Quaternary of Scotland

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Chapter 5

Caithness

INTRODUCTION

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Geographically, Caithness (Figure 5.1) forms a link between the Orkney Islands and the Northern Highlands. The north-east part of the district is a gently undulating erosion surface *c.* 90–180 m OD developed on the underlying sandstone bedrock, whereas to the south, conglomerates and quartzites form the upstanding hill masses of Morven (705 m), Maiden Pap and Scaraben. The effects of glacial erosion are limited by comparison with the north-west Highlands, and in studies of the Quaternary of Caithness, the glacial deposits have been the principal focus of research. Particular attention has centred on patterns of ice movement, the characteristics of a distinctive shelly till, the interaction between ice of local origin and the external ice that deposited the shelly till, the number and ages of separate glaciations represented in the stratigraphic record and the question of whether or not part of north-east Caithness was ice-free during the Late Devensian.

During the last century the glacial deposits were the subject of numerous papers particularly on account of their content of marine fossils (Busby, 1802; Peach, 1858, 1863a, 1863b, 1863c, 1865b, 1867; Jamieson, 1866; Crosskey and Robertson, 1868c; Brady *et al.*, 1874; Dick, *in* Smiles, 1878; Peach and Horne, 1881c). The abundance of these fossils led to a considerable debate as to whether the deposits were indeed the product of land ice (Croll, 1870a; J. Geikie, 1877) or whether they had been deposited in the sea from icebergs (Cleghorn, 1850, 1851; Peach, 1863a, 1863c; Jamieson, 1866). Caithness also became noted for the number and size of the Mesozoic and Cenozoic erratics found there (Peach, 1859, 1860; Peach and Horne, 1881c; Tait, 1908, 1909; Carruthers, 1911; Crampton and Carruthers, 1914). These erratics were thought to have come from the Moray Firth or the eastern coast of Sutherland and hence supported the interpretation that the last ice movement over most of Caithness was from the south-east towards the north-west (Croll, 1870a; J. Geikie, 1877; Peach and Horne, 1881c) and not, as had been suggested by Jamieson (1866), in the opposite direction.

During this early phase of study of the glacial deposits, the main outlines of the glacial stratigraphy of Caithness were also established. The sequence consisted of a lower till containing erratics derived from immediately inland (Jamieson, 1866; Peach and Horne, 1881c; Crampton and Carruthers, 1914), an overlying till containing the marine fossils and erratics already referred to, and, in the southern and western parts of the county, a local till together with morainic and glaciofluvial deposits (Peach and Horne, 1881c; Crampton and Carruthers, 1914). The superposition of the lower and the shelly tills can be seen at localities such as Baile an t-Sratha (Dunbeath) and Drumhollistan, and an additional lower till may be present at the site of the largest known Mesozoic erratic at Leavad. Significant observations were also made on the periglacial features found on the hills in the south of Caithness (Carruthers, 1911), and the absence of raised shorelines from much of the coast was also noted (Crampton and Carruthers, 1914).

Despite this early interest, little further work has been carried out on the glacial deposits in Caithness until recent years. Various summaries and syntheses of the published evidence were produced (for example, Bremner, 1934a; Charlesworth, 1956; Phemister, 1960; Godard, 1965), but little original work was carried out until that of Omand (1973). He systematized the glacial stratigraphy and named the lower, local till (the Dunbeath Till), the shelly till (the Lybster Till), and the upper local till (the Reay Till); the moraines and glaciofluvial deposits were assigned to the latest Bower stage. No break was noted in deposition between the Dunbeath and Lybster tills, the first being deposited by ice flowing from the south-west and the second by ice from the south-east. This sequence of events is broadly similar to that interpreted for the glacial deposits of Orkney by Rae (1976) (see Chapter 4), which strongly suggests contemporaneity of the glacial phases, as does the sedimentary succession (Sutherland, 1984a). This glacial phase was therefore characterized by initial unimpeded expansion of Scottish ice, but subsequently the ice turned to flow towards the north-west, presumably due to the influence of the Scandinavian ice in the North Sea Basin as originally suggested by Croll (1870a, 1875) (but see below). There is some debate as to whether the Reay Till and the Bower stage represent significantly later glacial events (Peach and Horne, 1881c; Smith, 1968, 1977; Omand, 1973; Flinn, 1981; Sutherland, 1984a) or are essentially retreat phenomena of the major glaciation (Crampton and Carruthers, 1914; Charlesworth, 1956; Sis-

