Quaternary of Scotland

Edited by

J. E. Gordon

Scottish Natural Heritage,
Edinburgh, Scotland.

and

D. G. Sutherland

Edinburgh, Scotland.

GCR Editor: W. A. Wimbledon

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Chapter 18

South-west Scotland

INTRODUCTION

D. G. Sutherland

South-west Scotland comprises that part of the Southern Uplands west of the A74 and the coastal lowlands along the Solway Firth (Figure 18.1). Little is known of the Quaternary history of the area prior to the last, Devensian ice-sheet glaciation, although, as in the rest of Scotland multiple glaciation may be inferred from the evidence from neighbouring regions, as well as the presence of landforms of glacial erosion that have developed over a long period.

The mountains in the Loch Doon area acted as one of the major centres of the last ice-sheet, as is indicated by the transport of various erratics to the north, west and south as well as the distribution of ice-moulded landforms and striated bedrock surfaces (Geikie, 1894; Charlesworth, 1926a; Cornish, 1982, 1983). The ice-sheet centred in the Galloway hills appears to have built up more slowly than that in the south-west Highlands, for the Highland ice initially impinged on the Southern Uplands, transporting erratics into the northern valleys of the hill mass as well as into the western coastal areas in Ayrshire and the Rhins of Galloway. The subsequent expansion of the Southern Uplands ice deflected the Highland ice to the east and west, producing typical till sequences in which lower, frequently shelly, tills with Highland or Ayrshire erratics are overlain by tills with Southern Uplands erratics. This classic sequence of the 'debatable ground' (J. Geikie, 1877) is shown at Nith Bridge (Chapter 15) and Port Logan.

On the southern and western side of the ice shed the pattern of ice flow is recorded in one of the largest drumlin fields in Scotland, covering much of lowland Kirkcudbrightshire as well as the Machars and Rhins of Wigtownshire (Cutler, 1978; Kerr, 1982); drumlins also occur in the eastern Solway lowlands (Hollingworth, 1931). Cornish (1979) has demonstrated that towards the ice-shed zone the drumlins merge into rogen moraine, the only instance of this type of moraine documented in Scotland. Charlesworth (1926a) noted a change over a short distance in the direction of the long axes of the drumlins in the Machars of Wigtownshire, which he interpreted as being due to a readvance of the ice, correlated with his Lammermuir–Stranraer Readvance. However, such changes in direction of drumlin long axes are not infrequent (Kerr, 1982; D. G. Sutherland, unpublished data) and appear to relate to topographical influence on ice flow rather than readvancing ice.

Many of the valleys on the southern side of the uplands contain massive spreads of glaciofluvial sands and gravels (Stone, 1959; Sissons, 1967a), with kames, kettle holes, kame terraces, eskers and meltwater channels forming complex and extensive areas of 'dead'-ice topography. The deposits around Stranraer where such features are fronted by a major outwash terrace merging into raised beaches (Sutherland, unpublished data) were considered by Charlesworth (1926b) to have been formed at the western end of his Lammermuir–Stranraer Readvance kame-moraine, but there is no evidence for such a readvance (e.g. Cutler, 1979), as has also been pointed out by Sissons (1961c) for the central and eastern parts of this putative limit.

Along the eastern Solway Firth coast the features of ice decay cannot be related to raised shorelines (Jardine, 1977, 1982; cf. Eyles and McCabe, 1989). In western Wigtownshire, however, such shorelines occur at altitudes of at least 20 m OD implying greater isostatic depression and/or later deglaciation in this latter area. In the Rhins of Wigtownshire there are possibly the only known examples of Errol beds on-shore in the west of Scotland (Brady *et al.*, 1874; Peacock, 1975c), these being deposited shortly after the deglaciation of this area. These beds, with their arctic fauna, suggest that deglaciation occurred prior to the oceanic polar front moving to the north of the British Isles, that is some time prior to about 13,000 BP.

There are no radiocarbon dates, however, that closely limit the time of deglaciation. A number of sites containing sediments deposited during the Lateglacial Interstadial have been investigated for both their pollen and beetle remains which have provided limiting relative ages on deglaciation as well as information about the progress of environmental change during the interstadial (Bishop, 1963; Moar, 1969b; Bishop and Coope, 1977; Jones, 1987). The sites with the earliest dated sediments are those of Roberthill and Redkirk Point in Dumfrieshire. At these localities coleopteran remains, from around 13,000 BP, indicate that the climate was almost as mild as at present although, due to low rates of migration, the vegetation was dominated by grasses and open-habitat taxa (Moar, 1963, 1969b; Bishop and Coope, 1977). Subsequently, during the interstadial, temperatures are inferred on the

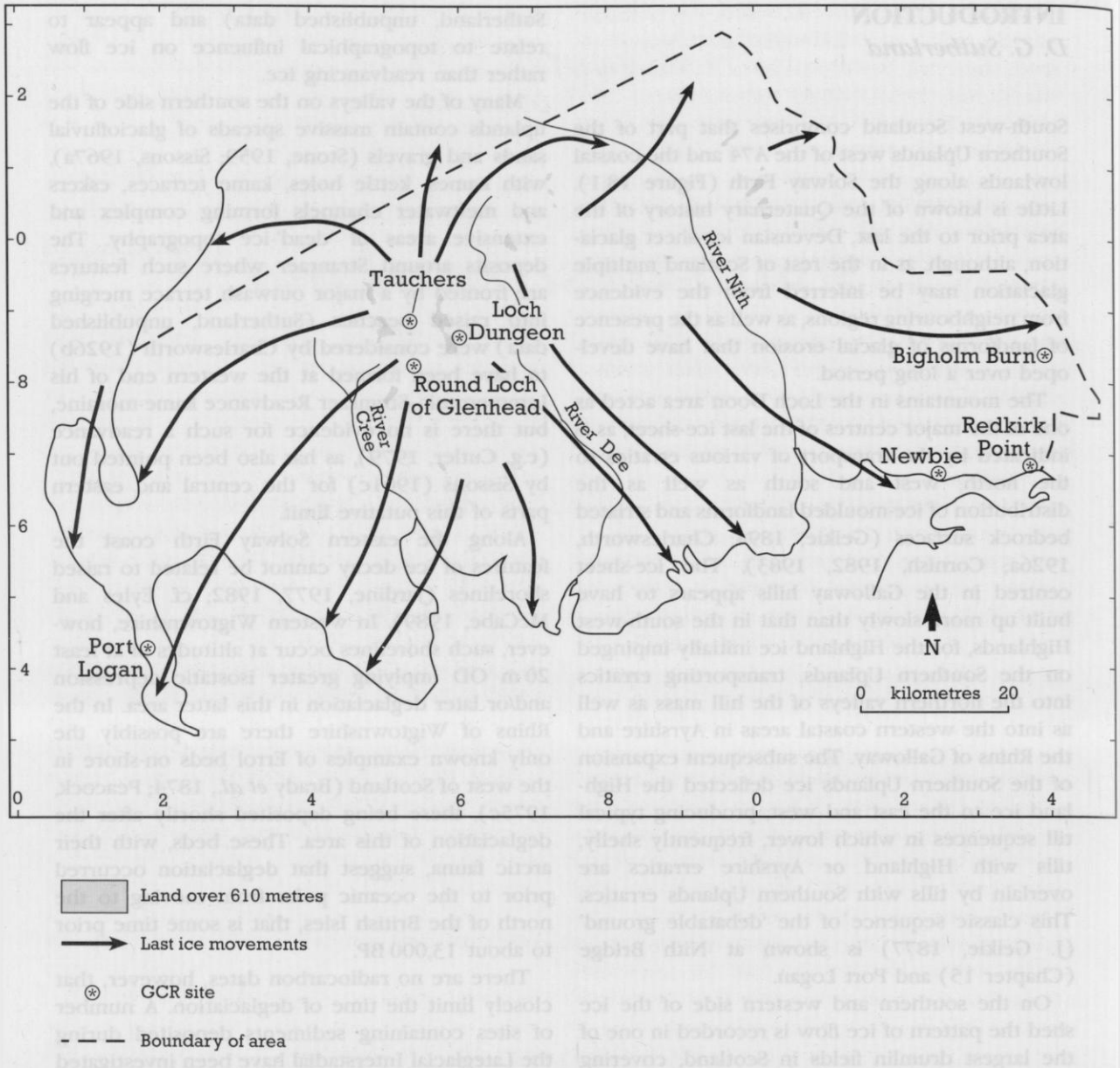


Figure 18.1 Location map of south-west Scotland and generalized directions of ice movement.

basis of the coleopteran faunas to have declined by 2–3°C, although there was during this period an increase in vegetation cover with the occurrence of stands of tree birch, willow and juniper. The freshwater and terrestrial deposits of Lateglacial age at Redkirk Point occur in the present intertidal area, indicating sea level to have been below that of the present throughout that period.

At the end of the Lateglacial Interstadial, at about 11,000 BP, there was a severe climatic deterioration and small glaciers became re-established in the Galloway hills (Cornish, 1981), depositing particularly clear end moraines at the Tauchers and Loch Dungeon. At lower altitudes there was slumping and solifluction of glacial deposits, as demonstrated at Bigholm Burn near Langholm (Bishop and Coope, 1977). This is one of the few lowland sites in Scotland where Lateglacial organic deposits have been found disrupted by soliflucted debris, allowing dating of the period of solifluction and analysis of the contemporaneous environmental conditions. Summer temperatures at that time were at least 6°C colder than at present (Bishop and Coope, 1977), which gave rise to a sparse, tundra-type vegetation.

The Holocene vegetational history of both the uplands and coastal lowlands has been investigated by Nichols (1967), Moar (1969b), and Birks (1969, 1972a, 1975). Mean summer temperatures rose very rapidly at the beginning of the Holocene and plant migration resulted in an early phase of juniper and herb dominance at around 10,000 BP. Birch and hazel expanded rapidly after this, and woodlands with those two species dominating became widely established by 9500 BP. Mixed deciduous woodlands with the addition of oak and elm developed in the lowlands by 8500 BP; pine appeared in the area by 8000 BP but was never a dominant species, attaining its widest extent in the Galloway hills at between 7500 and 6800 BP. The treeline at the time of maximum expansion of trees was at least at 600 m OD.

As demonstrated at both the Loch Dungeon and Round Loch of Glenhead sites, blanket peat began to expand in the middle Holocene, and pine was reduced significantly as an element in the forest composition. Man's initial impact on the forests is manifest in the decline of elm at slightly prior to 5000 BP, but the diatom and radiocarbon analyses carried out at the Round Loch of Glenhead are particularly important for the temporal framework they provide for the much more recent human impact related to acidification. This can be demonstrated to have increased markedly in this area in very recent times (Jones, 1987; Jones *et al.*, 1989).

During the early Holocene, sea level was several metres, at least, below its present level (Jardine, 1975, 1980b) and peat accumulated across the low-gradient coastal fringe. With the onset of the Main Postglacial Transgression these peats were successively transgressed, and radiocarbon dating at sites such as Redkirk Point and Newbie (Jardine, 1971, 1975, 1980b) allow the progress of the rising sea level to be followed. At its maximum, major marine embayments occurred at the head of the Solway Firth, at the mouth of the Nith valley and at the head of Wigtown Bay. Subsequent regression of the sea resulted in the renewed accumulation of peat on the surface of the estuarine deposits. Curiously, this sequence of events, although taking place between 8000 and 3000 years ago has been incorporated into folklore in the form of a witch's curse in which Lochar Moss by Dumfries was 'once a moss and then a sea' and became 'again a moss and aye will be' (Wood, 1975).

PORT LOGAN

D. G. Sutherland

Highlights

The coastal section at Port Logan displays a sequence of glacial deposits resting on a shore platform. These provide sedimentary evidence for the pattern of Late Devensian ice-sheet flow in south-west Scotland and show successive ice movements from sources in the Highlands and Southern Uplands.

Introduction

Port Logan (NX 092402) is a coastal section 20 km south of Stranraer in the Rhins of Galloway. This area was among the first to be surveyed by the Geological Survey of Scotland (Irvine, 1872) and it was noted that the glacial deposits contained a considerable variety of erratics. Particular attention was given to the occurrence of marine shells associated with the glacial deposits, which had previously been reported in that area by Moore (1850). It was noted that shells occurred in both laminated clays as well as in the underlying till (Irvine, 1872), and the cliffs immediately to the south of Port Logan were reported as a good example of the latter type of deposit.

