Quaternary of Scotland

Edited by

J. E. Gordon
Scottish Natural Heritage
Edinburgh, Scotland.

and

D. G. Sutherland
Edinburgh, Scotland.

GCR Editor: W. A. Wimbledon

JOINT NATURE CONSERVATION COMMITTEE

CHAPMAN & HALL
London · Glasgow · New York · Tokyo · Melbourne · Madras

Chapter 15

Fife and lower Tay

INTRODUCTION

D. G. Sutherland

This area includes the peninsula of Fife between the Firth of Tay and Firth of Forth, the lower Tay valley and Strathearn (Figure 15.1). The low-lying coastal areas and the lower parts of the valleys contain extensive accumulations of Late-glacial and Holocene marine deposits, the investigation of which has been the principal research theme in this area. The Fife and lower Tay area contains evidence for only one period of glaciation, that of the Late Devensian ice-sheet. It can reasonably be inferred, however, that the area was glaciated on more than one occasion and that the ice-moulded nature of most of the hills is the cumulative result of successive glaciations rather than solely the product of the last ice-sheet. Good evidence for glaciation of this region during the early Middle Pleistocene has been provided from the immediate offshore zone by Stoker and Bent (1985), and subsequent ice-sheet glaciation on at least three occasions may be inferred from evidence in neighbouring regions (Bowen *et al.*, 1986). The only feature that is known from the region to pre-date the last ice-sheet is the rock platform at, or close to, present sea level which can be followed around much of the coast of eastern Fife. This platform and its associated cliffline are overlain in places by glacial deposits and they have been presumed to be interglacial in origin (Sissons, 1967a).

Ice-moulded landforms and striated rock surfaces indicate that during the last ice-sheet glaciation, ice from the western Highlands moved into the region from the north-west (Geikie, 1900, 1902; Forsyth and Chisholm, 1977; Armstrong *et al.*, 1985). As the glaciation proceeded, the western part of the region continued to be affected by ice flowing from that direction, but to the east there was latterly a change to an easterly or even north-easterly movement. The transport of erratics and the general colour and composition of the till are in accord with these ice movements.

The most notable glacial deposits and landforms were produced during the period of ice-sheet retreat when extensive areas of sand and gravel were laid down and there was a widespread marine invasion of the lower ground around the coasts. Major accumulations of glaciofluvial sediments were deposited in the Wormit Gap, the northern Howe of Fife, near Barry in Angus and west of Loch Leven, these being areas that were topographically suitable for the isolation of 'dead'-ice masses and the concentration of melt-water drainage (Rice, 1961, 1962; Chisholm, 1966; Cullingford, 1972; Browne, 1977; Paterson, 1977; Armstrong *et al.*, 1975, 1985).

Certain of these areas of 'dead' ice terminated in the sea which during deglaciation attained altitudes of between 30 m and 40 m OD around the coasts. The marine deposits from this period are typically red, laminated clays, the Errol beds (see Inchcoonans and Gallowflat) that contain a high-arctic faunal assemblage (Brown, 1867; Geikie, 1902; Davidson, 1932; Peacock, 1975c; Paterson *et al.*, 1981). These are found around all the coasts of the region and also within the Howe of Fife into which the sea penetrated at the time of deglaciation. The surface morphology of the marine sediments consists of a series of distinct terraces, which have been mapped and levelled by Cullingford (1972, 1977), Cullingford and Smith (1966, 1980) and Sissons and Smith (1965a). These studies have demonstrated that a succession of easterly sloping shorelines was formed progressively as the ice retreated to the west, each shoreline having a lower gradient than its predecessor. The 'staircase' of shorelines around Kincraig Point (Geikie, 1902; Smith, 1965) probably formed at this time.

The shoreline sequence and the associated marine and estuarine clays are as yet undated. However, the progressive change in gradient of the shorelines (a consequence of isostatic uplift) allows approximate ages to be extrapolated from the known ages of younger and lower-gradient shorelines (Andrews and Dugdale, 1970). Such a calculation suggests that eastern Fife was deglaciated prior to 15,500 BP and the remainder of the region became ice-free during the ensuing 2000 years (Sutherland, 1991a).