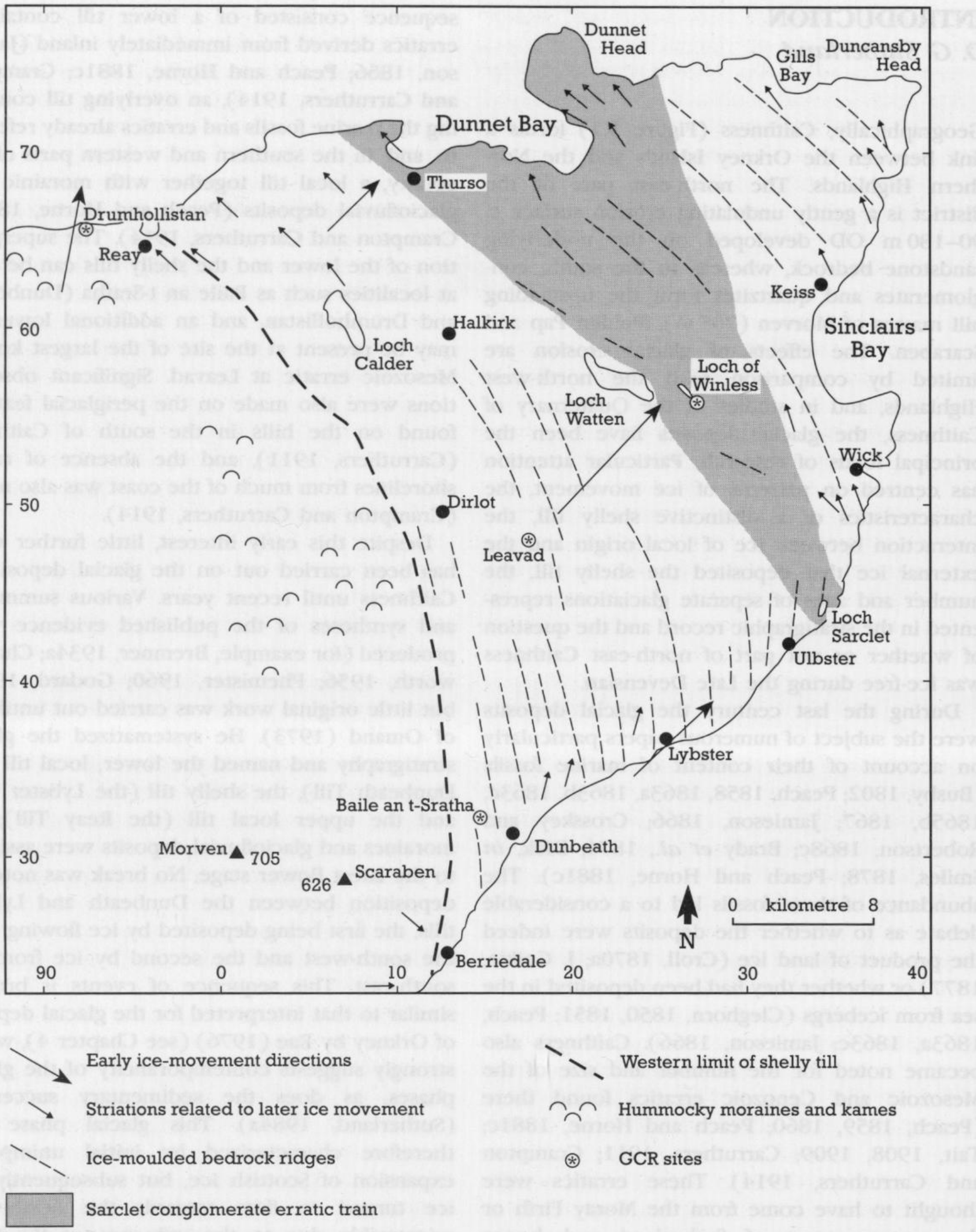

Figure 5.1 Location map and principal features of the glaciation of Caithness, including patterns of striations, ice-moulded landforms, distribution of erratics and shelly till (from Peach and Horne, 1881c; Sissons, 1967a; Sutherland, 1984a).

sons, 1967a). This outline stratigraphy has been confirmed and amplified in southern Caithness by Hall and Whittington (1989).

There is no direct evidence that bears on the age of the glacial deposits in Caithness. No *in situ* organic sediments have been found below or interstratified with the glacial deposits. Radiocarbon dating of the shells within the till has produced only a 'greater than' age (Omand, 1973) and amino acid analyses suggest that the majority of the shells have been derived from deposits of last interglacial age or older (Bowen and Sykes, 1988; Bowen, 1989). Various workers (Smith, 1977; Synge and Smith, 1980; Flinn, 1981; Sutherland, 1984a) have proposed that the shelly till may date from earlier than the Late Devensian and that only the overlying morainic and glaciofluvial deposits in the west and south of the county are of Late Devensian age. Hall and Whittington (1989) and Hall and Bent (1990), however, have argued that there is no evidence for a hiatus between sediments dated to the Lateglacial Interstadial and the underlying glacial deposits, thus inferring a Late Devensian age for the latter.

Overlying the glacial sediments are thicknesses of head and soliflucted till (Omand, 1973; Smith, 1977; Futty and Dry, 1977; Hall and Whittington, 1989). These have been interpreted as supporting the concept of this area being ice-free during the Late Devensian, the area being presumed to be subject to severe periglacial processes at that time. However, the mass-movement sediments may equally reflect early deglaciation as well as further activity during the Loch Lomond Stadial (see Hall and Whittington, 1989). In the south of the county the summits of the quartzite and conglomerate hills above about *c.* 450 m OD are notable for a range of active and fossil periglacial features, including wind and frost-related effects in the hill-top detritus and vegetation (Crampton, 1911; Crampton and Carruthers, 1914).

The earliest known deposits post-dating the last glaciation of Caithness are those at the Loch of Winless (Peglar, 1979), where the initial deposition of organic sediment has been dated to after 13,000 BP. This site has the most detailed published Lateglacial Interstadial pollen diagram in this region of Scotland and it shows certain differences from the north-west Highlands, with the possible local development of tree birch. Further Lateglacial Interstadial pollen records have been described by Hall and Whittington (1989) and by Charman (1990) from the Caithness–Sutherland border.

Apart from the information on the sparse local vegetation from the Loch of Winless, there is little information available on the environment during the Loch Lomond Stadial. It may be presumed, on the basis of inference from neighbouring areas, that certain of the periglacial features at both low level and on the mountain summits in the south of the county were formed or modified at this time, and this is confirmed by the work of Hall and Whittington (1989).

The vegetational development during the Holocene is important in this region for an understanding of the forest history of Scotland and the development of the blanket peat of the Flow Country. Lewis (1906) and Crampton (1911) provided details of vegetation and forest changes represented in the macrofossils preserved in peat sections, including the extensive occurrence of pine stumps in the central and western parts of Caithness. However, apart from the early work of Durno (1958) and the investigation of peat mounds by Robinson (1987), the only detailed pollen analytical work is that from the Loch of Winless. Caithness during the Holocene appears to have been largely treeless, although local, sheltered patches of birch–hazel woodland had developed by 9300 BP. Fossil pine stumps occur within blanket bog in western Caithness (Birks, 1977; Gear and Huntley, 1991) but in the east of the county the sampled pollen values for pine are so low that it seems unlikely that the tree ever grew there. Radiocarbon dating of the pine stumps has shown that the pine forest in Caithness was short-lived, expanding and retreating within a period of about 400 years around 4000 BP (Gear and Huntley, 1991). Clearance of the limited woodland cover in Caithness by Man appears to have started at around 3000 BP.

THE GLACIATION OF CAITHNESS

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The main features of the glaciation of Caithness are illustrated in Figure 5.1.

The glacial deposits of Caithness vary considerably in their distribution and thickness: typically they attain their greatest thickness in pre-existing valleys, topographic depressions and coastal re-entrants, and are relatively thin on higher ground and interfluves (Cleghorn, 1851; Jamieson, 1866; Peach and Horne, 1881c; Crampton and Carruthers, 1914; Godard, 1965; Omand, 1973; Hall and Whittington, 1989).

Three main suites of glacial deposits are characteristic of the area (Jamieson, 1866; Peach and Horne, 1881c; Crampton and Carruthers, 1914; Omand, 1973; Hall and Whittington, 1989). These comprise a locally derived till generally occurring west of a line from Reay to Berriedale (Figure 5.1) and deposited by ice originating in the hills of southern Caithness and Sutherland, a distinctive shelly till (often weathered in its upper layers) to the east and derived from offshore in the Moray Firth, and hummocky glacial deposits which locally overlie both till sheets in the main valleys.

Long recognized as a distinctive deposit on account of its abundant shell content, the shelly till, has received considerable documentation. The first known report of marine shells in the Caithness drift was by Busby (1802; cited by Crampton *et al.*, 1914, p. 118). Later, in the course of his energetic travels around Caithness, Robert Dick identified the widespread occurrence of shelly boulder clay, which he explained as a marine deposit associated with sea ice and glaciers (Smiles, 1878). He collected and identified many shells, some well preserved, from the deposits and also recorded the presence of Chalk flints and oolitic limestone clasts. Shells collected by Cleghorn were listed by Smith (1850a) and their arctic character noted (Smith, 1850b). Cleghorn (1850, 1851) thought the till to be a marine deposit and attributed the fragmentary nature of the shells to the feeding habits of catfish! Miller (1847 – see Miller, 1858) first publicized Dick's and Cleghorn's observations, and later exhibited some of Dick's specimens (Miller, 1851).