Description

The Mull of Galloway was last glaciated by ice moving from the north-east, as is indicated by the long axes of the many drumlins on the peninsula (Kerr, 1982). Thick drift sections are present along the coast where these drumlins have been truncated by marine erosion. A lower, calcareous, shelly till associated with an earlier phase of glaciation from the north is also recorded (Kerr, 1982). In the cliffs south of Port Logan, a brown clayey till, with only occasional clasts near the base, but becoming more stoney higher up the section, rests directly on bedrock. Fragments of shells occur within the till (Brady *et al.*, 1874; D. G. Sutherland, unpublished data) or within a sandy lens in the till (Irvine, 1872). Approximately 2–3 m of the deposit are presently exposed, with the greater part of the 20 m of drift being vegetated. Near the top of the deposits approx-

imately 1 m of sand and gravel with interbedded massive red clays overlie the till (D. G. Sutherland, unpublished data).

Only a limited fauna has been reported from Port Logan. Brady *et al.* (1874) recorded the molluscs *Astarte sulcata* (da Costa), *Nuculana pernula* (Müller) and *Yoldiella lenticulata* (Müller) and the ostracod *Cytheridea punctillata* Brady; Irvine (1872) recorded *Astarte sulcata* (da Costa), *Macoma baltica* (L.), *Nuculana* cf. *pernula* (Müller) and *Hiatella arctica* (L.).

The bedrock surface on which the shelly till rests is part of a shore platform which can be traced around the coast of the Mull of Galloway at approximately 10 m above present sea level. It clearly pre-dates the last glaciation of the area and may be equivalent to the rock platforms described by Stephens (1957) on the opposite side of the North Channel and by Gray (1978a) on the Mull of Kintyre (see Glenacardoch Point).

Interpretation

The shelly till of the Rhins of Galloway may relate to an early phase of the last (Late Devensian) ice-sheet glaciation when Highland ice extended across this area from the north, transporting, *inter alia*, erratics of Ailsa Craig microgranite and Arran granite on to the peninsula (Charlesworth, 1926a; Kerr, 1982; Sutherland, 1984a). Subsequently, Southern Uplands ice expanded, and a north-east to south-west ice flow developed across the area, moulding the drumlin landscape and carrying erratics of Loch Doon granite. This sequence of events is thus similar to that in the southern Central Lowlands (see Nith Bridge and Hewan Bank) where expansion of the Southern Uplands ice displaced Highland ice as the last glaciation progressed. Port Logan is thus important in a regional context, providing evidence of the relative pressures exerted by the two principal ice masses in Scotland during the last glaciation. This field evidence will help provide the necessary constraints for models of ice-sheet dynamics and palaeoclimatic reconstruction.

Additional interest in the site is provided by the glaciated rock platform, as there is currently considerable debate as to the age and origin of rock platforms along the west coast of Scotland (Sissons, 1981a, 1982b; Dawson, 1984; Sutherland, 1984a).

Conclusion

Port Logan is a representative site for the glacial sequence in south-west Scotland and forms part of the site network showing the major regional variations in the flow patterns of the last ice-sheet (around 18,000 years ago). In particular, the deposits reveal successive movements of ice across the area from the Highlands and Southern Uplands during the Late Devensian ice age.

TAUCHERS

D. G. Sutherland

Highlights

Tauchers displays an excellent example of a double end moraine formed by a corrie glacier of the Loch Lomond Readvance in the Southern Uplands. The site demonstrates clearly the importance of topographic factors in influencing glacier location and development.

Introduction

The Loch Doon granitic intrusion forms a large basin in the western Southern Uplands, the surrounding hills being composed of contact-metamorphosed greywackes and shales. In the centre of the basin is a prominent north–south ridge which culminates in the hill of Mullwharchar (692 m OD). The corrie-like embayment on the north-east flank of this hill is known as the Tauchers (NX 462876). The Southern Uplands was a major centre of ice dispersal during the Late Devensian ice-sheet glaciation (Sissons, 1967a; Sutherland, 1984a), but during the Loch Lomond Readvance only minor valley and corrie glaciers developed (Sissons, 1979d) in contrast to the much more extensive glaciation of the western Highlands at that time. In the western Southern Uplands, Cornish (1979, 1981) mapped 11 glaciers considered to be part of the Loch Lomond Readvance. Of these, the geomorphological evidence defining the former glaciers is most clear and most complete for the Tauchers glacier and has been described by Cornish (1979, 1981).

Description

Cornish (1979, 1981) has described the evidence that delimits a former glacier that flowed eastwards out of the Tauchers embayment. The terminus of the glacier is defined by a double end moraine complex (Figure 18.2). The outer moraine is up to 200 m wide and its outer edge has been eroded by the Gala Lane, showing it to be composed of an olive-brown, bouldery till with a sandy matrix. At its southern end the moraine has a maximum height of 10–12 m and comprises a series of ridges and depressions with an amplitude of 2–3 m. The inner end moraine is 3–5 m high and composed of olive-brown sandy till. It is somewhat sinuous in detail but broadly forms an arc parallel with the outer moraine.

On its north side, twin lateral moraines extend upslope from the ice-proximal and ice-distal slopes of the outer end moraine, terminating at 290 m and

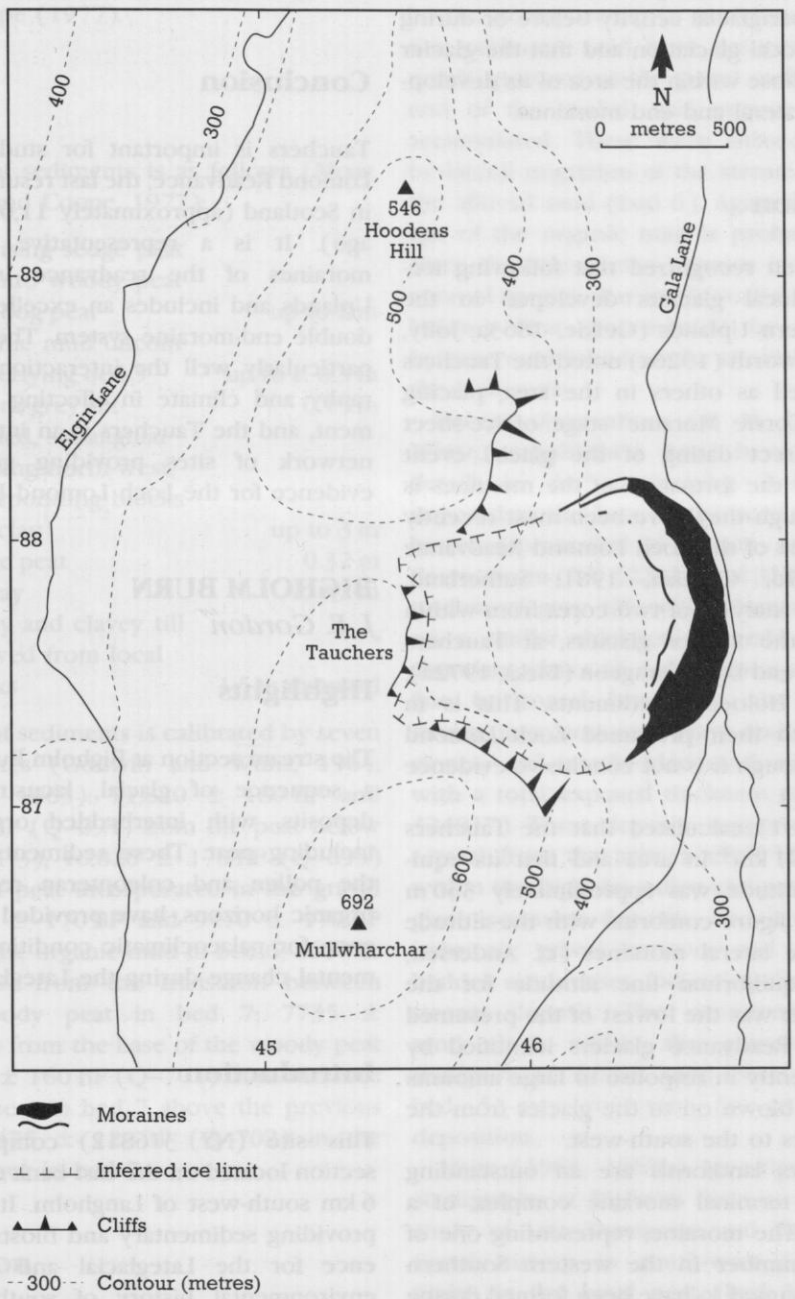


Figure 18.2 Loch Lomond Readvance moraines and ice limits at the Tauchers (from Cornish, 1981).

335 m OD respectively. These lateral moraines are composed of granite boulders up to 5 m in diameter. The northern margin of the inner moraine is also continued upslope to an altitude of 335 m OD by a lateral moraine composed of boulders.

The ground 'outside' the moraines of the former glacier is littered with large granite boulders, yet 'inside' the moraines such boulders are almost absent, those present apparently having rolled down from the slopes above. The implication is that the granite boulders were produced by periglacial activity before or during the period of local glaciation and that the glacier incorporated those within the area of its development into its lateral and end moraines.

Interpretation

It has long been recognized that following ice-sheet decay local glaciers developed in the western Southern Uplands (Geikie, 1863a; Jolly, 1868). Charlesworth (1926a) noted the Tauchers moraine as well as others in the area, placing them in his 'Corrie Moraine' stage of ice-sheet retreat. No direct dating of the glacial event responsible for the formation of the moraines is available, although they have been most recently accepted as part of the Loch Lomond Readvance (Sissons, 1979d; Cornish, 1981; Sutherland, 1984a). Pollen analyses of two cores from within the limits of the former glaciers, at Tauchers (Moar, 1969b) and Loch Dungeon (Birks, 1972a), revealed only Holocene sediments. This is in conformity with their presumed Loch Lomond Stadial age, although it is not conclusive evidence (Cornish, 1981).

Cornish (1981) calculated that the Tauchers glacier was 0.91 km^2 in area and that its equilibrium line altitude was approximately 330 m OD. This latter figure conforms with the altitude attained by the lateral moraines (cf. Andersen, 1968). The equilibrium line altitude for the Tauchers glacier was the lowest of the presumed Loch Lomond Readvance glaciers identified by Cornish, apparently in response to large amounts of snow being blown on to the glacier from the extensive slopes to the south-west.

The Tauchers landforms are an outstanding example of a terminal moraine complex of a corrie glacier. The moraine, representing one of only a small number in the western Southern Uplands, is presumed to have been formed during the Loch Lomond Readvance, and is hence an integral part of the glacial history of that region. The evidence for only minor glaciers existing in the region during the Loch Lomond Stadial (see also Loch Skene) is an important part of the national pattern of glaciation at that time, which is fundamental to the understanding of the Loch Lomond Stadial environment and climate (cf. Sissons, 1979d). The Tauchers site illustrates particularly well the relationships between topography (snow-blowing area) and glacier growth in a marginal situation for glacier development.

Conclusion

Tauchers is important for studies of the Loch Lomond Readvance, the last resurgence of glaciers in Scotland (approximately 11,000–10,000 years ago). It is a representative site for corrie moraines of the readvance in the Southern Uplands and includes an excellent example of a double end-moraine system. The site also shows particularly well the interaction of local topography and climate in affecting glacier development, and the Tauchers is an integral part of the network of sites providing geomorphological evidence for the Loch Lomond Readvance.

BIGHOLM BURN

J. E. Gordon

Highlights

The stream section at Bigholm Burn demonstrates a sequence of glacial, lacustrine and fluvial deposits, with interbedded organic sediments including peat. These sediments, together with the pollen and coleopteran records from the organic horizons, have provided important evidence for palaeoclimatic conditions and environmental change during the Lateglacial.