Only a limited number of sites (as at Creich Castle (Cundill and Whittington, 1983) and Black Loch (Whittington *et al.*, 1991a) have been investigated for Lateglacial pollen in order to provide evidence of terrestrial environmental change following deglaciation. The marine record makes it clear that deglaciation occurred when the climate was still very cold, but no pollen evidence has been reported which accords with such conditions. This implies that either the sites investigated to date were locations of 'dead'-ice masses that did not melt until the climate ameliorated or that there was insufficient vegetation to provide enough identifiable contem-

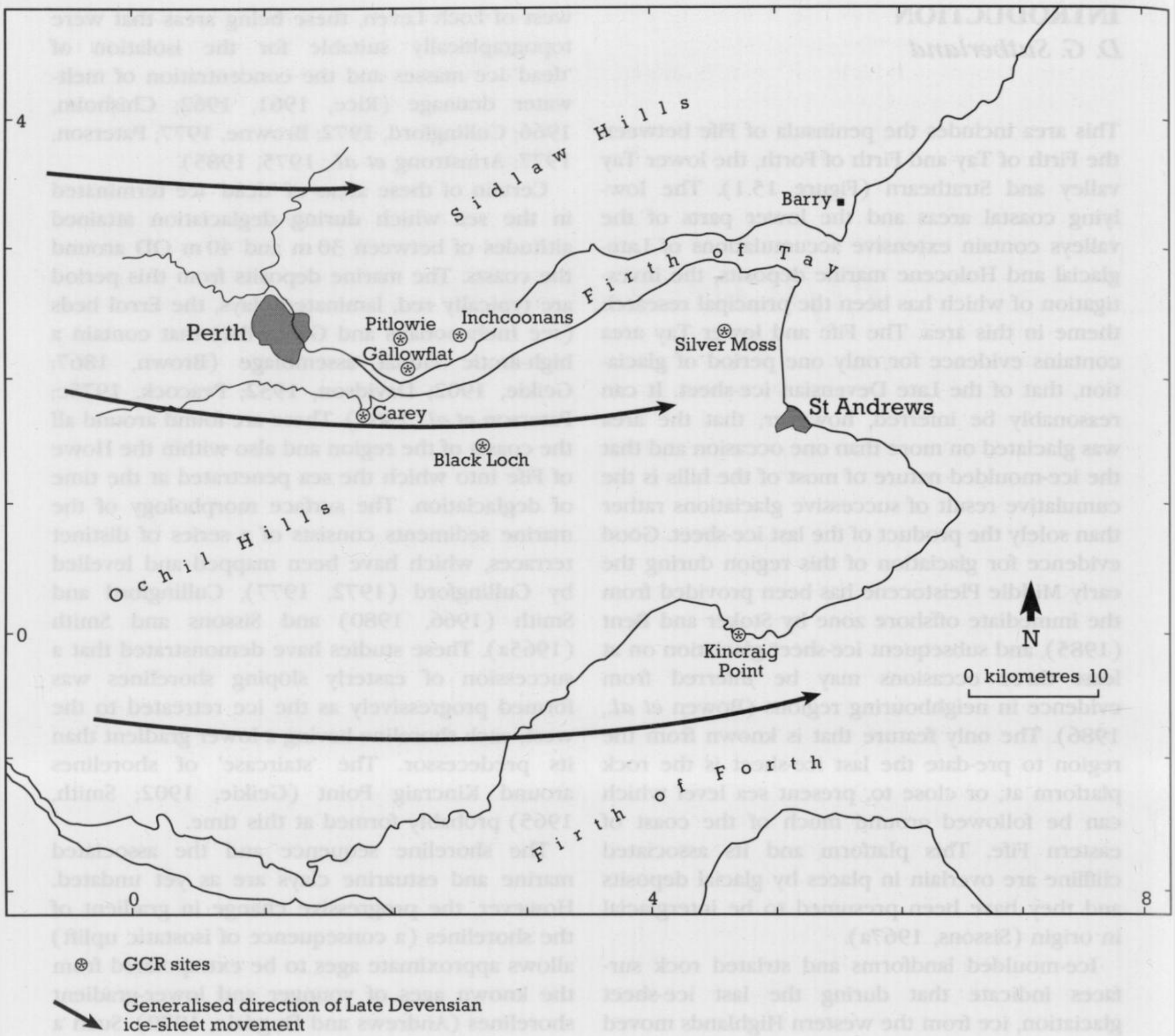


Figure 15.1 Location map of the Fife and the Lower Tay area.

poraneous pollen, given the apparently high background of derived or long-distance transported pollen grains (Cundill and Whittington, 1983).