C. W. Peach added greatly to the knowledge of the fossil content of the till (Peach, 1858, 1859, 1860, 1863a, 1863b, 1863c, 1865b, 1867), listing the remains of 142 species, including molluscs, Foraminifera, bryozoa, sponges and algae. Further details of Foraminifera were provided by Crosskey and Robertson (1868c) and 'Entomostraca' by Brady *et al.* (1874). The most abundant molluscs are *Arctica islandica* (L.), *Spisula solida* (L.), *Mya truncata* L., *Turritella communis* Risso, *Tridonta elliptica* (Brown) and *Tridonta borealis* Schumacher (Crampton and Carruthers, 1914).

Interpretations of the glacial sequence in Caithness have centred notably on the patterns of ice movement represented by the different deposits and, more recently, on questions concerning the age(s) of the deposits and the extent of the Late Devensian glaciation.

The first regional synthesis of the glaciation of Caithness was put forward in an important study by Jamieson (1866). He believed the shelly drift to be a marine deposit disturbed and mixed into its present state by drift-ice moving north-west to south-east across the county, which he inferred from striations, the apparent distribution of stoss and lee slopes and the overlap patterns of drift on bedrock in different areas. Chronologically he related the shelly drift to the glacial-marine period or submergence, which he believed followed the main glaciation (see Clava and Nigg Bay) on the basis of the sub-arctic character of its fauna, which he did not appreciate was a derived assemblage. Jamieson (1866) also described up to 20 ft (6.1 m) of reddish-brown clay with boulders (sandstone, quartz, mica-schist and granite) with few or no shells resting on the shelly till at Wick and Keiss.

C. W. Peach reached a different conclusion about the origin of the Caithness till. Revising his earlier ideas of glaciomarine processes (Peach, 1863a, 1863c), he informed Croll in 1868 (Croll, 1870a) that the drift had been formed by land ice moving from the Moray Firth to the Atlantic. Croll (1870a, 1875) supported and elaborated this view, arguing that Scottish ice in the Moray Firth was deflected across Caithness by Scandinavian ice in the North Sea and carried with it shales, Chalk flints and Chalk fossils from the sea bed in its boulder clay. This interpretation was also favoured by J. Geikie (1877), who noted that the striation and till patterns cited by Jamieson for a south-east ice movement were equally explicable in terms of a north-west movement, and the stoss and lee forms were somewhat indistinct. Moreover, an ice movement towards the south-east did not take account of the Chalk and other foreign material in the till. Geikie concluded that the Caithness till was simply an ordinary glacial boulder clay, but with shells dispersed through it.

Using as evidence the patterns of striations, roches moutonnées and the distribution of indicator stones, Peach and Horne (1881c) confirmed the existence of two separate ice streams: local ice moving east-north-east and north-north-east, deflected by external ice moving north-west. They described the characteristics of the till units associated with the separate ice masses and presented a revised species list for the shelly till, noting the general deep-water character of the faunal assemblage. They concluded that both tills were deposited by land ice. Peach and Horne (1881c) also presented the first detailed account of 'moraines' and gravel in Caithness, although examples near Dirlot had been recorded earlier by Dick (Smiles, 1878). The features largely comprise ridges and mounds of gravel resting on both the local and shelly tills. They are largely confined to the central and north-west part of the county and are generally absent from the east, as noted by Jamieson (1866). Peach and Horne suggested that they were formed by local ice moving out from the hilly ground to the west and reaching a limit near Dirlot, long after the retreat of the Scandinavian ice.

Further confirmation of onshore ice movement was provided by Tait (1908, 1909) and by the location of the famous Leavad and other erratics (Tait, 1909, 1912; Carruthers, 1911; Crampton and Carruthers, 1914; Sutherland, 1920).

Crampton and Carruthers (1914) later showed the moraines and gravels to be more extensive than was previously recognized. From the existence of cross striations away from the zone of confluence of the two main ice streams and the presence of a local till beneath the shelly till at Leavad, they thought it highly probable that local ice advanced across part of lowland Caithness before the external ice reached its full extent. After the latter had waned, the moraines and gravels were deposited by an advance of local ice across part of the area covered by the shelly till with lobes extending to near Thurso and reaching the sea at Wick and Sinclair's Bay.

Bremner (1934a) explained the shelly till of Caithness as the ground moraine of his 'Second Ice Sheet' moving north-west from the Moray Firth to the Atlantic. He suggested that some of the erratic material recognized by Crampton and Carruthers (1914) was carried south-east from the northern Highlands into the Moray Firth by the 'First Ice Sheet', then moved into Caithness by the second. As evidence for a pre-shelly till glaciation he quoted striae patterns and the presence of local till beneath the Leavad erratic. A third ice sheet was indicated by the surface moraines and gravels, and although less extensive than the previous one, it covered 'quite half of the Caithness plain north-east of a line from Lybster to Reay'. Here Bremner was following Crampton and Carruthers (1914). Charlesworth (1956, 1957) largely echoed Bremner's views although he placed the limit of the third ice sheet (his Highland Glaciation) further north than Peach and Horne, in Orkney.

Phemister (1960) reconstructed two separate ice-sheet movements in Caithness from striae orientations. The earlier one, from south-east to north-west, deposited the shelly boulder clay. The later one was to the north as the Scandinavian ice barrier withdrew eastwards and although it must also have transported a shelly till, two separate shelly tills had not been identified. Phemister correlated the northerly ice movement with the so-called Strathmore Glaciation of north-east Scotland and mapped it as extending beyond the Caithness coast. He also noted an early, local ground moraine beneath the shelly till.

Godard (1965) identified three superimposed till sheets in Caithness, reflecting the changing predominance of mainland and Scandinavian ice, and interpreted them in terms of Bremner's triple ice-sheet model (Bremner, 1934a). A lower local ground moraine was overlain by a shelly till deposited by ice moving north-west from the Moray Firth; above was an upper local ground moraine associated with ice from a more southerly direction which extended into Orkney.

Sissons (1965, 1967a) considered that during the last glaciation Scottish ice bifurcated in the Moray Firth due to the presence of Scandinavian ice to the east. One stream moved north-west across Caithness and Orkney, depositing the shelly till. Subsequently, during the so-called Aberdeen–Lammermuir Readvance, inland ice moved north-east across Caithness to a limit of till, morainic mounds and kames resting on the shelly till near Dirlot, as identified by Peach and Horne (1881c).

Smith (1968, 1977) proposed a rather different chronology for glacial events in Caithness. He thought that the moraines at Dirlot and near Lothbeg represent the limit of the Weichselian (Late Devensian) glaciation in Caithness and that the shelly till was of Saale ('Wolstonian') age. He noted great depths of shattered bedrock, extensive colluvium at the base of slopes and lack of 'fresh' forms over large parts of the county. However, the one radiocarbon date from the shelly till at Gills Bay (>40,800 BP (Birm–179); Shotton and Williams, 1971) does not necessarily support his argument – as he states (Smith, 1977), it is inconclusive.