Introduction

This site (NY 316812) comprises a stream section located on the east bank of Bigholm Burn, 6 km south-west of Langholm. It is important in providing sedimentary and biostratigraphic evidence for the Lateglacial and early Holocene environmental history of south-west Scotland. The key interest includes assemblages of fossil

Coleoptera, which, together with those from Redkirk Point and other sites in the region, reveal a significantly different pattern of Lateglacial climatic change to that suggested by pollen evidence: the mildest climate occurring about 13,000 BP, followed by a progressive deterioration throughout the Lateglacial Interstadial, which led into the severe conditions of the Loch Lomond Stadial. The sequence of sediments at Bigholm Burn and their lateral variations have been described by Moar (1964, 1969b) and Bishop and Coope (1977).

Description

The sequence of sediments is as follows (Moar, 1969b; Bishop and Coope, 1977):

7.	Peat, comprising sedge peat passing up into woody peat and blanket bog peat	up to 2 m
6.	Brown organic mud uncomformably overlying bed 5	up to *c.* 0.5 m
5.	Lenses of dark-grey silt	0.15 m
4.	Poorly bedded, subangular gravels dipping north-west, locally incorporating blocks of peat and clay	up to 3 m
3.	Folded sedge peat	0.32 m
2.	Blue-grey clay	*c.* 0.2 m
1.	Grey, pebbly and clayey till largely derived from local Silurian rocks	1.5 m exposed

This sequence of sediments is calibrated by seven radiocarbon dates (Godwin and Willis, 1964; Godwin *et al.*, 1965): 11,820 ± 180 BP and 11,580 ± 180 BP (Q–694) from the peat below the gravel (bed 3); 10,820 ± 170 BP (Q–695) from a block of peat incorporated in the gravel (bed 4); 9590 ± 170 BP and 9470 ± 170 BP (Q–697) from the organic mud in bed 6; 8650 ± 165 BP (Q–699) from the transition between sedge and woody peat in bed 7; 7735 ± 155 BP(Q–700) from the base of the woody peat in bed 7; 7640 ± 160 BP (Q–701) from the base of the woody peat in bed 7 above the previous sample, and 5475 ± 120 BP (Q–702) in the blanket bog above in bed 7.

Interpretation

Bishop (Bishop and Coope, 1977) interpreted the succession as beginning with the accumulation of fine-grained sediments (bed 2) and then sedge peat (bed 3) in pools in the till surface. The coarse angular gravel above (bed 4) represented solifluction deposits formed during the Loch Lomond Stadial. The weight of this gravel compressed the peat and caused it to buckle, and in places to rupture, so that blocks became incorporated into the gravels. The radiocarbon date of 10,820 ± 170 BP on one such block may indicate the end of the period of peat formation, but could be too young owing to enrichment by percolation of humic acid from the peat above. Small ponds appeared on the gravel surface towards the end of the stadial, and organic silts (bed 5) accumulated. These were subsequently eroded by lateral migration of the stream that deposited the alluvial mud (bed 6). Again the radiocarbon age of the organic mud is probably too young, since the coleopteran remains indicate the presence of species that imply stadial conditions (see below). Peat (represented by bed 7) finally became established on the alluvial surface during the Holocene.

Recent observations (A. M. Hall and C. M. White, unpublished data) have added further details to the stratigraphy. Bed 1 is poorly exposed at the base of the section and is much better represented in stream sections *c.* 1 km downstream (NY 322815 and 324817), where up to 2 m of grey till, with Silurian pebbles, rests on a similar thickness of red-brown till, with abundant clasts of red sandstone. Bed 2 shows fine horizontal lamination and passes downstream into laminated clays and silts, with drop stones, and interbedded sand and gravel bands with a total exposed thickness of *c.* 4 m (at NY 324817). These deposits suggest that during ice retreat from the area, a small lake was ponded within the Bigholm valley and partially infilled by glaciolacustrine deposits. Bed 4 includes locally imbricate gravel horizons and cross- and flat-bedded sand lenses, indicating that it is a braided stream deposit. The occasional presence of sand clasts within the gravels demonstrates transport of frozen sand blocks. The silts of bed 5 may represent fine-grained overbank deposition.

Moar (1964, 1969b) investigated the pollen stratigraphy at Bigholm Burn as part of a wider study of Late Devensian and Holocene vegetational history in south-west Scotland. Pollen grains in the basal peat (bed 3) and the peat included in the gravel (bed 4) are representative

of an open-vegetation assemblage (including Cyperaceae, Gramineae, Compositae, *Filipendula* and *Empetrum*) and compatible with a Lateglacial Interstadial age. Pollen grains in the silts (bed 5) above the gravels are from dominantly herbaceous plants of types associated with open, unstable habitats (for example, Cyperaceae, Gramineae, Compositae, Cruciferae, *Epilobium*, *Saxifraga oppositifolia* type, *Thalictrum*, *Artemisia* and *Koenigia*) and suggest that the deposit originated during the Loch Lomond Stadial. In the transition to the milder climate of the Holocene, pollen zone FI (lower part of bed 6) shows a rise in *Betula*, *Juniperus* and *Salix*, high frequencies of non-arboreal pollen and a remarkable development of aquatic types. *Betula* is dominant in zone FII (upper part of bed 6) and in the early part of zone FIII (bed 7) before being replaced by *Pinus*, *Ulmus*, *Quercus* and *Alnus*. Radiocarbon dates from the Holocene sediments at Bigholm Burn are comparatively younger than those for equivalent pollen zones at Scaleby Moss 21 km to the south-east (Godwin *et al.*, 1957) and may reflect rootlet penetration from above or contamination by humic acid percolation (Bishop and Coope, 1977).

The overall regional pattern of the vegetational history of south-west Scotland to emerge from Moar's work was one of open, treeless vegetation during the Lateglacial. The regional Lateglacial pollen zone I was dominated by Gramineae, Cyperaceae and *Rumex* together with dwarf shrubs. In zone II the vegetation became more stable and denser. Herbs remained dominant, and shrubs increased. Zone III was characterized by a sharp increase of open, unstable habitats. Open vegetation persisted at the start of the Holocene before the slow spread of birch woodland into the area and its subsequent dominance until partly replaced by mixed oak forest in Holocene zone IV.

Coope (Bishop and Coope, 1977) investigated the assemblages of fossil Coleoptera in the organic layers at Bigholm Burn and other sites in the region. The assemblage from the lower peat (bed 3) at Bigholm Burn includes *Diacheila arctica* Gyll., *Agonum consimile* Gyll., *Hydroporous arcticus* Th., *H. longicornis* Sharp, *Ilybius angustior* Gyll., *Helophorous aquaticus* L., *H. flavipes* F., *Pycnoglypta lurida* Gyll., *Olophrum assimile* Payk., *O. fuscum* Gr. and *Stenus* spp. It closely resembles the assemblage from a broadly contemporaneous peat dated at 11,205 ± 177 BP (Birm–41) at Redkirk Point (see below), although there is some indication from a slightly higher representation of phytophagous species that the vegetation was more diverse at Bigholm Burn. The assemblage at Bigholm Burn has a definite northern chatacter, but the presence of two relatively southern species (*Eubrychius velutus* Beck. and *Gymnetron beccabungae* L.) suggests slightly less severe conditions than at Redkirk Point, with an average July temperature of about 12°C. A second sample from the organic silt (bed 5) yielded an impoverished fauna dominated by *Olophrum boreale* Payk., suggesting little or no plant cover and average July temperatures well below 10°C at the time of the Loch Lomond Stadial. This sample from Bigholm Burn demonstrates further climatic deterioration after deposition of the Redkirk Point sample dated at 10,898 ± 127 BP (Birm–40) and is the only one of stadial age in Scotland so far investigated for fossil Coleoptera.

The combined evidence from the assemblages of fossil Coleoptera at Bigholm Burn, Redkirk Point and other sites discussed by Bishop and Coope (1977), each covering a slightly different time period, suggests a pattern of Lateglacial climatic change in which temperatures rose to as warm as present by about 13,000 BP (or possibly later – cf. Atkinson *et al.*, 1987). Temperatures then fell sharply in two stages between about 12,500–12,000 BP and 11,000–10,500 BP, culminating in the Loch Lomond Stadial. The drop in July temperatures inferred from the coleopteran assemblages was as much as 6–7°C. At the end of the stadial a temperature rise of similar magnitude occurred within 700 years. This interpretation differs from the traditional view based on pollen analysis (see above) that the Lateglacial thermal maximum occurred during pollen zone II of the Jessen–Godwin Scheme, usually equated with the Allerød Interstadial between about 11,800 and 11,000 BP. The evidence from the Coleoptera, however, indicates that the thermal maximum was already past by this time and that temperatures were decreasing. Such a pattern is substantiated by similar studies elsewhere in Britain (see Coope, 1977; Atkinson *et al.*, 1987). It appears that vegetation recolonization at the end of the Late Devensian ice-sheet glaciation lagged behind the climatic changes. In contrast, the more mobile beetles responded more rapidly to the changing climate, and hence fossil coleoptera are more sensitive indicators of past climate change than are pollen assemblages (cf. Coope and Brophy, 1972;

Coope, 1975, 1981; Coope and Joachim, 1980).

Bigholm Burn is an important locality for interpreting the Lateglacial and early Holocene environmental history of south-west Scotland. The sedimentary and biostratigraphic evidence complements that at Redkirk Point, particularly the fossil coleopteran assemblages. The deposits show:

1. the transition from cold conditions, accompanied by glacial and glaciolacustrine sedimentation, at the end of the Late Devensian glaciation to the establishment of temperate conditions during the Lateglacial Interstadial;
2. subsequent climatic deterioration culminating in the Loch Lomond Stadial, with accelerated mass movement, frost weathering and associated cold-climate fluvial activity;
3. climatic amelioration at the start of the Holocene.

Conclusion

Bigholm Burn is important for studies of environmental history during the final phase of the Late Devensian, the Lateglacial (approximately 13,000–10,000 years ago). Detailed study of the sequence of deposits, including analysis of the pollen and beetle remains they contain, has provided a vital record of Lateglacial environmental conditions and geomorphological changes in south-west Scotland. The evidence from the fossil beetles, in conjunction with that from Redkirk Point, is particularly significant in showing rapid climatic warming early in the Lateglacial, followed by a considerable climatic deterioration in two steps. Bigholm Burn forms a key part of the network of sites for establishing Lateglacial environmental conditions.

REDKIRK POINT

J. E. Gordon

Highlights

The coastal section at Redkirk Point displays a sequence of estuarine deposits and buried peat. Analysis of these deposits, and the pollen and coleopteran remains they contain, has provided detailed information about palaeoclimatic conditions, environmental change and coastline development during the Lateglacial and early Holocene.

Introduction

Redkirk Point (NY 301652) is located on the coast of the Solway Firth, 11 km east of Annan. It shows a sequence of interbedded organic and marine sediments exposed on the foreshore and in the backing cliff. These deposits are important for interpreting the patterns of Lateglacial and early Holocene environmental history and sea-level change in south-west Scotland. The sediments exposed at Redkirk Point have been described by Jardine (1964, 1971, 1975, 1980b) and in greatest detail by Bishop (Bishop and Coope, 1977).

Description

Bishop and Coope (1977) recorded the following sequence partly infilling a shallow channel cut in the New Red Sandstone bedrock (see also Figure 18.3) (see also Jardine, 1980b):

9.	Disturbed ground and soil profile	0.15 m
8.	Sandy silts and alluvium	0.40 m
7.	Grey clays and silts (carse clays) with thin peat layer	3.00 m
6.	Grey clays and fine sands with several discontinuous peat lenses and disturbed bedding	3.0 m
5.	Highly compacted and disturbed woody peat with *in situ* tree stumps	0.15 m
4.	Grey silts and fine sands with disturbed bedding	1.60 m
3.	Highly compacted and disturbed peat, with local peat lens below	0.25 m
2.	Carbonaceous silts and fine sands	0.30 m
1.	Red, sandy and pebbly till	1.50 m

The peat layers are typically deformed and buckled under the weight of the overlying clays (carse). Five radiocarbon dates have been obtained on material from the organic layers (Bishop and Coope, 1977): 12,290 ± 250 BP (Q–816) from the peat lens below bed 3 (Godwin *et al.*, 1965); 11,205 ± 177 BP (Birm–41) from the bottom 0.06 m of bed 3 (Shotton *et al.*, 1968); 10,898 ± 127 BP (Birm–40) from the top 0.03 m of bed 3 (Shotton *et al.*, 1968); 10,300 ± 185 BP (Q–815) from wood (*Populus*) from the eroded top of bed 3 (Godwin *et al.*, 1965), and 8135 ± 150 BP (Q–637) from the outer rings of an *in situ* tree stump in bed 5 (Godwin and Willis, 1962).