During the Lateglacial Interstadial an open grass–herb vegetation was dominant, with a lower representation of woody taxa, such as birch, than in the neighbouring regions.

Sea level fell during the early part of the interstadial, and throughout the region in the latter part of the Lateglacial it was below the level subsequently attained during the Holocene. There has been some disagreement as to the exact course of sea-level change during the Lateglacial and, in particular, over the age of a widespread marine erosional episode, evidence for which is found at or below present sea level (Sissons and Rhind, 1970; Browne and Jarvis, 1983). Sissons (1969, 1974d, 1976a) first identified this period of Lateglacial marine erosion (the landward margin of which he termed the Main Lateglacial Shoreline) on the southern side of the Forth valley and Firth of Forth, and Cullingford (1972) suggested correlation with gravel horizons in the Tay and Earn valleys. It was argued by Sissons (1974d, 1976a) that the erosion of this feature occurred during the latter part of the Lateglacial and was promoted by the severe climate of this period. The Main Lateglacial Shoreline is tilted to the south-east at a gradient of 0.17 m km^{-1}.

Paterson *et al.* (1981) and Armstrong *et al.* (1985) have discussed erosional features in the Tay and Earn area which they have correlated with the Main Lateglacial Shoreline. However, they suggested that these features formed during the early part of the Lateglacial when sea level was falling from the Main Perth Shoreline. They further suggested that during the latter part of the Lateglacial, sea level was particularly low resulting in the erosion of deep channels along the Tay estuary (see also Buller and McManus, 1971; McManus, 1972). It may be noted with respect to the correlations proposed by Paterson *et al.* (1981) that they provide no mechanism for an erosional event in the early Lateglacial in areas that are otherwise characterized by fine-grained sedimentation throughout the Lateglacial and Holocene. Browne and Jarvis (1983) have reported marine erosional features in St Andrews Bay. They correlated a surface cut across glacial and glaciomarine (Errol beds) sediments with the erosional surface identified by Sissons (1969, 1976a), but suggested that a bedrock surface at approximately the same altitude could have been inherited from an early phase of marine erosion prior to the Devensian. A further erosional surface cut across glacial and glaciomarine sediments at Buddon Ness, but overlain by Holocene deposits, has been described by Paterson (1981).

Sea-level changes during the early and middle Holocene are more clearly understood and are particularly well documented in this region. The sites at Carey (Cullingford *et al.*, 1980) and Silver Moss (Chisholm, 1971; Morrison *et al.*, 1981) provide details of the early Holocene changes, including the Main Postglacial Transgression, and the site at Pitlowie (Smith *et al.*, 1985b) has been the focus of the most detailed study in Scotland to date of the minor changes in sea level at the time of the maximum of that transgression, when the Main Postglacial Shoreline was formed. These various sites show that at the beginning of the Holocene, sea level was about 3 m OD in the lower Earn valley but that it progressively fell, reaching a low, probably below present sea level, at around 8000 BP. Subsequently there was a rapid rise in sea level culminating at around 6100 BP at Pitlowie, and at prior to 5900 BP at Silver Moss. The Silver Moss site also contains evidence of a brief marine invasion of the coastal zone at around 7000 BP (Morrison *et al.*, 1981). This event (described above – see Maryton) has been observed at sites throughout the east coast of Scotland (Smith *et al.*, 1985a; Dawson *et al.*, 1988; Haggart, 1988b; Long *et al.*, 1989a).