From his investigation of the field evidence Omand (1973) suggested there had been three main phases in the glaciation of Caithness. The first is represented in a number of sections, as at Baile an t-Sratha, where a local till (Dunbeath Till) underlies the shelly till, indicating early local glaciation. During the second phase, ice from the Moray Firth was diverted across Caithness by Scandinavian ice in the North Sea Basin and deposited the shelly till (Lybster Till). This ice stream merged with and deflected local inland ice, which deposited an upper local till (Reay Till) identified by Omand west of the shelly till limit. However, the distinction between the two local tills is unclear and, so far as is known, they are not seen together in any section. Probably they are both part of the same till unit, its distribution reflecting variations in the dominance of different ice masses. During the final phase (Bower stage), local ice deposited moraines and gravels as it wasted back more or less continuously in the eastern part of the county. Omand concluded there was no evidence for a separate Lateglacial readvance or a separate till associated with the Bower stage. From the periglacial modification of the tills by solifluction and cryoturbation and from the radiocarbon date cited above, Omand proposed either that the glacial maximum in Caithness was early in the Devensian, or the deposits in Caithness were older, possibly 'Wolstonian' in age as suggested by Smith (1968). He implied that the latter was more probable since evidence elsewhere in the country supported a Late Devensian ice maximum.

Studies in the central North Sea Basin apparently indicate that Scottish and Scandinavian ice did not coalesce during the Late Devensian (Jansen, 1976; Sutherland, 1984a; Cameron *et al.*, 1987; Sejrup *et al.*, 1987; Nesje and Sejrup, 1988) (see also Lambeck 1991a, 1991b). Thus, as Flinn (1981) and Sutherland (1984a) noted, if the flow of the ice that deposited the shelly till was to the north-west as a consequence of deflection by Scandinavian ice, then the till must pre-date the Late Devensian. However, the assumption that Scandinavian ice is required to produce such a flow pattern may not be warranted; for example, a strong outflow of ice from the Moray Firth might also produce such a pattern (see for example, Hall and Bent, 1990). On the basis of a small number of striations, Flinn (1981) proposed that subsequent to deposition of the shelly till, local ice flowed outwards across the Caithness coast, northwards to Orkney and south-eastwards into the Moray Firth. In contrast, Sutherland (1984a) suggested that much of northern and eastern Caithness may have been ice-free during the Late Devensian. Some support for such a proposal comes from preliminary results of amino acid analyses of shells from the Caithness till, which suggest that the shelly till may relate to glaciation during the Early Devensian (Bowen and Sykes, 1988; Bowen, 1989, 1991). The results also indicate a Late Devensian age for the shelly till at Latheronwheel. This raises questions of whether there might be more than one shelly till or whether sampling elsewhere might have missed younger shells.

Hall and Whittington (1989), working on the stratigraphy of south-east Caithness, have continued the debate. From the field evidence they conclude that the inland till and the shelly till relate to a single glacial episode and, following retreat of the ice in the Moray Firth, there was a late minor advance of the inland ice. Furthermore, from an assessment of several lines of relative age evidence, including the degree of weathering of the tills, periglacial deposits and comparisons with Buchan (see Chapter 8: North-east Scotland), Hall and Whittington infer that this episode was during the Late Devensian. They conclude that the maximum limit of the Late Devensian ice must therefore have been as far north as the Orkney–Shetland Channel, assuming that the shelly till of Caithness and Orkney is a single lithological unit. Subsequently, Hall and Bent (1990) have elaborated on the model citing additional evidence from a wider area of the Moray Firth and Buchan. They propose that the last Scottish ice-sheet extended northwards across Caithness and Orkney to a limit in the Orkney–Shetland channel, and eastwards across the adjacent shelf to a limit at the Bosies' Bank moraine (Bent, 1986).

Hall and Whittington (1989) also report the presence in south-east Caithness of peat deposits radiocarbon-dated to the Lateglacial Interstadial, which are overlain by Loch Lomond Stadial gelifluction deposits. This evidence is important in demonstrating the significance of periglacial mass wasting in Caithness during the stadial.

It is clear from the above review that several important questions remain to be answered about the glacial sequence in Caithness. In particular these concern:

1. the position of the Late Devensian ice limit;
2. the direction, age and extent of the last ice movement;
3. the age of the shelly till and its weathering and periglacial modifications;
4. the origin of the shelly till: was it deposited by land-based ice or as a glaciomarine deposit?
5. the age of the local till below the shelly till and its stratigraphic relationships to local till elsewhere;
6. the significance of the moraines and gravels above both the local and shelly tills;
7. the origin and significance of the reddish-brown, stoney clay on top of the shelly till at Wick and Keiss described by Jamieson (1866).

The answers to these questions have an important bearing on a wider scale concerning the extent of the last ice-sheet in northern Scotland and adjacent areas of the North Sea Basin, Orkney and Shetland. Three sites have been selected to represent the main units and features of the glacial deposits of Caithness: Baile an t-Sratha, Drumhollistan and Leavad.

BAILE AN T-SRATHA

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Highlights

The stream sections at Baile an t-Sratha demonstrate the stratigraphical relationship between the main glacial deposits recognized in south-east Caithness. Local till derived from inland is overlain by shelly till deposited by ice moving across the sea floor and then onshore towards the north-west. These deposits provide important evidence for interpreting the successive patterns of ice movement.

Introduction

Baile an t-Sratha (ND 142307) is a stream section in the valley of the Dunbeath Water; it is a key locality demonstrating the two main till units of Caithness, the local inland till characteristic of the western part of the county, and the shelly till characteristic of the eastern part (Peach and Horne, 1881c; Omand, 1973; Hall and Whittington, 1989). It is particularly important since it occurs in the zone of overlap of the two tills and illustrates their stratigraphic relations and contact. The deposits in the valley of the Dunbeath Water are described by Hall and Whittington (1989). The valley of the Dunbeath Water has long been a notable locality for glacial deposits. Dick (see Smiles, 1878), Jamieson (1866) and Peach and Horne (1881c) all referred to fine examples of shelly till, although they did not describe exposures. More recently, Omand (1973) noted that Dunbeath was one of only four places in Caithness where he found shelly till overlying a local till.

Description

The site indicated by Omand's (1973) grid reference is slumped and vegetated at present, and the best section in 1980 was at Baile an t-Sratha. There, the Allt an Learanaich, a tributary of the Dunbeath Water, has excavated sections up to 40 m high in a till infill on the south side of the valley. The exposures show two superimposed till units (Hall and Whittington, 1989: Balantrath and Balcraggie sites):

3. Grey, shelly till, weathered near the surface to a maximum depth of 2.7 m; clast lithologies dominated by Devonian sandstones, but also including distinctive pebbles of Mesozoic sedimentary rocks.
2. Brown to dark reddish-brown till of local provenance; Devonian sandstones dominant.
1. Devonian mudstone bedrock with striations orientated W–E.