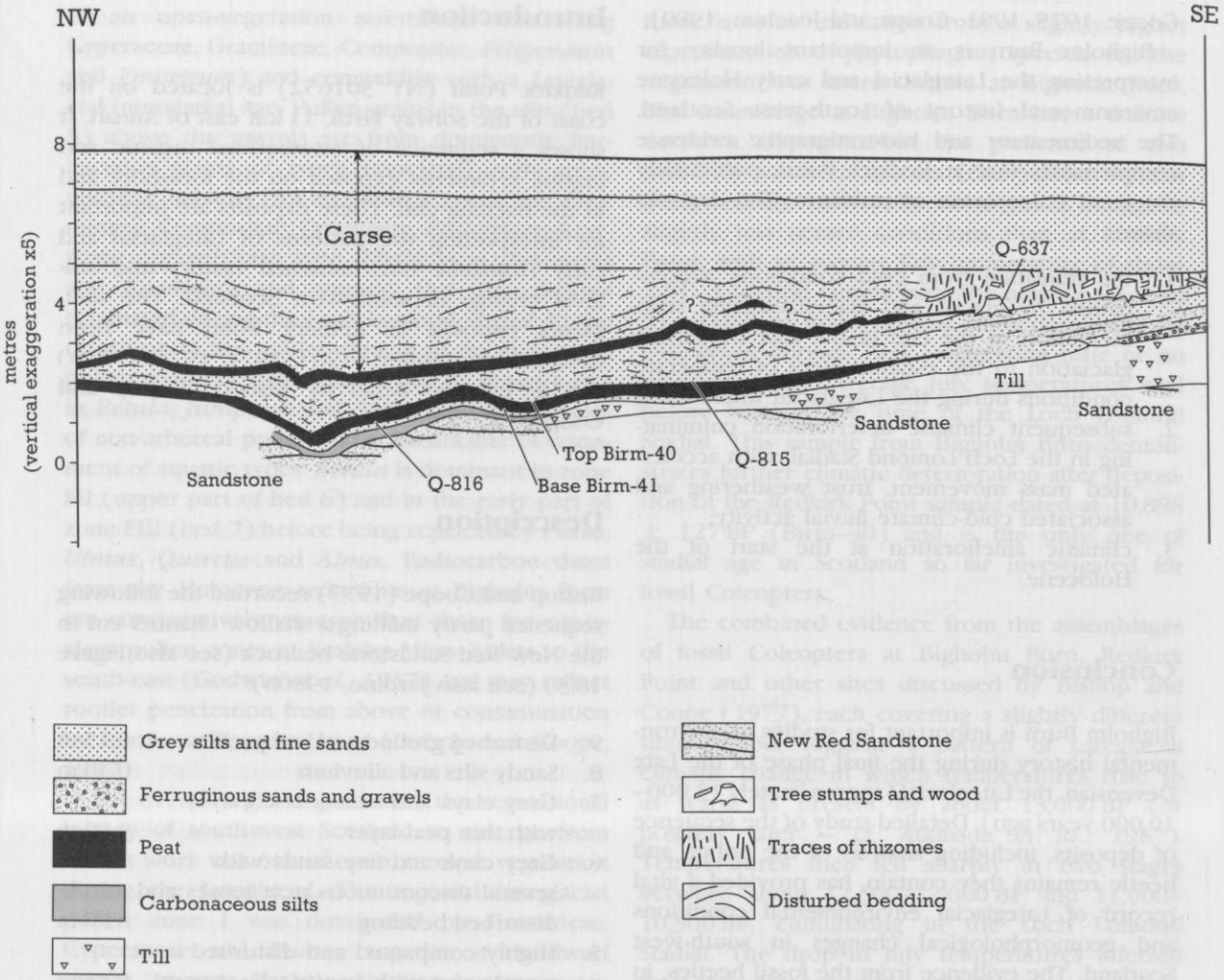


Figure 18.3 Redkirk Point: sediment succession (from Bishop and Coope, 1977).

Interpretation

Bishop (Bishop and Coope, 1977) interpreted the sequence of events beginning with a period of low sea level following glaciation, during which a shallow channel was eroded in the till and sandstone. Sedimentation of the carbonaceous silts and sands (bed 2) under fluvial conditions began before 12,000 BP. The pollen of the peat lens below bed 3 indicates a typical Lateglacial floral assemblage with abundant herbaceous types (including *Selaginella*, *Empetrum*, *Thalictrum* and cf. *Saussurea alpina*) and limited arboreal types (*Betula*, *Pinus* and *Salix*) (Godwin and Switsur, 1966). The peat of bed 3 probably attained a thickness of about 1.25 m before compression. Its development was curtailed by freshwater ponding associated with a rising sea level around 10,300 BP, followed by deposition of the grey silts and fine sands of bed 4. Thereafter, a relative fall in sea level allowed re-establishment of vegetation and development of a tree cover (represented in the deposits of bed 5). A subsequent rise in relative sea level after about 8100 BP associated with the Main Postglacial Transgression (Jardine, 1964, 1971, 1975, 1980b) was accompanied by deposition of over 6 m of carse clays (beds 6, 7 and 8).

The peat beds in the sequence at Redkirk Point preserve a valuable record of changing environmental conditions. The pollen record has not been investigated in detail, although the regional pattern of the Late Devensian and Holocene vegetational succession has been established from studies at a number of other lowland sites in south-west Scotland (Moar, 1964, 1969b; Nichols, 1967). The key palaeoecological evidence at Redkirk Point lies in the remains of Coleoptera

preserved in the sediments. These, together with the fossil assemblages from Bigholm Burn (see above) and other sites, each covering a slighty different time period, provide critical information on Lateglacial climatic conditions (Bishop and Coope, 1977).

The assemblage of fossil Coleoptera in bed 2 at Redkirk Point, below the peat dated at 12,290 ± 250 BP, is characterized by a relative abundance of species of running water (e.g. Elminthidae and *Hydraena gracilis* Germ.) and stream bank (e.g. *Bembidion schueppeli* Dej. and *Hypnoidus riparius* F.) habitats. The presence of species with both northern (e.g. *Bembidion schueppeli* Dej. and *Arpedium brachypterum* Gr.) and southern (e.g. *Bembidion gilvipes* Sturm, *Cymindis angularis* Gyll. and *Esolus parallelepipedus* Müll.) distributions today suggests a temperate climate similar to that of south-west Scotland at present, reflecting moderately oceanic conditions and a mean July temperature of about 15°C. Sparse vegetation cover is also indicated by the rarity of phytophagous species, and the overall environmental conditions are similar to those deduced by Coope (Bishop and Coope, 1977) from the assemblage in a peat layer at Roberthill (NY 110797) dated at 12,940 ± 250 BP (Q–643) (Bishop, 1963). The remains from the horizon in bed 3, dated at 11,205 ± 177 BP, at Redkirk Point are of species which have overall northern affinities (e.g. *Diacheila arctica* Gyll., *Elaphrus lapponicus* Gyll., *Patrobus septentrionis* Dej., *Amara torrida* Ill., *Agonum consimile* Gyll., *Hydroprous tartaricus* Lec., *Ilybius anqustior* Gyll., *Olophrum boreale* Payk., *Acidota quadrata* Zett., *Boreaphilus henningianus* Sahlb. and *Otiorhynchus nodosus* Müll.), and eastern affinities (e.g. *Chlaenius costulatus* Mtsch. and *Bembidion transparens* Gebl.), reflecting a marked contrast in environmental conditions compared with those indicated by the sample from bed 2. Climatic deterioration was accompanied by increased continentality, a fall in average July temperatures to about 12°C and widespread development of acid bog and wetlands. Similar conditions at this time are also implied by the Coleoptera in a bed, dated at 11,580 ± 180 BP to 11,820 ± 180 BP (Q–694,) at Bigholm Burn (see above). Further climatic deterioration is indicated by increased numbers of the northern species in the horizon in bed 3 dated at 10,898 ± 127 BP. The greater abundance of species such as *Pycnoglypta lurida* Gyll., *Olophrum fuscum* Gr., *Arpedium brachypterum* Gr. and *Boreaphilus henningianus* Sahlb. is indicative of increasingly more open tree cover. However, the absence of species characteristic of alpine and tundra environments suggests average July temperatures of about 10°C.

The organic deposits at Redkirk Point from which the beetle assemblages have been studied span the period from prior to 12,290 BP to about 10,890 BP, covering much of the Lateglacial Interstadial and the beginning of the Loch Lomond Stadial. Redkirk Point is one of only a few sites in Scotland where Lateglacial environmental conditions have been interpreted from beetle remains (see Bigholm Burn). The significance of the coleopteran evidence from these sites is that it points to a pattern of Lateglacial climatic conditions quite distinct from that suggested by pollen assemblages for the same period (Bishop and Coope, 1977). The beetles indicate that climatic amelioration occurred early in the interstadial, with temperatures as warm as those of the present day attained by about 13,000 BP (or possibly later – cf. Atkinson *et al.*, 1987). Subsequently, climatic deterioration began about 12,500 BP and intensified between 11,000 BP and 10,500 BP during the Loch Lomond Stadial. Conversely, the pollen record shows open habitat, treeless conditions prior to 13,000 BP followed by the main expansion of vegetation between 11,800 BP and 11,000 BP. The pattern of Lateglacial climatic change inferred from the evidence at Redkirk Point is similar to that established from beetle evidence elsewhere in Britain (Coope, 1977; Atkinson *et al.*, 1987) and reflects the great sensitivity and response rate of the beetle populations to changing environmental conditions (cf. Coope and Brophy, 1972; Coope, 1975, 1981; Coope and Joachim, 1980).

Redkirk Point is also a key site providing stratigraphic and geochronometric evidence for the pattern of Lateglacial and early Holocene sea-level change in south-west Scotland, complementing the interest at Newbie. This evidence demonstrates that from the time of deglaciation (prior to 13,000 BP) and throughout almost the whole of the Lateglacial, sea level was below that of the present day. The first evidence of marine influence apparently occurs at the end of the Lateglacial and the start of the Holocene (bed 4), which invites comparison with the marine transgression that occurred at this time in the Western Forth Valley (see above). Subsequently, sea level fell and peat (bed 5) accumulated. During the Main Postglacial Transgression grey silts and clays (beds 6 and 7) were deposited on top of the peat.

These last events have been studied in greater detail at Newbie (see below).

Conclusion

The deposits at Redkirk Point provide important evidence for changes in sea level and coastal environmental conditions in south-west Scotland during the phase which closed Devensian times (the Lateglacial) and the succeeding and warmer early Holocene (between approximately 13,000 and 8000 years ago). This evidence is derived from detailed analysis of the sediments and the pollen and beetle remains they contain, and is supported by radiocarbon dating. The length and detail of the record, and in particular the combined evidence from the pollen and beetles, make Redkirk Point a key reference site for studies of Lateglacial environmental history in south-west Scotland and an integral component in the national site network.

NEWBIE

J. E. Gordon

Highlights

The coastal section at Newbie shows a sequence of interbedded estuarine and organic deposits, including peat. These deposits provide important evidence for interpreting sea-level changes on the Solway coast during the Holocene.

Introduction

The site at Newbie (NY 165651) is a section on the coast of the Solway Firth, 2.5 km south-west of Annan. It shows a sequence of interbedded marine and organic sediments that provides stratigraphic and geochronometric evidence for Holocene sea-level change in the Solway Firth area, notably the Main Postglacial Transgression. The deposits at Newbie have been described in several papers by Jardine (1964, 1971, 1975, 1980b) from section and borehole evidence.