The Main Postglacial Shoreline formed at the maximum of the transgression has been shown to be isostatically tilted towards the south-east at a gradient of approximately 0.08 m km^{-1} (Sissons, 1983a). During the subsequent fall of sea level to the present level, lower shorelines were formed (Cullingford, 1972) but these are not well dated.

Holocene terrestrial environmental change has been studied in considerable detail at Black Loch. This site provides evidence of early and middle Holocene forest expansion and development, but it is particularly notable for the detail of the late Holocene changes in vegetation consequent upon Man's impact from the Neolithic onwards.

INCHCOONANS AND GALLOWFLAT

D. G. Sutherland

Highlights

Inchcoonans and Gallowflat are important reference sites for the Errol beds, a sequence of fossiliferous estuarine sediments deposited largely in eastern Scotland as the Late Devensian ice-sheet melted. They provide important evidence for the high-arctic nature of the marine environment during the early part of the Lateglacial.

Introduction

The sites at Inchcoonans (NO 242233) and Gallowflat (NO 211202) are located, respectively, 1 km north-west and 4.5 km south-west of Errol, between Perth and Dundee. Both occur in an area of fossiliferous Late Devensian raised estuarine deposits (Errol beds). Inchcoonans comprises a small area of undisturbed deposit adjacent to a former claypit (now infilled) which provided the type sequence for these deposits; Gallowflat is a working claypit, where the sediments are exposed.

A broad twofold subdivision of the marine and estuarine sands, silts and clays that were laid down around the Scottish coasts during Late Devensian ice-sheet retreat and in the Lateglacial period has long been recognized; between those deposits containing a restricted high-arctic fauna and those containing a much more diverse boreal to arctic fauna (Jamieson, 1865; Brady *et al.*, 1874; Robertson, 1875). This subdivision has been noted to correspond, in general, to the geographical distribution of the deposits, those on the east coast being predominantly high arctic in character and those on the west being predominantly boreal to arctic (Robertson, 1875; Anderson, 1948; Sissons, 1965). Peacock (1975c) proposed the informal terms Errol beds and Clyde beds to apply, respectively, to the high-arctic and the boreal-to-arctic deposits, this terminology reflecting the locations where the different deposits had been first described in detail. The Inchcoonans and Gallowflat area, by Errol to the north of the Tay estuary, is therefore the principal reference area of the high-arctic deposits.

At the western end of the Carse of Gowrie on the north of the Tay estuary the surface of an area of higher ground is mantled by Late Devensian estuarine clays. The clays extend to altitudes of approximately 30 m OD and their surface forms a series of terraces, the lowest of which is below 12 m OD. The western, southern and eastern sides of this higher ground are flanked by Holocene estuarine deposits. A number of claypits excavated in the upper deposits resulted in the discovery during the last century of marine fossils of species indicative of very cold conditions when the clays were deposited (Jamieson, 1865; Brown, 1867; Brady *et al.*, 1874). The most detailed studies were carried out in the Inchcoonans claypit (now infilled) by Davidson (1932), whose work has in recent years been verified and amplified by Paterson *et al.* (1981) and Graham and Gregory (1981). The deposits at Gallowflat have been described by McManus (1972), MacGregor (1973) and Duck (1990). In addition, the raised shorelines contemporaneous with deposition of the marine clays have been studied in detail by Cullingford (1972, 1977). A summary of the current understanding of these deposits is given in Armstrong *et al.* (1985).

Description

The first systematic description of the stratigraphy of the Inchcoonans claypit was given by Davidson (1932). He identified three principal units:

3.	Yellowish-brown, sandy clay	2.5–3.0 m
2.	Fine, blue clay, coarsening upwards	1.5–2.1 m
1.	Fine, red clay	over 1.2 m

Pebbles, cobbles and even boulders were scattered throughout the deposits, the surface of which was at about 12 m OD. More recent investigations have added detail to this outline, and Paterson *et al.* (1981) determined the following sequence (Figure 15.2):

5.	Yellowish-grey sandy clay	
	erosion surface	1.0–1.75 m
4.	Yellowish-grey silty clay	1.25–2.9 m
3.	Brownish-grey clay	0.9–1.5 m
2.	Reddish brown clay	1.3 m
1.	Sand and gravel	