Interpretation

Hall and Whittington (1989) interpreted the lower till (the Balantrath Till member in their lithostratigraphy), as a lodgement till emplaced by inland ice moving down the valley. Locally the contact with the overlying shelly till (their Forse Till member) is planar, sharp and erosional. Elsewhere at the contact, glaciotectonic folding was noted, and the presence of local structures and interlaminated brown and grey muds and diamicts is inferred by Hall and Whittington to indicate that the two respective ice masses were contemporaneous, and that the shelly till was deposited as the inland ice receded. According to them several features indicate that the shelly till is the product of land-based ice and not a glaciomarine deposit; first it rests on striated bedrock; second, it contains locally eroded bedrock and reworked local till; and third, it reaches an elevation of 110 m OD, which appears to be too high for glaciomarine deposition, even allowing for glacio-isostatic depression (cf. Sutherland, 1981a).

The lower till at Baile an t-Sratha is part of a suite of local till units, occurring west of a line from Reay to Berriedale and described by Jamieson (1866), Peach and Horne (1881c) and Crampton and Carruthers (1914). Currently, good sections occur in the valleys of the Dunbeath Water, Langwell Water and Berriedale Water, and also at the coast near Reay and Berriedale (for details see Omand, 1973; Hall and Whittington, 1989). The upper till at Baile an t-

Sratha is part of the classic shelly till unit of Caithness occurring east of a line from Reay to Berriedale, with many exposures along the east coast and in stream valleys (Omand, 1973; Hall and Whittington, 1989). The age of the tills is currently a matter of debate (see above).

The significance of Baile an t-Sratha is that it provides one of the best current exposures clearly showing local and shelly tills, their respective characteristics and their stratigraphic relationships in the zone of interaction of the two ice streams that converged in Caithness. As such it is an important reference locality demonstrating a key part of the glacial succession in Caithness. Similar sections showing the superimposition of the two till units occur at Latheronwheel, Watten and Drumhollistan (Omand, 1973), but the stratigraphic relationships are most clearly seen at Baile an t-Sratha. In a wider context the multiple till sequence at Baile an t-Sratha is similar in several respects to those, for example, at Den Wick, Boyne Quarry, Nigg Bay and Nith Bridge where the interaction of ice masses from separate sources also produced distinctive, superimposed tills. Further study of such sites will contribute important field evidence to test and constrain reconstructions and mathematical models of regional ice-sheet dynamics and the factors controlling changes in ice-sheet flow patterns.

Conclusion

Baile an t-Sratha demonstrates the succession of glacial (ice-deposited) sediments in south-east Caithness: a local till derived from inland is overlain by a distinctive shelly till deposited by ice moving onshore and towards the north-west. The importance of the site lies in its value as a reference locality for establishing the relationships between the two tills and the respective patterns of ice movement that they indicate. There is currently debate about the age of the deposits and whether they were formed during the Early or Late Devensian (approximately 65,000 and 18,000 years ago, respectively).

DRUMHOLLISTAN

J. E. Gordon

Highlights

Sections in the stream gully at Drumhollistan show the till succession on the north coast of Caithness and allow interpretation of the associated patterns of ice movement.

Introduction

Drumhollistan (NC 920654) is located on the north coast of Caithness, west of Reay, where stream erosion has dissected a drift plug in a clifftop depression. The sections exposed are important in demonstrating the succession of Pleistocene deposits on the north coast of Caithness. They show a multiple till sequence locally overlain by head deposits, and complement the interests at Baile an t-Sratha and Leavad. The only account of the site is that by Omand (1973).

Description

The deposits are exposed along a narrow stream valley that deepens to over 30 m at its western end. The flanks of the valley are heavily dissected by gullies separated by narrow, intervening ridges. The deposits were recorded by Omand (1973) and comprise the following composite sequence:

4.	Head	up to 1 m
3.	Brown till with shell fragments near the base	up to 21 m
2.	Sand and gravel; boulders up to 0.75 m length in the lower 1.5 m, fining upwards	up to 3.5 m
1.	Grey till	> 3 m

The lower till (bed 1) is exposed only at the western end of the gully. It is lighter in colour than the upper till and the matrix appears gritty and sandy. No shells have been found in it. A stone count of 50 clasts by Omand (1973) revealed that 94% of the sample consisted of gneiss or migmatite, probably derived from the area to the south and west of the site. At the western end of the gully on the south side, the lower till is overlain by unbedded sand and gravel with a layer of sand at the top. The upper till (bed 3) in its lower part is a darker, chocolate-brown colour with a sandy/silty matrix. Of 50 clasts sampled by Omand, 76% were from the Old Red Sandstone group and probably derived from the area to the south-east of the site. The upper part of the till is weathered to a depth of 5–6 m and has a reddish appearance. A few shell fragments were found in this till, but they are scarce and considerably comminuted in comparison with those at Dunbeath and other sites on the east coast of Caithness. On the north side of the gully the brown till (bed 3) rests directly on the grey till (bed 1). The lower layers of the former are bouldery with lenses of sand and gravel in the lower 3 m.

In the middle part of the gully on the south side, a layer of sand occurs at the base of the upper till. Possibly it corresponds with the sand and gravel at the western end of the section, but the continuity of the beds could not be traced because of slumping. Bands of the upper till are interbedded with the sands which here have a rusty, weathered appearance, and the two units interdigitate.

A stone layer occurs at the surface of the upper till beneath a cover of peat. On the northern side of the gully at the western end, up to 1 m of head locally covers the upper till.

An additional feature of the site is the fine example it provides of active gullying and incipient earth pillar formation along the corrugated and dissected flanks of the main gully.

Interpretation

The general characteristics and distribution of the glacial deposits of Caithness, the theories proposed to explain them and the outstanding problems have already been discussed. The evidence at Drumhollistan appears to confirm two distinct ice movements on the north coast followed by a period or periods of weathering and head formation. The lower till, associated with a northerly ice movement occupies a similar stratigraphic position to the lower till at Dunbeath, but it is still open to question whether it represents an early local glaciation or was broadly contemporaneous with the shelly till as at Dunbeath (Hall and Whittington, 1989). The upper till is part of the widely recognized shelly till of Caithness deposited by ice moving northwest. The weathering of the upper part of the sequence at Drumhollistan is typical of many parts of Caithness (Jamieson, 1866; Peach and Horne, 1881c; Omand, 1973; Hall and Whittington, 1989), as is the overlying head (Omand, 1973; Futty and Dry, 1977; Hall and Whittington, 1989).

In south-east Caithness, Hall and Whittington (1989) noted weathering and mottling of the tills, with decalcification to a depth of 2.7 m. They concluded that this was compatible with Holocene weathering. Although the weathering at Drumhollistan extends to a greater depth of 5–6 m, this could reflect local factors and is still compatible with depths of Holocene weathering in eastern England (Madgett and Catt, 1978; Eyles and Sladen, 1981). At present there is no evidence that the weathering in Caithness might reflect a long period of ice-free conditions during the Devensian. The head deposits at Drumhollistan are undated, but in south-east Caithness comparable deposits have been ascribed to the Loch Lomond Stadial (Hall and Whittington, 1989). Again, there is no evidence that they might relate to periglacial episodes earlier in the Devensian, although this cannot be completely ruled out without further work.