Description

At Newbie Cottages, marine deposits infill the remnants of several small kettle holes in an area of Late Devensian glaciofluvial deposits (Jardine, 1964, 1971, 1975, 1980b). Jardine (1980b) described several sections in detail, but the full generalized sequence is as follows (see also Figure 18.4):

5.	Blown sands with interbedded layers of sand containing fragments of charcoal and organic matter	up to 3.5 m
4.	Peat	up to 1 m
3.	Sands, silts or clayey silts (carse)	up to >4.5 m
2.	Organic detritus	up to 0.3 m
1.	Glaciofluvial sands and gravels displaying at the top, podsolic A_2 and B_2 soil horizons	

The carse deposits (bed 3) comprise two units. The lower one consists of medium and fine-grained sand, locally laminated, and the upper, of silt and clay. The lower sediments also have a relatively higher content of microfaunal remains, and plant debris is present in the upper sediments. Jardine (1967, 1975, 1980b) and Jardine and Morrison (1976) have discussed the sediment characteristics and environment of accumulation of carse deposits both in general terms and in relation to Newbie.

Radiocarbon assays on material from the upper part of the lower organic layer (bed 2) gave the following dates (Jardine, 1975): 7254 ± 101 BP (GU–64) (Baxter *et al.*, 1969), 7540 ± 150 BP (Birm–222) (Shotton and Williams, 1971) and 7400 ± 150 BP (Birm–325) (Shotton and Williams, 1973). Dates obtained from the lower part of the upper organic layer (bed 4) were (Jardine, 1975): 5630 ± 116 BP (Birm–220) (Shotton and Williams, 1971) and 4290 ± 100 BP (I–5070) (Buckley and Willis, 1972). Of the dates on bed 4, the latter may be less reliable than the former as the sample was not pre-treated for humic acid extraction. Charcoal from the wind-blown sands (bed 5) was dated at 3480 ± 110 BP (Birm–218) (Shotton and Williams, 1971).

A borehole located a few hundred metres inland from the coast section at Newbie Cottages penetrated 0.01 m of organic material dated at 7812 ± 130 BP (GU–375) (Ergin *et al.*, 1972) within the sequence of carse sediments (Jardine, 1975). Sand below this organic layer contained frequent Foraminifera tests and a few small fragments of mollusc shells and echinoid spines; the sand above contained occasional fragments of

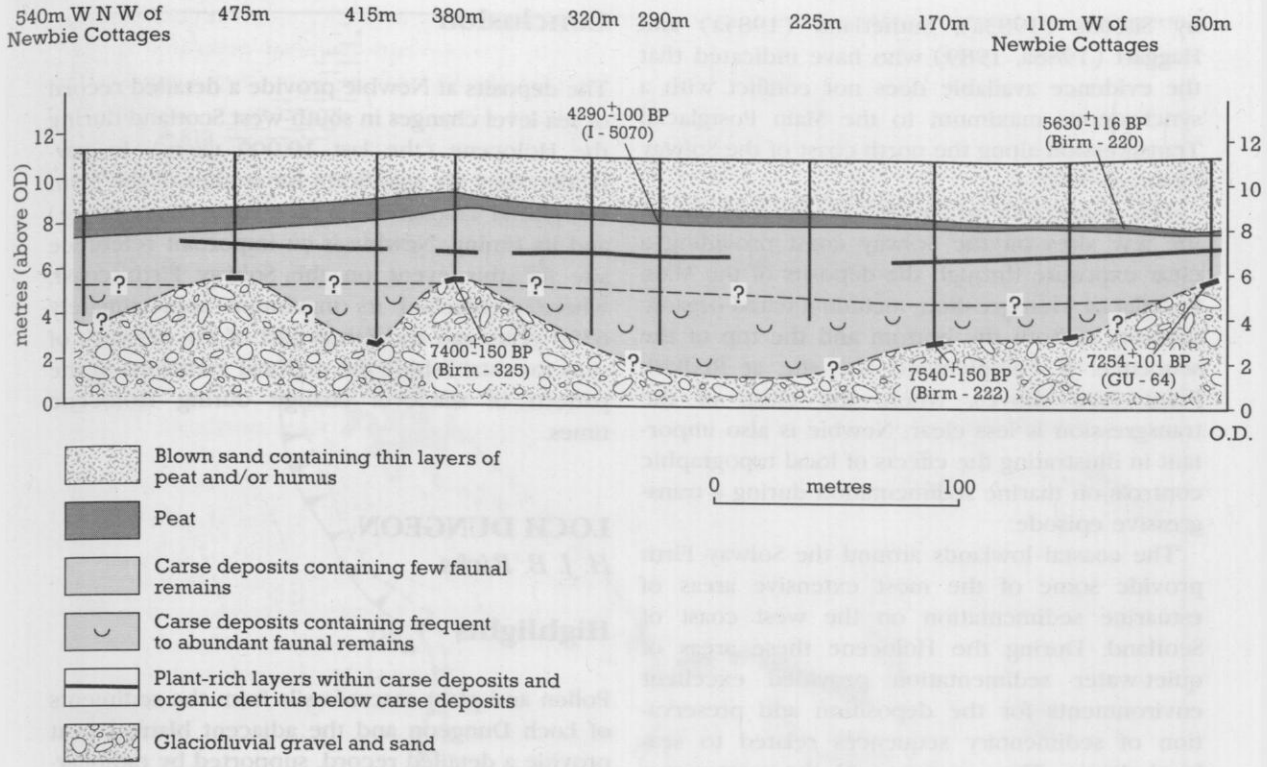


Figure 18.4 Newbie: sediment succession (from Jardine, 1980b).

echinoid spines and sponge spicules.

The biostratigraphy of the organic beds at Newbie has not been investigated. However, Nichols (1967) has studied the pollen stratigraphy of comparable peat layers above and below Main Postglacial Transgression sediments in a borehole at Lochar Moss, and Moar (1964, 1969b) has established the Late Devensian and Holocene vegetational successions at a number of sites in the area.

Interpretation

Jardine (1975, 1980b) interpreted the Newbie deposits to represent a locally diachronous marine transgression controlled by the form of the topography. The lower area where the borehole was located was inundated by the sea before 7800 BP. This was followed by a brief interruption in marine sedimentation at around 7800 BP, then a further transgressive overlap. The kettle holes at Newbie Cottages were not breached by the sea until about 7450 BP. The marine transgression then culminated at, or some time prior to, 5600 BP.

The position of the local succession at Newbie in the overall chronology and pattern of Holocene marine transgression and regression in the Solway area was discussed by Jardine (1964, 1971, 1975, 1980b). Depending on the altitude of the individual sites, the date of the first evidence for the transgression varies from place to place along the north coast of the Solway, ranging from 9400 BP to 7200 BP. The earliest occurrence is recorded in a borehole at Carsethorn (NX 988594), south of Dumfries (−1.05 m OD: 9400 BP). In the eastern Solway the transgression was first registered at Redkirk Point (2.90 m OD: 8100 BP) and then at Newbie (2.95 m OD to 5.80 m OD: between 7500 BP and 7200 BP). The Newbie dates are broadly similar to that for the transgression into the northern part of the Lochar 'gulf' (7400 BP). In the western Solway at the head of Wigtown Bay the transgression started prior to 7900 BP.

Jardine (1975, 1980b) inferred from the radiocarbon dates on the peat overlying the grey silts and clays that the culmination of the transgression was also diachronous. He suggested that the Lochar 'gulf was abandoned by 6600 BP, but that regression did not start at Newbie until 5600 BP and at the head of Wigtown Bay until 4700 BP. This interpretation has been disputed

by Sissons (1983a), Sutherland (1984a) and Haggart (1988a, 1989) who have indicated that the evidence available does not conflict with a synchronous maximum to the Main Postglacial Transgression along the north coast of the Solway Firth.

The importance of Newbie is that it is one of the few sites on the Solway coast providing a clear exposure through the deposits of the Main Postglacial Transgression, including dated organic deposits at both the bottom and the top of the sequence. It complements the site at Redkirk Point (see above), where the close of the transgression is less clear. Newbie is also important in illustrating the effects of local topographic controls on marine sedimentation during a transgressive episode.

The coastal lowlands around the Solway Firth provide some of the most extensive areas of estuarine sedimentation on the west coast of Scotland. During the Holocene these areas of quiet-water sedimentation provided excellent environments for the deposition and preservation of sedimentary sequences related to sea-level change. They contrast with the greater part of the west coast, where higher energy environments were typical, resulting in the reworking and destruction of much of the sedimentary evidence. The Solway Firth estuarine sequences are more akin to those found around the large estuaries on the east coast and comparison between these various locations is instructive. For example, it is notable that no equivalent has been found in the Solway of the grey, micaceous, silty, sand layer deposited widely along the east coast at around 7000 BP (see Western Forth Valley, Silver Moss and Maryton). This suggests that the event that led to deposition of this sand was confined to the North Sea Basin, thus lending support to its interpretation as a storm surge or tsunami (Smith *et al.*, 1985a; Dawson *et al.*, 1988). The date of the maximum of the Main Postglacial Transgression may also provide an instructive contrast between the two regions. Most east coast sites suggest that the transgression reached its maximum increasingly late with increasing distance from the western Highlands ice centre. However, in the Solway Firth area, the transgression may have reached its maximum relatively early compared with its distance from the western Highlands, thus suggesting a significant role for the Southern Uplands ice centre in glacio-isostatic depression and recovery.

Conclusion

The deposits at Newbie provide a detailed record of sea-level changes in south-west Scotland during the Holocene (the last 10,000 years). In particular, they are significant for studies of the Main Postglacial Transgression (see Silver Moss above) and its timing. Newbie is an important reference site for this event on the Solway Firth coast, where it reached its maximum approximately 6500 years ago and forms part of the network of sites for establishing the regional variations in the pattern of sea-level change during Holocene times.

LOCH DUNGEON

H. J. B. Birks

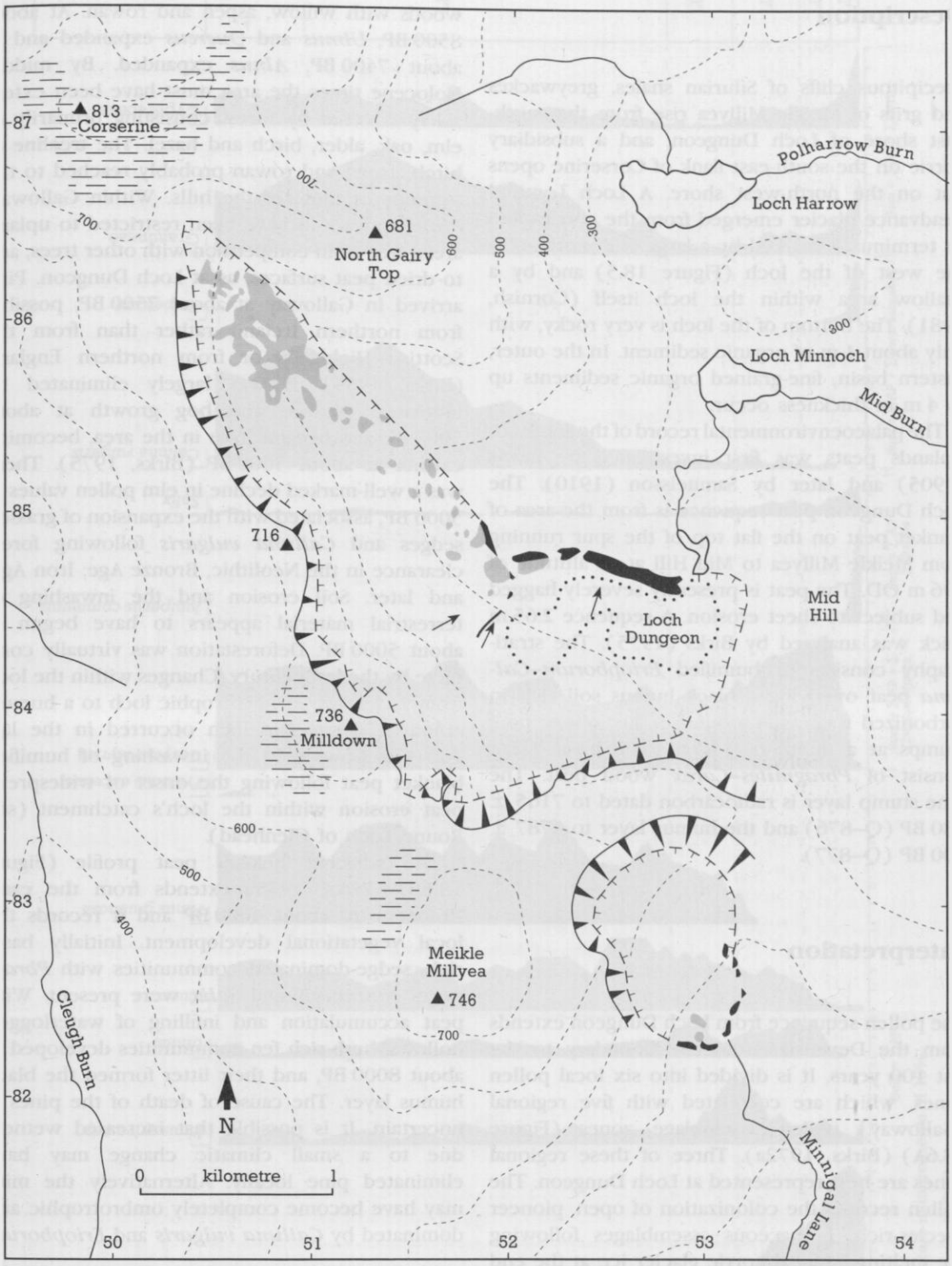
Highlights

Pollen and plant macrofossils from the sediments of Loch Dungeon and the adjacent blanket peat provide a detailed record, supported by radiocarbon dating, of vegetational history and environmental change in the uplands of south-west Scotland during the Holocene.

