terraces is frost action, whereas in the latter, the action of wind on the vegetation has orientated the features towards the effective wind direction, forming composite stripe/terraces.

Wind stripes are strikingly developed on Ward Hill. Goodier and Ball (1975) distinguished three separate types. The first comprises regular, continuous stripes in which the vegetated parts are generally straight-sided and parallel; the second, regular continuous stripes with non-uniform widths and curving margins; and the third, scattered crescentic vegetated areas on deflation surfaces. The first type occurs on the exposed southern face of the hill, and here the stripe alignment is generally parallel to the contours. The vegetated stripe widths in this area are from 0.2 to 1.7 m and the inter-stripe zones are

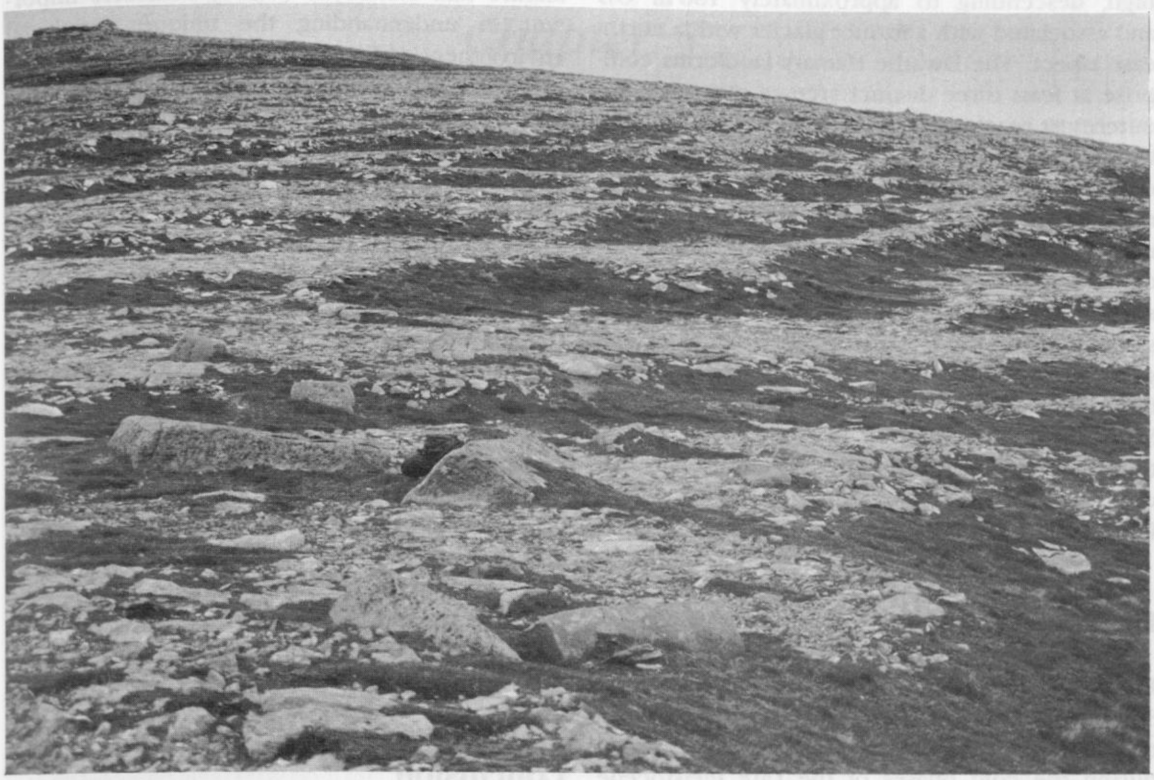


Figure 4.4 Solifluction terraces on Ward Hill, Hoy. The turf-banked terraces are orientated approximately parallel with the contours. (Photo: J. E. Gordon.)

0.52–0.78 m wide. The wind-cut stripe faces average 0.14 m in height. These regular features merge along-slope with wind-formed vegetation waves where vegetation cover is complete, but elongate zones of growing *Calluna vulgaris* alternate with zones of dead *Calluna* stems and lichens (see Bayfield, 1984).