Drumhollistan has not been investigated in detail, and (as is also the case for Baile an t-Stratha) several intriguing questions remain unanswered about the deposits, their wider relationships with other sites and the implications they carry for the Pleistocene history of Caithness. These concern:

1. the age(s) of the lower and upper tills and whether or not they are broadly contemporaneous;
2. the significance of the sand and gravel layer between the till beds and whether it is part of a single, complex melt-out sequence (cf. Nigg Bay, Boyne Quarry and Hewan Bank) or represents a significant break in glacial sedimentation;
3. the age and degree of the weathering in the upper till;
4. the age of the overlying head;
5. the relationships of the tills at Drumhollistan to the local till exposed at the surface along the Sandside Burn at Reay, 4 km to the east (Omand, 1973).

Drumhollistan is an important reference site for the succession of Pleistocene deposits on the north coast of Caithness. It demonstrates the western extent of the shelly till and the northern extent of local till, together with evidence for subsequent head formation and weathering. Comparable sites to Drumhollistan on the south-east coast of Caithness that show shelly till superimposed on local till, occur at Dunbeath (Baile an t-Stratha), Leavad and Latheronwheel (Omand, 1973; Hall and Whittington, 1989).

Baile an t-Stratha is notable for better exposure of local till and better preservation of shells in the upper till, whereas at Leavad the main interest is a large erratic of soft strata incorporated in the shelly till. Exposures at Latheronwheel are poor and have not been recorded in detail. Together, therefore, Drumhollistan, Baile an t-Sratha and Leavad demonstrate key aspects of the Pleistocene deposits of Caithness.

The contemporary erosion and gullying of the till are also of interest and are representative of a type of phenomenon that is known from a number of localities in Scotland, for example at Rosemarkie Dens (Miller, 1858; Geikie, 1901), Fochabers (Hinxman and Wilson, 1902; Geikie, 1903) and in the Nairn valley near Clava. The narrow ridges illustrate an incipient form of earth pillar formation, although the absence of large boulders has inhibited the development of classic earth pillars (cf. Whalley, 1976b).

Conclusion

The deposits at Drumhollistan demonstrate the glacial history of the north coast of Caithness. They show two (ice-deposited) tills, locally separated by a layer of sand and gravel. The value of the site is as a reference locality for establishing the glacial succession and pattern of ice movements in this area. There are different interpretations of the age of these deposits and whether they were formed during the Early or Late Devensian (approximately 65,000 and 18,000 years ago, respectively).

LEAVAD

J. E. Gordon

Highlights

The principal interest at Leavad comprises a large raft of Lower Cretaceous sandstone believed to have been transported from the sea floor off Caithness by ice moving onshore. The erratic mass is an outstanding example of its kind and lies within a sequence of glacial deposits which includes three tills. The latter provide important evidence for interpreting the glacial sequence of Caithness and the patterns of ice movement.

Introduction

The principal interest at Leavad (ND 174462) in eastern Caithness is a large (nearly 800 m long) erratic of Lower Cretaceous sandstone believed to have been transported by ice over a distance of at least 15 km from the sea floor off the Caithness coast. The erratic occurs in a sequence of deposits, including three tills, so that Leavad is potentially an important reference site for the Pleistocene stratigraphy of Caithness. The deposits at Leavad were formerly exposed in a quarry and have also been investigated by boreholes (Tait, 1908, 1909, 1912; Carruthers, 1911; Crampton and Carruthers, 1914).

Description

The first accounts of the Leavad Quarry (Tait, 1908; Carruthers, 1911) described a decomposed calcareous sandstone with more resistant concretions, quite unlike any other sandstone in the neighbourhood. Tait (1908) initially considered it to be a small outlier of Jurassic rocks resting unconformably on Old Red Sandstone, but was unable to confirm this because no contact was seen. He recognized similarities between the large concretions in the sandstone and egg-shaped stones dredged from Wick harbour, transported there by ice from a source near Brora. Subsequently, Tait (1909) reported fissures of boulder clay with Highland metamorphic rocks between the concretions and, within the latter, fossils identified as a Lower Cretaceous (Neocomian) assemblage by Kitchin (Lee, 1909). Above the calcareous sandstone was a boulder clay, coarser in texture and with more stones of local origin (Old Red Sandstone). Tait raised the possibility that the Cretaceous sandstone might be a glacially transported mass, similar to that at Moreseat in Aberdeenshire (see Moss of Cruden).

To settle the question of the origin of the Leavad sandstone a series of boreholes was put down in 1910. The findings were described by Carruthers (1911), Tait (1912) and summarized by Crampton and Carruthers (1914). The deposits containing the sandstone mass occupied a buried channel of the Little River to a depth of at least 24.1 m below the floor of the quarry. They comprised the following sequence (Tait, 1909, 1912):

15. Sandy till with stones of local

	origin (exposed in the quarry)	0.6 m
14.	Sand and sandstone with Cretaceous fossils (5.2 m exposed in the quarry)	7.9 m
13.	Dark-green, bedded clay with shells and Foraminifera	1.5 m
12.	Dark clayey sand	0.6 m
11.	Dark-green clay with shells	0.4 m
10.	Clay and sand	0.8 m
9.	Greenish clay with shell fragments	0.2 m
8.	Dark shelly till with striated stones	0.6 m
7.	Yellowish-green, sandy till with stones of local origin	5.0 m
6.	Gravel	0.8 m
5.	Yellowish sandy clay and gravel	0.6 m
4.	Gravel	1.5 m
3.	Yellowish sandy clay and gravel	8.0 m
2.	Brown sandy clay	0.6 m
1.	Clean sand and gravel	>0.7 m

The boreholes confirmed that the sandstone (bed 14) is an erratic block, and its size was estimated at 878 m long, 549 m wide and 7.9 m thick.

Tait noted that beds 3, 5 and 7, which he interpreted as till, with interbedded gravel layers (beds 4 and 6), were quite distinctive from the dark, shelly till of bed 8, being more sandy in composition, lighter in colour and containing stones largely of local Old Red Sandstone origin. Lee (in Carruthers, 1911) identified the fossil assemblage in the dark-green clay (beds 9, 11, 13) as post-Cretaceous, but noted differences with that found elsewhere in the shelly till of Caithness. He suggested that the clay might belong to some part of the Crag, but the dominance of thermophilous forms, typical of the Miocene, indicates an earlier age (Hall, unpublished data). If the dark-green clay does indeed represent an erratic mass of Miocene clay then its occurrence at Leavad is of great interest, for no sediments of this age are known from the Moray Firth west of 1°W (Andrews *et al.*, 1990).