Introduction

Loch Dungeon (NX 525846) lies within a complex corrie at an altitude of 305 m OD on the east side of the Rhinns of Kells. The pollen and plant macrofossils contained in the lake sediments and in the adjacent area of blanket peat provide a detailed record of the local and regional Holocene vegetational history of the Galloway hills of south-west Scotland. Loch Dungeon is the site at which many of the Galloway regional pollen assemblage zones were delimited and defined by Birks (1972a). Fossil pine stumps occur locally in the blanket peats of the Galloway hills, forming the southernmost area of pine stumps in Scotland (Birks, 1975). Loch Dungeon is one of the few areas in the British Isles where pollen diagrams have been constructed from both a lake and nearby bog profiles.

Figure 18.5 Geomorphology of the Loch Dungeon area (from Cornish, 1981).



Moraine

Hummocky moraine

Inactive periglacial features

Inferred ice limit

Cliffs

300 Contour (metres)

Striae

Description

Precipitous cliffs of Silurian shales, greywackes and grits of Meikle Millyea rise from the south-east shore of Loch Dungeon, and a subsidiary corrie on the south-east flank of Corserine opens out on the north-west shore. A Loch Lomond Readvance glacier emerged from the corries and its terminus is marked by a large end moraine to the west of the loch (Figure 18.5) and by a shallow area within the loch itself (Cornish, 1981). The bottom of the loch is very rocky, with only about 1 m of organic sediment. In the outer, eastern basin, fine-grained organic sediments up to 4 m in thickness occur.

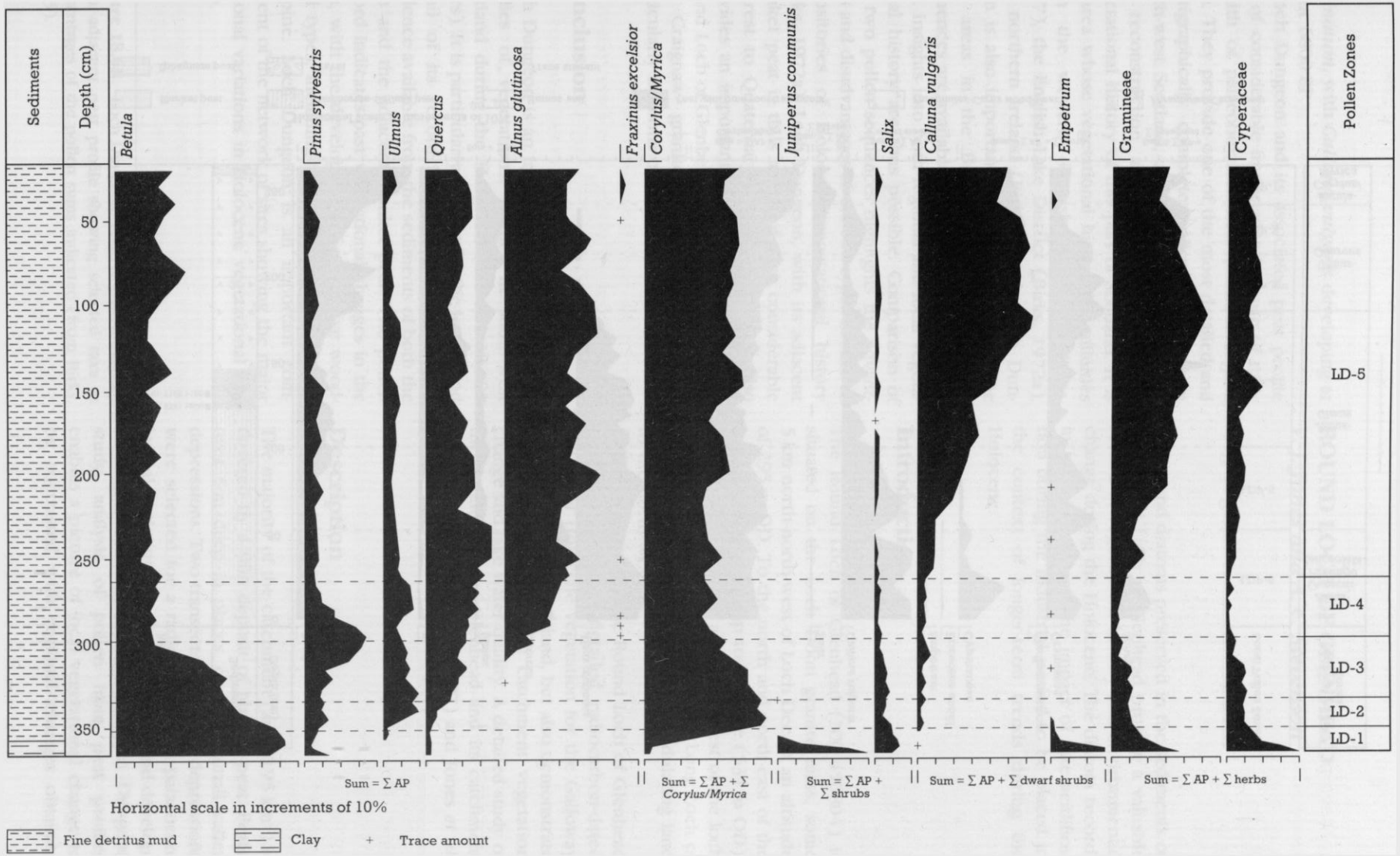
The palaeoenvironmental record of the Southern Uplands peats was first investigated by Lewis (1905) and later by Samuelsson (1910). The Loch Dungeon peat sequence is from the area of blanket peat on the flat top of the spur running from Meikle Millyea to Mid Hill at an altitude of 396 m OD. The peat is presently severely hagged and subject to sheet erosion. A sequence 2.65 m thick was analysed by Birks (1975). The stratigraphy consists of humified *Eriophorum–Calluna* peat overlying a black humus soil rich in carbonized fragments around or just above pine stumps at a depth of 1.45 m. The basal 1.2 m consist of *Phragmites–Carex* wood peat. The pine stump layer is radiocarbon dated to 7165 ± 180 BP (Q–876) and the humus layer to 6787 ± 200 BP (Q–877).

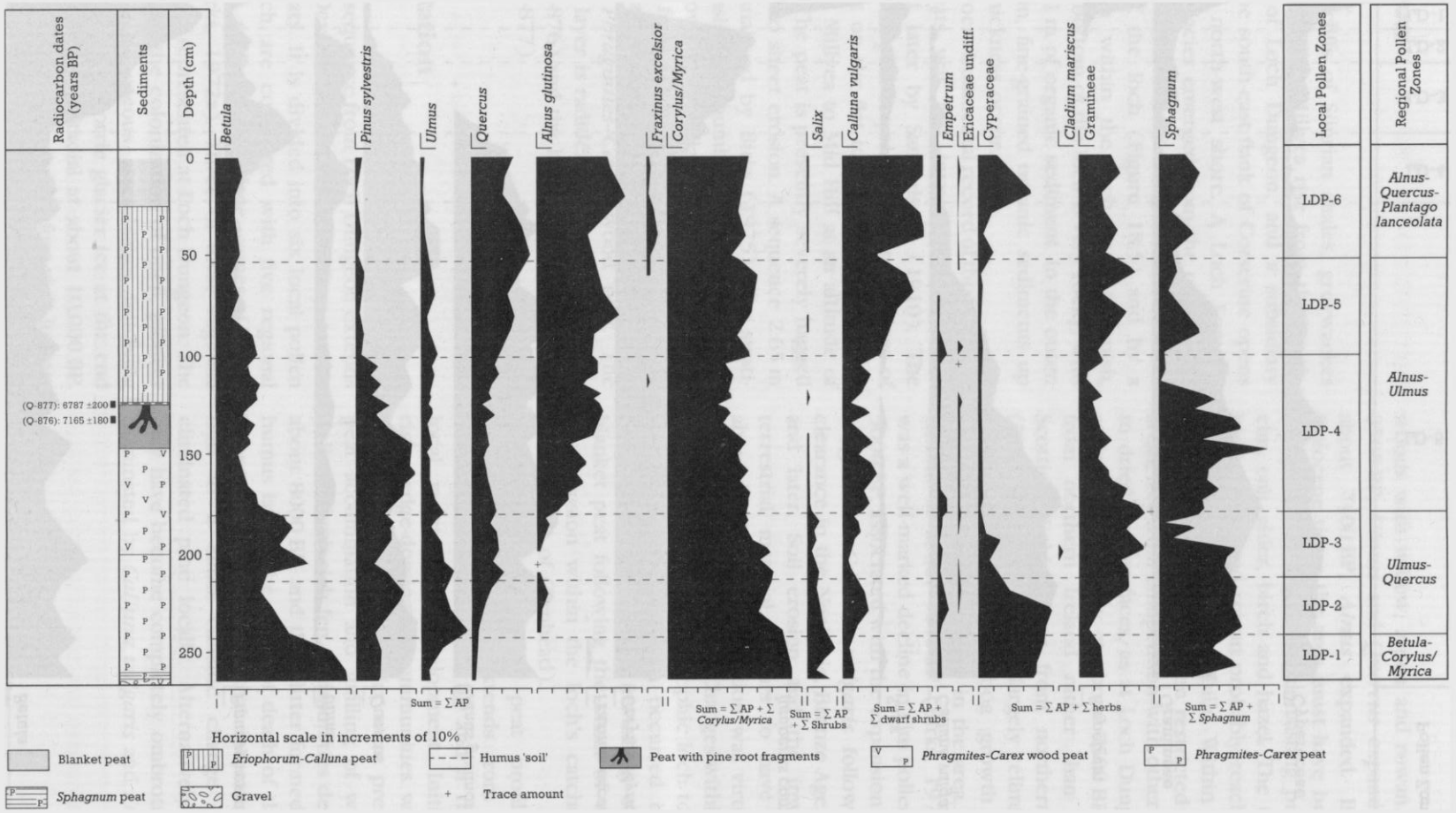
Interpretation

The pollen sequence from Loch Dungeon extends from the Devensian/Holocene boundary to the last 100 years. It is divided into six local pollen zones, which are correlated with five regional (Galloway) pollen assemblage zones (Figure 18.6A) (Birks, 1972a). Three of these regional zones are best represented at Loch Dungeon. The pollen records the colonization of open, pioneer species-rich, herbaceous assemblages following the melting of local corrie glacier ice at the end of the Loch Lomond Stadial at about 10,000 BP. These were rapidly replaced by fern-rich juniper and birch scrub with abundant tall herbs during the transition to the milder climate of the Holocene. In the early Holocene, *Betula* and *Corylus avellana* expanded to form extensive woods with willow, aspen and rowan. At about 8500 BP, *Ulmus* and *Quercus* expanded and at about 7400 BP, *Alnus* expanded. By middle Holocene times the area must have been extensively covered by forest consisting primarily of elm, oak, alder, birch and hazel. The treeline of birch, aspen and rowan probably reached to the summits of most of the hills. Within Galloway, *Pinus* appears to have been restricted to upland areas, free from competition with other trees, and to dried peat surfaces, as at Loch Dungeon. Pine arrived in Galloway at about 7500 BP, possibly from northern Ireland rather than from the Scottish Highlands or from northern England (Birks, 1989). It was largely eliminated by increased wetness and bog growth at about 7000 BP and became rare in the area, becoming extinct at about 5000 BP (Birks, 1975). There was a well-marked decline in elm pollen values at 5000 BP, associated with the expansion of grasses, sedges and *Calluna vulgaris* following forest clearance in the Neolithic, Bronze Age, Iron Age, and later. Soil erosion and the inwashing of terrestrial material appears to have begun at about 5000 BP. Deforestation was virtually complete by the last century. Changes within the loch from a clear-water oligotrophic loch to a humus-coloured dystrophic loch occurred in the last 200 years owing to the inwashing of humified blanket peat following the onset of widespread peat erosion within the loch's catchment (see Round Loch of Glenhead).