The main difference from Davidson's section was the recognition of an erosion surface formed during the deposition of the upper yellowish-grey sediments. In a neighbouring borehole (Figure 15.2) clayey gravels were encountered within beds 3 and 4. These were considered to be due to slumping from a mound of submerged glaciofluvial sand and gravel (Paterson *et al.*, 1981) or deposited from an iceberg (Armstrong *et al.*, 1985). The change in colour during the period of deposition of the clays was thought to relate to the retreat of the ice-sheet towards the west: the reddish clays at the base reflected derivation from local Old Red Sandstone, whereas the upper yellowish clays received their colour from material principally derived from Highland rock types.

The fauna described by Davidson (1932; Graham and Gregory, 1981) came principally from beds 3 and 4. The molluscan fauna consisted of the gastropods *Buccinum groenlandicum* (Chemnitz) and *Lunatia pallida*? (Broderip and Sowerby) and the bivalves *Astarte borealis* (Schumacher), *Hiatella arctica* (L.), *Macoma calcarea* (Chemnitz), *Musculus laevigatus* (Gray), *Musculus niger* (Gray), *Palliolum groenlandicum* (Sowerby) (=*Arctinula greenlandica*), *Portlandia arctica* (Gray), and *Thracia* cf. *septentrionalis* (Jeffreys). Although some of these species have wide geographical ranges, others, such as *Portlandia arctica* and *Palliolum groenlandicum* are strongly indicative of high-arctic conditions. Certain of the ostracods recovered are similarly indicative, for example, *Krithe glacialis* (Brady, Crosskey and Robertson), *Rabimilis mirabilis* (Brady) and *Cytheropteron montrosiense* (Brady, Crosskey and Robertson). Other macrofossils recovered include bones of the common seal, *Phoca vitulina* L.

The reinvestigation of the site allowed a correlation to be established between the stratigraphy and the microfaunal distribution. The lowest marine deposits (bed 2) are characterized