Interpretation

Carruthers (1911), Tait (1912) and Crampton and Carruthers (1914) all considered that the Leavad erratic was transported to its present position from the floor of the Moray Firth by the same ice moving onshore which deposited the shelly till of Caithness (Peach and Horne, 1881c; see Baile an t-Sratha). The nearest Lower Cretaceous sediments to Leavad occur just offshore (Andrews *et al.*, 1990) implying a minimum distance of transport of about 15 km. A similar sandstone has also been encountered about 1 km north of Leavad (Crampton and Carruthers, 1914). This may also be presumed to be an erratic.

On account of its size the Leavad erratic is frequently quoted as a spectacular example of a glacially transported mass (Charlesworth, 1957; Sissons, 1967a; Embleton and King, 1975a). Similar features in Scotland include the Moreseat erratic (Jamieson *et al.*, 1898), the Comiston boulder (Campbell and Anderson, 1909), the Kidlaw erratic (Kendall and Bailey, 1908) and the Plaidy erratic (Jamieson, 1859, 1906; Read, 1923; Pringle, 1936). Others elsewhere in Britain are described by Charlesworth (1957), Sparks and West (1972) and Embleton and King (1975a). Possible mechanisms of entrainment of such masses have been discussed by Weertman (1961) and Boulton (1972a) (see also Clava).

If Tait's descriptions of the section and boreholes are valid, the Leavad erratic is also of considerable stratigraphic interest as the only known site where the three main till units represented in Caithness are superimposed: a till of local origin appears to overlie a shelly till derived from offshore, which in turn overlies a lower local till. Leavad may therefore be an important reference site demonstrating the succession of Pleistocene deposits in Caithness, the interpretation and chronology of which are still debatable. At present no exposures exist in the original sandpit, although along the Burn of Tacher (ND 176465) a dark till overlies a lighter brown one. Possibly these represent the shelly till and lower local till, respectively. The upper local till is not exposed.

Conclusion

Leavad is notable for a large mass of sandstone incorporated within a sequence of till deposits. It is a well-known example of a large erratic and was transported by an ice-sheet from its original location in the bedrock offshore and deposited within the glacial sediments at Leavad. The occurrence of three tills in the sequence provides potentially important evidence for the pattern of successive ice movements across the area and the interaction of different ice masses. As yet, the ages of these deposits are not firmly established.

LOCH OF WINLESS

H. J. B. Birks

Highlights

Pollen grains preserved in the layers of sediment which infill the bed of this loch provide a detailed record of the vegetational history of Caithness during the Lateglacial and Holocene. This information contributes significantly towards the understanding of the environmental history of this ecologically unique area.

Introduction

Caithness is an area of unique ecological interest. In the north-east, the area of shelly till, the so-called Caithness Plain, is today mainly crofting and farm land. To the west and south, the area of non-calcareous, sandy till is dominated by vast areas of patterned blanket-bog or 'flows'. This is the largest area of continuous peatland in Britain and is of international importance to ecologists and palaeoecologists (Stroud *et al*., 1987; Lindsay *et al*., 1988). Caithness is today one of the most extensive treeless areas in Britain (excluding recent plantations of exotic conifers).

Despite its importance ecologically, very little is known of the Late Quaternary vegetational and ecological history of Caithness. Loch of Winless (ND 293545) is the only site from which a detailed Lateglacial and Holocene pollen diagram, with radiocarbon dates, has been published (Peglar, 1979). Loch of Winless lies approximately 8 km west-north-west of Wick at an elevation of 9 m OD. It is a small lochan within a basin now almost completely infilled with fen peat and lake sediments up to 6 m depth. The palynological results from this site are thus of particular significance in the context of Holocene vegetational history of Britain and of Scotland (see Birks, 1977, 1989).

Description

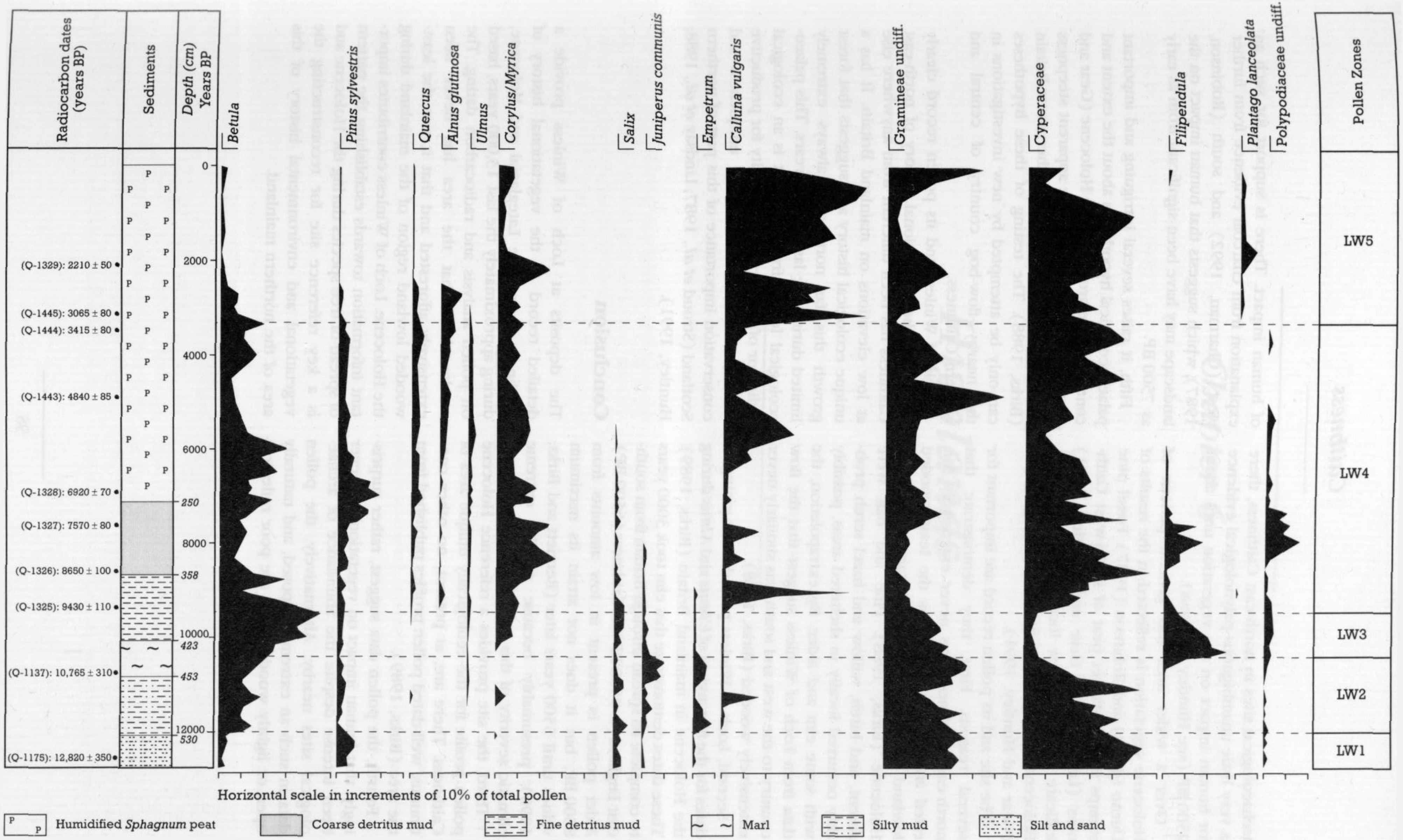
The sediment infill at Loch of Winless is *Sphagnum* peat overlying coarse detritus (organic) muds, marl, and silts (Figure 5.2). Ten radiocarbon dates are available (Figure 5.2) and suggest that the basal sediments may be as old as 12,800 BP. However, the earlier dates are likely to be subject to hard-water errors because of the calcareous nature of the surrounding boulder clay and underlying Old Red Sandstone. Peglar (1979) proposed that the basal sediments may only extend to about 12,500 BP. The pollen record has been divided into five local pollen assemblage zones (Figure 5.2). Zones LW1 and LW2 are assigned to the Lateglacial; zones LW3–LW5, to the Holocene.