The adjacent blanket peat profile (Figure 18.6B) (Birks, 1975) extends from the early Holocene to about 4000 BP and it records the local vegetational development. Initially base-rich, sedge-dominated communities with *Phragmites communis* and *Salix* were present. With peat accumulation and infilling of waterlogged hollows, herb-rich fen communities developed at about 8000 BP, and their litter formed the black humus layer. The cause of death of the pines is uncertain. It is possible that increased wetness due to a small climatic change may have eliminated pine locally. Alternatively the mire may have become completely ombrotrophic and dominated by *Calluna vulgaris* and *Eriophorum*

Figure 18.6A Loch Dungeon: relative pollen diagram from the loch showing selected taxa as percentages of the pollen sums indicated (from Birks, 1972a).


Sediments
Depth (cm)
Betula
Pinus sylvestris
Ulmus
Quercus
Alnus glutinosa
Fraxinus excelsior
Corylus/Myrica
Juniperus communis
Salix
Calluna vulgaris
Empetrum
Gramineae
Cyperaceae
Pollen Zones
50
100
150
200
250
300
350
LD-5
LD-4
LD-3
LD-2
LD-1
Sum = Σ AP
Sum = Σ AP + Σ Corylus/Myrica
Sum = Σ AP + Σ shrubs
Sum = Σ AP + Σ dwarf shrubs
Sum = Σ AP + Σ herbs
Horizontal scale in increments of 10%
Fine detritus mud
Clay
+ Trace amount


Radiocarbon dates (years BP)
Sediments
Depth (cm)
0
50
100
150
200
250
(Q-877): 6787 ±200
(Q-876): 7165 ±180
Betula
Pinus sylvestris
Ulmus
Quercus
Alnus glutinosa
Fraxinus excelsior
Corylus/Myrica
Salix
Calluna vulgaris
Empetrum
Ericaceae undiff.
Cyperaceae
Cladium mariscus
Gramineae
Sphagnum
Sum = ∑ AP
Sum = ∑ AP + ∑ Corylus/Myrica
Sum = ∑ AP + ∑ Shrubs
Sum = ∑ AP + ∑ dwarf shrubs
Sum = ∑ AP + ∑ herbs
Sum = ∑ AP + ∑ Sphagnum
Local Pollen Zones
LDP-6
LDP-5
LDP-4
LDP-3
LDP-2
LDP-1
Regional Pollen Zones
Alnus-Quercus-Plantago lanceolata
Alnus-Ulmus
Ulmus-Quercus
Betula-Corylus/Myrica
Horizontal scale in increments of 10%
Blanket peat
Eriophorum-Calluna peat
Humus 'soil'
Peat with pine root fragments
Phragmites-Carex wood peat
Phragmites-Carex peat
Sphagnum peat
Gravel
Trace amount

vaginatum, with *Calluna vulgaris* developing at about 6800 BP.

Loch Dungeon and its associated peat profile are of considerable importance because of their wealth of palaeobotanical and palaeoecological data. They provide one of the most detailed and stratigraphically complete pollen profiles from south-west Scotland, and are thus important in the reconstruction and understanding of the vegetational history of this part of Scotland. It is an area whose vegetational history has affinities with the western Scottish Highlands (Birks, 1977), the English Lake District (Birks, 1972a), and northern Ireland (Birks, 1989). Loch Dungeon is also important because it is one of the few areas in the British Isles where pollen sequences are available from a lake and a nearby bog. Insights into both regional and local vegetational history are thus possible. Comparison of the two pollen sequences highlights the advantages and disadvantages of the two types of sites as repositories of Holocene vegetational history (Birks, 1972a). Loch Dungeon, with its adjacent blanket peat is thus a site of very considerable interest to Quaternary palaeoecologists. It also provides an important contrast with the nearby Round Loch of Glenhead (see below) situated on the Craignaw granite (Jones *et al.*, 1989), particularly in terms of recent lake changes.

Conclusion

Loch Dungeon is an important reference site for studies of vegetational history in south-west Scotland during the Holocene (the last 10,000 years). It is particularly notable for the length and detail of its record, and the combination of evidence available from the sediments of both the loch and the adjacent blanket peat. The pollen record indicates past vegetational changes in the area, with the development of successive woodland types, including the expansion and decline of pine. Loch Dungeon is an important component of the network of sites showing the major regional variations in Holocene vegetational history.

Figure 18.6B Loch Dungeon: relative pollen diagram from adjacent peat profile showing selected taxa as percentages of the pollen sums indicated (from Birks, 1975).

ROUND LOCH OF GLENHEAD

V. J. Jones and A. C. Stevenson

Highlights

Pollen and diatoms preserved in the sediments of the Round Loch of Glenhead provide a valuable record of vegetational history and environmental change during the Holocene. The diatom record, in particular, allows the impact of lake acidification during the industrial period to be placed in the context of longer-term trends during the Holocene.

Introduction

The Round Loch of Glenhead (NX 450804) is situated on the Loch Doon granite mass, some 5 km north-north-west of Loch Dee, at an altitude of 295 m OD. To the north and north-east of the loch steep cliffs rise up to Craiglee (531 m OD). The land to the south and south-west of the loch is less steep and the twin loch, the Long Loch of Glenhead, is separated by gently undulating land to the north-west.

The sediments in the Round Loch of Glenhead provide not only a detailed radiocarbon-dated history of Holocene vegetation for the Galloway hills in south-west Scotland, but also demonstrate the relationship between catchment vegetation change and lake water quality. A detailed study of the Round Loch of Glenhead and its catchment has been made by Jones (1987) and Jones *et al.* (1986, 1989).

Description

The majority of the catchment (area 0.95 km^2) is covered by a thin deposit of blanket peat. Peats, over 5 m deep in places, occur in small valley depressions. Two transects across the depressions were selected for a radiocarbon and palaeoecological study into peatland initiation and development (Jones, 1987). As in the Loch Dungeon study, analysis of pollen from peat profiles enables a picture of local vegetational change to be contrasted with regional changes obtained

from the lake sediment. At present, peat hags are found in the catchment.

A core (RLGH3) was obtained from the deepest part of the loch (13 m). A Lateglacial sequence of two clay layers separated by an organic mud corresponding to the Lateglacial Interstadial occurs below a depth of 2.27 m (Figure 18.7). The Holocene sediments above are relatively uniform, with loss-on-ignition values of 20–30%. However, there was a change in the sediment type above 0.47 m in the core to a blackish, fine detritus mud with higher loss-on-ignition values (40–50%). From the core, a series of 20 radiocarbon dates has been obtained (Figure 18.7) which shows a conformable sequence from 9280 ± 80 BP (SRR–2821) to 3970 ± 70 BP (SRR–2815). After the last date, erosion of organic material from the catchment occurred, resulting in reworking and ages older than expected. This problem was intensified at about AD 1600 with the onset of a major phase of peat erosion in the catchment (Stevenson *et al.*, 1990).

From the peat profiles, ten radiocarbon dates of the basal peats show that peat accumulation began in wet hollows early in the Holocene; for example a date of 9390 ± 60 BP (SRR–2865) was found at one site. On the better drained slopes peat accumulation began later, for example at 5450 ± 40 BP (SRR–2871), and it is probable that the shallow blanket peats which cover the majority of the catchment began to form at that time.