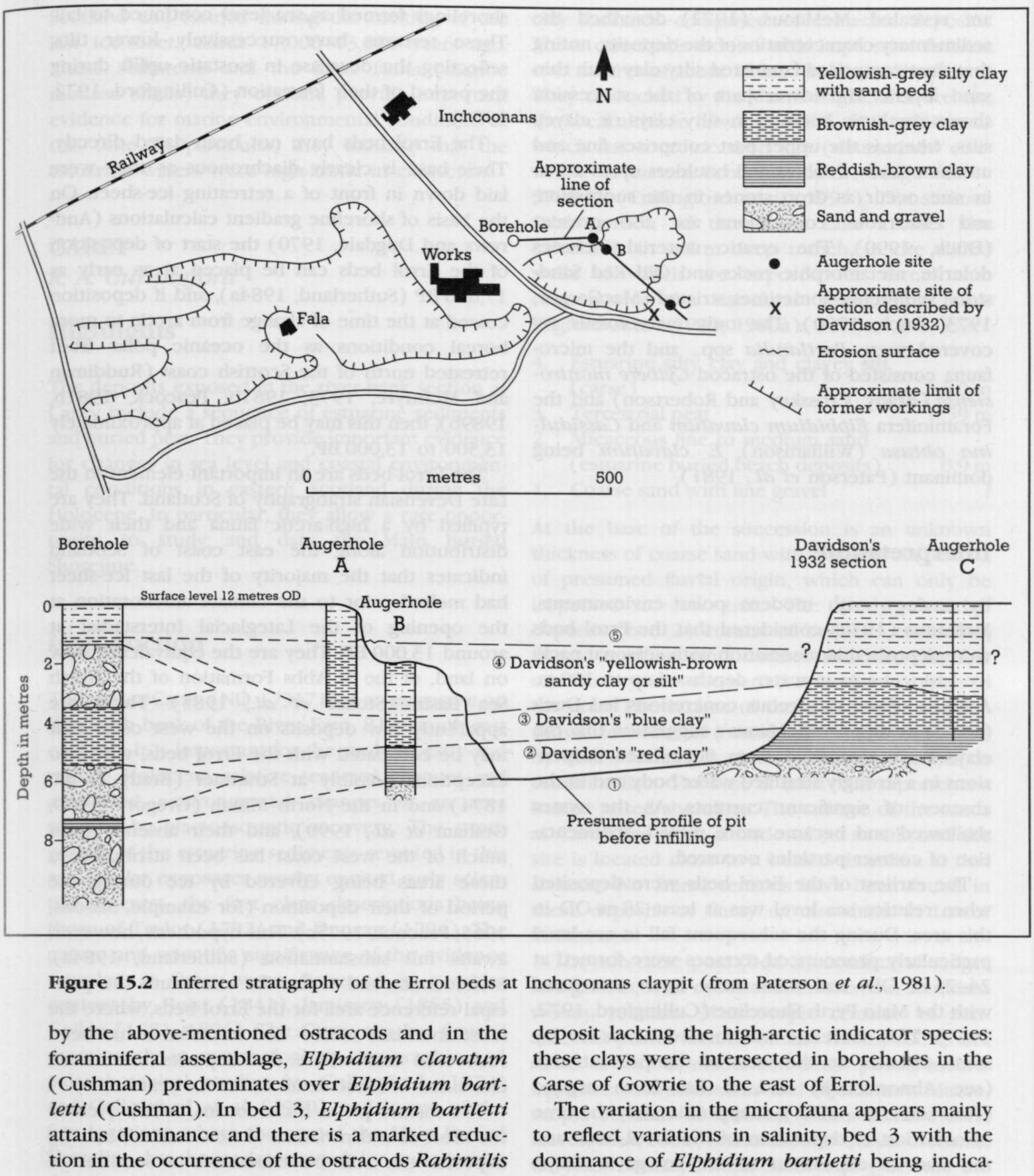


Figure 15.2 Inferred stratigraphy of the Errol beds at Inchcoonans claypit (from Paterson *et al.*, 1981).

by the above-mentioned ostracods and in the foraminiferal assemblage, *Elphidium clavatum* (Cushman) predominates over *Elphidium bartletti* (Cushman). In bed 3, *Elphidium bartletti* attains dominance and there is a marked reduction in the occurrence of the ostracods *Rabimilis mirabilis* and *Cytheropteron arcuatum* (Brady, Crosskey and Robertson). *Krithe glacialis* disappears in bed 4, and *Elphidium clavatum* regains dominance in the foraminiferal assemblage. Bed 5 was barren of both micro- and macrofauna. Paterson *et al.* (1981) have suggested that it is not part of the Errol beds but should be correlated with the Powgavie Clays, a later deposit lacking the high-arctic indicator species: these clays were intersected in boreholes in the Carse of Gowrie to the east of Errol.

The variation in the microfauna appears mainly to reflect variations in salinity, bed 3 with the dominance of *Elphidium bartletti* being indicative of more fully marine conditions than either beds 2 or 4. The reduced salinity of bed 2 may be due to meltwater influx from the retreating ice-sheet, whereas bed 4 may have been deposited in shallower water as sea level fell consequent upon isostatic uplift.

At the Gallowflat claypit (surface altitude about 25 m OD), deposits similar to those at Inchcoonans are revealed. McManus (1972) described the sedimentary characteristics of the deposits, noting that they comprised laminated silty clay with thin sand layers. The lower part of the succession shows rhythmic bedding in silty clays or clayey silts, whereas the upper part comprises fine and medium sands. Pebbles and boulders up to 1.3 m in size occur as drop stones in the succession, and calcareous concretions are also present (Duck, 1990). The erratic material includes dolerite, metamorphic rocks and Old Red Sandstone sediments, sometimes striated (MacGregor, 1973; Duck, 1990). The only macrofossils recovered were *Portlandia* spp., and the microfauna consisted of the ostracod *Cythere montrosiense* (Brady, Crosskey and Robertson) and the Foraminifera *Elphidium clavatum* and *Cassidulina obtusa* (Williamson), *E. clavatum* being dominant (Paterson *et al.*, 1981).