The features termed hill dunes by Goodier and Ball (1975) consist of areas in which eroded sand-sheets capped by vegetation stand as remnants above deflation surfaces. The name is therefore somewhat misleading, as the 'dunes' are not constructional features. The sands have a distinct stratification: a surface horizon of about 0.1 m of grey sand overlies a yellowish-brown sand to a depth of 0.7 m, with a buried surface horizon between 0.7 m and 0.84 m, a second bed of brown sand to 0.94 m and then a further buried surface horizon at 0.9 m–0.95 m, with underlying sand to 1.2 m. Below the sands is a diamicton consisting of weathered sandstone clasts in a sandy clay matrix. A similar diamicton also underlies the deflation surfaces. The stratification of the sand deposits is indicative of alternating periods of stability and sand movement, but no studies have been carried out on the age of the deposits. Similar sand-sheets and interbedded soil horizons have been described on Ronas Hill (Ball and Goodier, 1974) and on An Teallach (Ballantyne and Whittington, 1987). At the latter locality it was demonstrated that sand deposition began in the early Holocene but was much reduced by the establishment of vegetation cover during the Holocene. However, recent disruption of the vegetation due either to climatic deterioration or to overgrazing has resulted in a renewed phase of sand erosion and redeposition. A similar history may apply to the Ward Hill sands, with the lower slopes of Ward Hill also providing clear evidence of former slope activity in the form of gullied drift and fan deposits.

The slopes of Ward Hill are covered in a debris mantle and there is no clear evidence within the corrie-like recesses flanking the hill for local glaciation post-dating the last period of ice-sheet glaciation. However, to the north in Enegars Corrie and to the south below Dwarfie Hamars, clear end moraines can be observed. The Enegars moraine is a single arcuate ridge, up to 6–8 m high, descending to approximately 100 m OD and associated with a former glacier with a north-east aspect. The Dwarfie Hamars landforms comprise at least three distinct arcuate moraines, the outermost reaching down to about 50 m OD. The famous Dwarfie Stone is an erratic boulder resting on one of the moraines. The age of these moraines has not been established, but there is a notable difference in the degree of development of screes and slope debris mantles within the moraines compared with those on the adjacent slopes outside them. This suggests that the small glaciers that formed the moraines developed in favoured localities during the Loch Lomond Stadial. If this attribution is correct, it suggests that the debris mantles on the slopes of Ward Hill developed in major part during, or prior to, the Loch Lomond Stadial.

Interpretation

Periglacial deposits occur on the summits of most Scottish mountains. It is possible to divide these deposits into two broad age-groups: those formed during the cold phases of the Late Pleistocene and those formed under the milder conditions of the Holocene (Ballantyne, 1984, 1987a). The processes responsible for the formation of the latter periglacial features are normally still operative on Scottish mountains. The types of both fossil and active periglacial landforms and sediments that may be encountered on particular summits are related to the underlying bedrock and the climatic conditions, especially the temperature regime and the degree of exposure. As the above conditions vary throughout the country, understanding of the development of the different types of periglacial deposits is dependent upon the study of summits in different areas. In this context, Ward Hill occupies a critical position because of its location in the Orkney Islands and the range of periglacial features developed on it. Initial studies have emphasized the role of wind in the landform development, a feature that Ballantyne (1981) considers important in understanding the unique periglacial environment of Scottish mountain tops. There is considerable potential for the further study of the sand deposits on Ward Hill. Their present erosion, together with the evidence from their stratification of episodic stability in the past, indicates the fragile nature of the balance between formation and disruption of these hill-top deposits.

The moraines of Enegars Corrie and Dwarfie Hamars are significant in a national context. If they are of Loch Lomond Stadial age, then they represent some of the northernmost glaciers at this time in Britain and therefore have a significant bearing on reconstructing the palaeoclimate of the stadial. In particular, they suggest glacier equilibrium line altitudes of about 150 m OD, which compares with values of 319 m for Skye (Ballantyne, 1989a) and 357 m OD for Rum (Ballantyne and Wain-Hobson, 1980) on the western seaboard of Scotland (see also Sissons, 1979d).

Conclusion

This area in the north of Hoy is important for its assemblage of landforms created by periglacial and glacial processes. It is particularly noted for a series of deposits formed principally by wind action, but also includes others modified by the combined action of wind and frost. These periglacial deposits provide a vital record from this northern locality of the history of past episodes of slope stability and erosion. There is significant potential for further research to establish the timing and causes of the erosion. The interest of the site also includes moraines believed to have been formed by glaciers, about 11,000–10,000 years ago, during the cold period known as the Loch Lomond Stadial. As such, they are the northernmost features of their kind in Britain and therefore are significant for reconstructing the climate of the stadial.