Interpretation

The pollen record shows that the Lateglacial vegetation was grassland and tall-herb communities, with abundant Cyperaceae and a variety of open-ground herbs including some arctic–alpine species which today are restricted to high elevations in north-west Scotland. In contrast to Lateglacial sequences from the north-west Highlands and the Inner Hebrides (see Pennington, 1977a; Lowe and Walker, 1986a) dwarf-shrubs such as *Empetrum* appear to have been unimportant throughout at Loch of Winless and on Orkney (Moar, 1969a), perhaps as a result of the higher fertility of soils on the Old Red Sandstone.

The early and middle Holocene vegetation (10,000–6000 BP) was probably a mosaic of species-rich, tall-herb and fern communities, birch, hazel, and willow scrub, and grassland. The pollen assemblages clearly indicate that oak and pine were never major components of the Holocene vegetation. Indeed it is likely that they were absent from the Loch of Winless area throughout the Holocene (Birks, 1989). The pollen data also suggest that the area was never extensively forested at any time during the Holocene, with tree pollen reaching a maximum of 50% and averaging around 25%. The most likely reconstruction is of birch, willow, and hazel scrub occurring locally in sheltered areas, and of widespread grassland and fern and tall-herb dominated stands on moist, well-drained, and fertile soils. With nutrient depletion by leaching, soils deteriorated and *Calluna* heath and moorland began to expand at about 6000 BP. *Alnus* may have been present in low amounts after about 5500 BP. Despite the abundance of

Figure 5.2 Loch of Winless: relative pollen diagram showing selected taxa as percentages of total pollen (from Peglar, 1979). Note that the data are plotted against a radiocarbon time-scale.



Radiocarbon dates (years BP)
Sediments
Depth (cm) Years BP
Betula
Pinus sylvestris
Quercus
Alnus glutinosa
Ulmus
Corylus/Myrica
Salix
Juniperus communis
Empetrum
Calluna vulgaris
Gramineae undiff.
Cyperaceae
Filipendula
Plantago lanceolata
Polypodiaceae undiff.
Pollen Zones
(Q-1329): 2210 ± 50
(Q-1445): 3065 ± 80
(Q-1444): 3415 ± 80
(Q-1443): 4840 ± 85
(Q-1328): 6920 ± 70
(Q-1327): 7570 ± 80
(Q-1326): 8650 ± 100
(Q-1325): 9430 ± 110
(Q-1137): 10,765 ± 310
(Q-1175): 12,820 ± 350
0
2000
4000
6000
8000
10000
12000
250
358
423
453
530
LW5
LW4
LW3
LW2
LW1
Horizontal scale in increments of 10% of total pollen
Humidified Sphagnum peat
Coarse detritus mud
Fine detritus mud
Marl
Silty mud
Silt and sand

archaeological sites in north-east Caithness, there is very little unambiguous palynological evidence for human impact on the vegetation until about 2500 BP (see Huntley, in press).

Over a wider area this general pattern of Holocene vegetation is reflected in the results of Durno (1958) and Robinson (1987). Fossil pine stumps in the blanket peat of south-west Caithness (Lewis, 1906; Gear and Huntley, 1991) indicate that pine grew locally during the mid-Holocene, but perhaps for only a short time (Gear and Huntley, 1991).

The site and its pollen record are important for several reasons. First, they demonstrate that north-east Caithness was never extensively forested and that the area was the least wooded lowland area of mainland Britain during the Holocene (Birks, 1988). Pine and oak were absent, and birch, willow and hazel scrub probably occurred locally in sheltered areas, possibly with some elm and alder. By extrapolation, the data from Loch of Winless suggest that the flow country to the west and south was similarly never extensively wooded (Birks, 1988).

Second, Loch of Winless provides the youngest dates for the first arrival of *Ulmus* and *Alnus* during the Holocene in mainland Britain (Birks, 1989). These dates demonstrate that elm took 3000 years to complete its spread through Britain from south-east England (*c.* 9500 BP) to Caithness (6500 BP). Alder pollen is present in low amounts from 8500 BP, but it does not attain its maximum values until 5500 years later (Bennett and Birks, 1990), presumably because of the extreme climatic severity of this exposed northern area.

Third, the site provides a reference Holocene pollen profile for the ecologically unique area of Caithness. There are, at present, no other continuous, well-dated pollen profiles published from the area (Birks, 1989).

Fourth, the pollen data suggest, rather surprisingly, that human impact on vegetation has never been intense despite the abundance of archaeological sites nearby. Alternatively, the pollen data in such an extreme, exposed, and naturally open or lightly wooded area, are poor reflectors of human impact. There is support for such an explanation from charcoal evidence from further west (Charman, 1992) and south (Robinson, 1987), which suggests that human impact on the landscape may have been significant from as early as 7500 BP.

Fifth, it raises several intriguing and important palaeoecological hypotheses about the extent and control of tree growth in the Holocene (Gear and Huntley, 1991) and about the apparent steepness of vegetational gradients in northernmost Britain (Birks, 1988). The testing of these hypotheses can only be attempted by new investigations in the nearby flow-bog country of central and western Caithness.

Loch of Winless and its pollen record clearly show that the vegetational history of north-east Caithness has been different from anywhere else at low elevations on mainland Britain. It has a unique ecological history and suggests that forest growth this far north was always extremely limited during the last 10,000 years. This palaeoecological lesson from the past is an ecological indicator of the area's unsuitability for productive forestry and of the ecological uniqueness and conservation importance of this part of northern Scotland (Stroud *et al.*, 1987; Lindsay *et al.*, 1988; Huntley, 1991).

Conclusion

The deposits at Loch of Winless provide a detailed record of the vegetational history of Caithness during the Lateglacial and Holocene, during approximately the last 13,000 years, based on pollen analysis and radiocarbon dating. The results show that the area has never been extensively afforested and that it was the least-wooded lowland region of the mainland during the Holocene. Loch of Winless contributes important information towards establishing the pattern of spread of tree species during the Holocene and is a key reference site for reconstructing the vegetational and environmental history of this area of the northern mainland.