Interpretation

By analogy with modern polar environments, McManus (1972) considered that the Errol beds were deposited in association with seasonal pack-ice and icebergs in water depths of up to 100 m. Analysis of the calcareous concretions led Duck (1990) to support McManus's suggestion that the clays were deposited from flocculated suspensions in a strongly stratified water body and in the absence of significant currents. As the water shallowed and became more mixed, sedimentation of coarser particles occurred.

The earliest of the Errol beds were deposited when relative sea level was at least 28 m OD in this area. During the subsequent fall in sea level particularly pronounced terraces were formed at 24–25 m OD, and these have been correlated with the Main Perth Shoreline (Cullingford, 1972, 1977). This shoreline was formed when ice lay some distance to the west of the present area (see Almondbank) and, it has been argued (Paterson *et al.*, 1981), at approximately the time of cessation of deposition of the Errol beds and the start of deposition of the Powgavie Clays, with their fauna indicative of a milder climate. The shoreline has been traced widely along the coasts of east-central Scotland (Sissons *et al.*, 1966; Smith *et al.*, 1969) and has a marked tilt to the south-east of $0.43\ \mathrm{m\ km^{-1}}$ resulting from isostatic uplift subsequent to the formation of the shoreline. The lower terraces in the Inchcoonans and Gallowflat area have been correlated with shorelines formed as sea level continued to fall. These terraces have successively lower tilts, reflecting the decrease in isostatic uplift during the period of their formation (Cullingford, 1972, 1977).

The Errol beds have not been dated directly. Their base is clearly diachronous as they were laid down in front of a retreating ice-sheet. On the basis of shoreline gradient calculations (Andrews and Dugdale, 1970) the start of deposition of the Errol beds can be placed at as early as 17,000 BP (Sutherland, 1984a), and if deposition ceased at the time of change from arctic to more boreal conditions as the oceanic polar front retreated north of the Scottish coast (Ruddiman and McIntyre, 1973, 1981b; Peacock, 1981b, 1989b), then this may be placed at approximately 13,500 to 13,000 BP.

The Errol beds are an important element in the Late Devensian stratigraphy of Scotland. They are typified by a high-arctic fauna and their wide distribution along the east coast of Scotland indicates that the majority of the last ice-sheet had melted prior to the climate amelioration at the opening of the Lateglacial Interstadial at around 13,000 BP. They are the equivalents, now on land, of the St Abbs Formation of the North Sea Basin (Stoker *et al.*, 1985). There are apparently few deposits on the west coast that may be correlated with the Errol beds, with two exceptions possibly at Stranraer (Brady *et al.*, 1874) and in the North Minch (Gregory, 1980; Graham *et al.*, 1990), and their absence from much of the west coast has been attributed to these areas being covered by ice during the period of their deposition (for example, Sissons, 1965; Peacock, 1975c). This hypothesis, however, awaits full substantiation (Sutherland, 1984a). Inchcoonans and Gallowflat constitute the principal reference area for the Errol beds, where the most abundant macro- and microfauna has been recovered and where the deposits have been examined in most detail in recent years.

The former pit at Inchcoonans, which yielded the most abundant faunas is now infilled, but the deposits can still be examined in sections at Gallowflat claypit.

Conclusion

Inchcoonans and Gallowflat are reference localities for a sequence of fossiliferous estuarine deposits (Errol beds) restricted almost entirely to eastern

Scotland and formed during the melting of the last ice-sheet, about 17,000–13,000 years ago. These sediments and the fossil fauna (marine mollusc shells) they contain, provide important evidence for marine environmental conditions at this time. In particular, they indicate that the estuarine waters were high-arctic in character.

CAREY

R. A. Cullingford

Highlights

The deposits exposed in the river-bank section at Carey include a sequence of estuarine sediments and buried peat. They provide important evidence for changes in sea level and coastal environmental conditions in eastern Scotland during the Holocene. In particular, they allow a rare opportunity to study and date the Main Buried Shoreline.