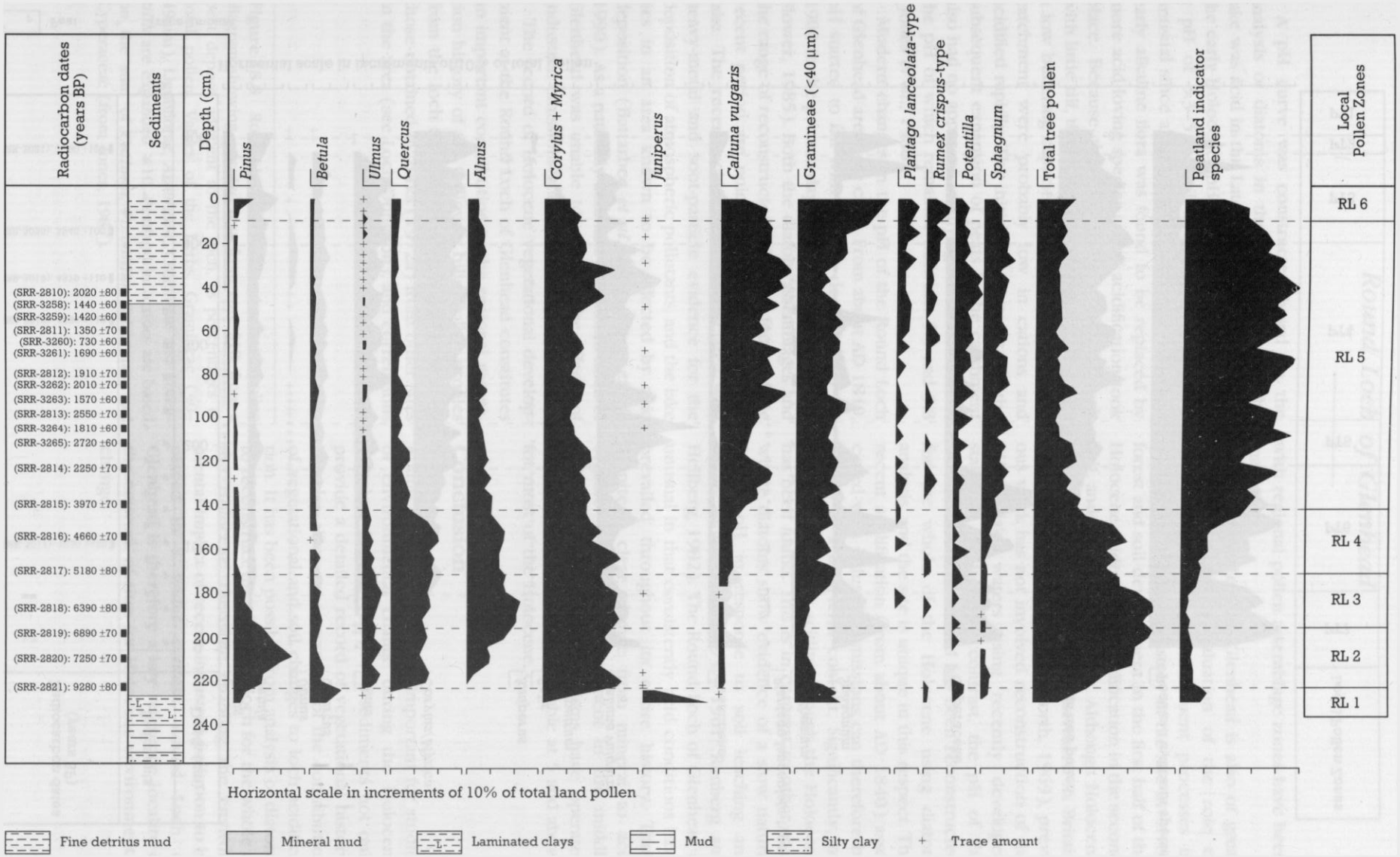
Interpretation

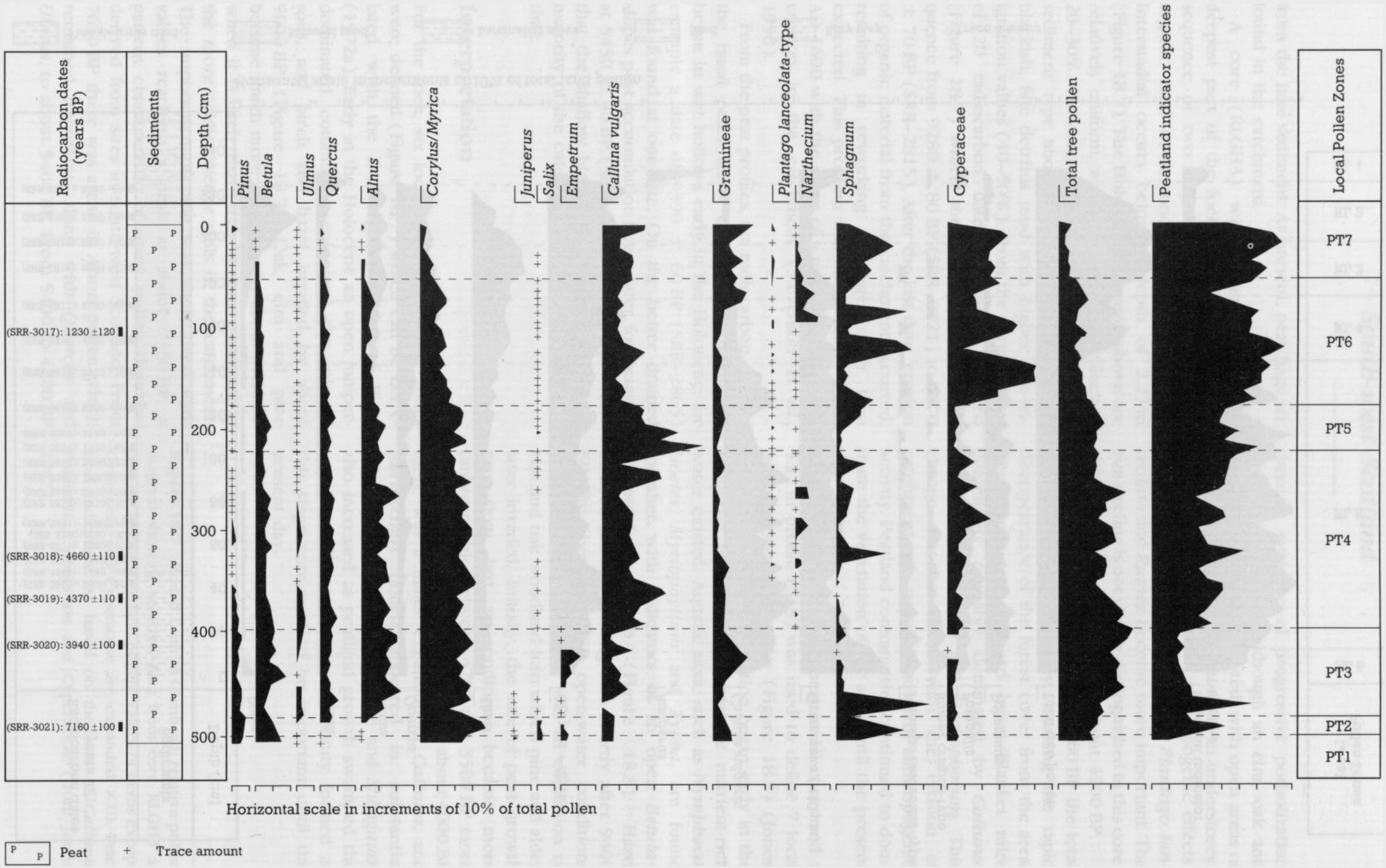
For the loch, six local pollen assemblage zones were defined (Figure 18.7) which can be correlated with the five regional zones of Birks (1972a). Early in the Holocene an open juniper-dominated community colonized the mineral soils, and birch and hazel invaded by about 9000 BP (Figure 18.7). Oak, elm and pine became much more important by about 8600 BP when it is likely that birch became restricted to the more acidic, wetter soils in the catchment. The importance of pine was short lived with values reaching a peak at about 7350 BP, a pattern characteristic of many pollen diagrams derived from sites in south-west Scotland. From 7650 BP there was a rise in *Alnus* pollen which remained important, along with *Quercus* and *Ulmus*, to about 5400 BP. From 5400 to 4200 BP there is evidence of progressive podsolization and peat expansion, although an elm, oak and alder woodland still persisted, with open areas of peaty soils and some *Calluna* as an understorey. There is also evidence of anthropogenic effects, as disturbance indicators such as *Plantago lanceolata* and *Rumex* become more important. The elm decline is not clearly distinguished in this core, although *Ulmus* values fell at about 4200 BP.

In sediments deposited after 4200 BP the total tree pollen falls suddenly, marking the rapid disappearance of the forest cover from the area. The forest was replaced by a blanket mire community probably dominated by *Calluna*, *Molinia*, *Eriophorum* and *Trichophorum*. This change was associated with the erosion of catchment soils, possibly caused by anthropogenic activity. Peatland communities continued to dominate the vegetation of the area until the present day.

Pollen analysis on the peat in 10 cores and a 5.12 m profile (S18) was used to define 7 local pollen assemblage zones (Figure 18.8) (Jones, 1987). Organic sedimentation began early in the Holocene in wet hollows where nutrient-rich water existed. Aquatic taxa, such as *Nymphaea*, *Isoetes*, *Myriophyllum* and *Typha*, are found together with indicators of an open *Betula–Juniper–Salix* scrub (Figure 18.8). Hazel invaded the surrounding area shortly after 9400 BP. By about 8800 BP open-water conditions ceased to exist and there was an expansion of elm and oak woodland into which pine and alder later invaded. Initially, the rate of peat growth was slow, but as conditions became more ombrotrophic between 4700 and 3500 BP more rapid accumulation occurred. After about 4000 BP there was a major expansion of *Calluna*, and *Narthecium* pollen appeared in substantial amounts. Values of Cyperaceae and *Sphagnum* also increased as peatland growth swamped the woodland. The peatland community formed at this stage continued to be important until the present day.

Figure 18.7 Round Loch of Glenhead: relative pollen diagram showing selected taxa from core RLGH3 as percentages of total land pollen. Values of herbs except Gramineae and Cyperaceae are expanded ×10. Peatland indicators are based on the sum of *Calluna*, *Potentilla*, *Sphagnum* and Cyperaceae (from Jones, 1987).


Radiocarbon dates (years BP)
Sediments
Depth (cm)
(SRR-2810): 2020 ±80
(SRR-3258): 1440 ±60
(SRR-3259): 1420 ±60
(SRR-2811): 1350 ±70
(SRR-3260): 730 ±60
(SRR-3261): 1690 ±60
(SRR-2812): 1910 ±70
(SRR-3262): 2010 ±70
(SRR-3263): 1570 ±60
(SRR-2813): 2550 ±70
(SRR-3264): 1810 ±60
(SRR-3265): 2720 ±60
(SRR-2814): 2250 ±70
(SRR-2815): 3970 ±70
(SRR-2816): 4660 ±70
(SRR-2817): 5180 ±80
(SRR-2818): 6390 ±80
(SRR-2819): 6890 ±70
(SRR-2820): 7250 ±70
(SRR-2821): 9280 ±80
0
20
40
60
80
100
120
140
160
180
200
220
240
Pinus
Betula
Ulmus
Quercus
Alnus
Corylus + Myrica
Juniperus
Calluna vulgaris
Gramineae (<40 µm)
Plantago lanceolata-type
Rumex crispus-type
Potentilla
Sphagnum
Total tree pollen
Peatland indicator species
Local Pollen Zones
RL 6
RL 5
RL 4
RL 3
RL 2
RL 1
Horizontal scale in increments of 10% of total land pollen
Fine detritus mud
Mineral mud
Laminated clays
Mud
Silty clay
+ Trace amount



Radiocarbon dates (years BP)
Sediments
Depth (cm)
Pinus
Betula
Ulmus
Quercus
Alnus
Corylus/Myrica
Juniperus
Salix
Empetrum
Calluna vulgaris
Gramineae
Plantago lanceolata-type
Narthecium
Sphagnum
Cyperaceae
Total tree pollen
Peatland indicator species
Local Pollen Zones
PT7
PT6
PT5
PT4
PT3
PT2
PT1
(SRR-3017): 1230 ±120
(SRR-3018): 4660 ±110
(SRR-3019): 4370 ±110
(SRR-3020): 3940 ±100
(SRR-3021): 7160 ±100
0
100
200
300
400
500
Horizontal scale in increments of 10% of total pollen
Peat
Trace amount

A pH curve was constructed based on the analysis of diatoms in the lake sediments. The lake was acid in the Lateglacial (pH 5.3–5.7) and the early Holocene (pH 5.3–5.9) and remained at a pH of 5.3–5.7 until about 4000 BP. This is unusual since at most sites in the British Isles an early alkaline flora was found to be replaced by more acid-loving species as soil acidification took place. Because the lake is on granite bedrock with little till, the lake and catchment initially had a low buffering capacity, and soils formed in the catchment were probably low in cations and acidified rapidly. The initial development and the subsequent expansion of peats in the catchment also had no apparent acidifying effect on the lake, the pH of which remained between 5.3 and 5.8 (Jones *et al.*, 1986).

Modern changes in the pH of the Round Loch of Glenhead are quite clear. From about AD 1840, pH started to fall with a major decline from AD 1900 to the present-day pH of 4.7 (Battarbee and Flower, 1985). Both the diatom assemblages and the range of reconstructed pH values found in the recent period are unique in the history of the lake. The recent acidification is associated with heavy-metal and soot-particle evidence for the deposition of atmospheric pollutants, and the lake lies in an area known to be affected by acid deposition (Battarbee *et al.*, 1989; Jones *et al.*, 1990). As a naturally acid lake the Round Loch of Glenhead was unable to counter the effects of industrial emissions and acidified rapidly.

The record of Holocene vegetational development at the Round Loch of Glenhead constitutes an important contribution to the regional vegetation history of the Galloway hills. Pollen profiles from the loch and catchment peats complement those obtained by Birks (1972a) from other sites in the area (see Loch Dungeon), and correlations with regional pollen assemblage zones have been made.

The Round Loch of Glenhead is also of great importance in the evaluation of the role of vegetation and soil development processes in lake acidification. The history of the site involved forest and soil development in the first half of the Holocene, widespread paludification in the second half, and recent peat erosion. Although Holocene diatoms have been studied elsewhere in Britain (e.g. Round, 1957, 1961; Haworth, 1969), previous work has not involved reconstruction of the pH of lake waters using recently developed statistical methods. In contrast, the pH of the Round Loch of Glenhead has been reconstructed for the whole of the Holocene using diatom analysis, and the site is unique in this respect. The recent acidification (from about AD 1840) associated with industrial emissions can therefore be placed in a long-term context. Significantly, no trend of increasing acidity through the Holocene has been found. This is in contrast to other sites where diatoms show evidence of a slow natural fall in pH in response to soil leaching and acidification (Round, 1957, 1961; Renberg and Hellberg, 1982). The Round Loch of Glenhead is unusual in that consistently acid conditions have prevailed throughout its entire history. Thus, despite a clear change from mineral to acid organic soils in the catchment in the middle Holocene, feedback mechanisms have operated to maintain a loch with pH stable at 5 and above for most of the Holocene.

Conclusion

Round Loch of Glenhead is important for studies of environmental change during the Holocene (the last 10,000 years). The sediments not only provide a detailed record of vegetational history, but also allow an assessment of the contribution of vegetational and soil changes to loch acidification. It has been possible from analysis of diatoms to reconstruct the pH of the loch for the whole of the Holocene, therefore enabling the environmental impact of recent industrial pollution to be placed in a wider context. Round Loch of Glenhead is therefore a key reference locality in the network of sites for Holocene environmental change.

Figure 18.8 Round Loch of Glenhead: relative pollen diagram showing selected taxa from core S18, from a peat deposit adjacent to the loch, as percentages of total pollen. Values of the herbs, Gramineae (40–49 μm), Liguliflorae, *Artemisia*, Cruciferae and *Potentilla* are expanded ×10. Peatland indicators are based on the sum of *Calluna*, *Potentilla*, *Sphagnum* and Cyperaceae (from Jones, 1987).