Introduction

The site at Carey (NO 173171) is an exposure on the south bank of the River Earn, 8 km south-east of Perth. It is important for the study of early and middle Holocene relative sea-level changes and associated environmental changes in an area affected by glacio-isostatic recovery. The stratigraphy of the estuarine sediments revealed in this and similar exposures nearby excited early scientific interest, the first clear descriptions being those of Taylor (1792) and Duncan (1794). The nature and scientific significance of the evidence revealed at Carey were discussed in a wider context by Buist (1841), Jamieson (1865) and Geikie (1881, 1894). The Carey site has figured prominently in morphological, stratigraphic and palaeobotanical studies by Cullingford (1972) and Cullingford *et al.* (1980), and is one of the few locations where the age of the Main Buried Shoreline has been determined by radiocarbon dating.

Description

Although in its broader Scots usage the term 'carse' denotes an alluvial flat or river floodplain, it has also long been applied more specifically to clay flat-lands composed of estuarine deposits. These carselands extend with impressive flatness over an area of about 18 km^2 in Lower Strathearn. They are backed by the Main Postglacial Shoreline, the local altitude of which is 9.8–10.2 m OD, and which has a radiocarbon age (determined elsewhere in eastern Scotland) in the range 6800–5700 BP (Cullingford *et al.*, 1991). The sinuous tidal portion of the River Earn crosses the carselands in a 6 m deep trench, in the cliffed walls of which are exposed the three main elements of the carseland stratigraphy (Cullingford *et al.*, 1980, 1989a):

4.	Estuarine silty clay and clayey silt (carse)	>6.0 m
3.	Terrestrial peat	0.59 m
2.	Micaceous fine to medium sand (estuarine buried beach deposits)	0.9 m
1.	Coarse sand with fine gravel	?

At the base of the succession is an unknown thickness of coarse sand with fine gravel (bed 1), of presumed fluvial origin, which can only be inspected at low tide. The sandy estuarine deposits (bed 2) consist of bedded, micaceous, fine to medium sand, coarser than the silty fine sand that typifies the buried estuarine materials in the area. The surface of these deposits has been shown to occur as a series of terraces, separated by bluffs, forming a series of buried beaches or estuarine flats. The base of each bluff represents a buried raised shoreline. The surface of the sands at Carey lies at an altitude of 3.2 m OD and the site is located close to a buried shoreline at that altitude. No faunal remains have been found in these deposits at Carey or elsewhere in Lower Strathearn.

The sub-carse peat (bed 3) consists of sedges and grasses, with occasional mosses and abundant woody remains. Macroscopic remains of non-arboreal plants include stems, leaves, roots, and seeds of various marsh and heath plants, including *Carex*, *Sarothamnus* and *Equisetum*. Macroscopic remains of arboreal plants include bark, leaves, fruit, roots, branches, and trunks of *Alnus*, *Corylus*, *Betula*, *Pinus*, *Salix* and *Quercus*, the first three being of most common occurrence, and the last rarest. The peat is highly compressed, as shown by its toughness and by the oval cross-sections of flat-lying branches and twigs, and it 'readily splits into laminae, on the surface of which many small seeds . . . appear, together with occasional wing cases of beetles' (Geikie, 1894, p. 292). The transition with the overlying carse

Table 15.1 Radiocarbon dates on the buried peat layer at Carey

Sample	Altitude OD (m)	Date (^{14}C years BP)	Laboratory number
Bottom 0.01 m of peat	3.19	9640 ± 140	I–2796
Bottom 0.04 m of peat	3.19	9524 ± 67	SRR–72
Top 0.01 m of peat	3.78	7605 ± 180	NPL–127
Top 0.04 m of peat	3.78	7778 ± 55	SRR–71

deposits is gradual, the top few centimetres of peat being silty, and the basal 0.3–0.5 m of silts and clays being heavily charged with both horizontal black streaks of vegetal material and plant stems passing vertically upwards from the peat. The base of the peat is more sharply defined, but roots penetrate from it into the sands below. The thin (0.005–0.05 m) iron pan between the peat and underlying sands is a highly localized consequence of concentrated groundwater flow in the immediate vicinity of the river cliff, for more than 250 boreholes sunk throughout the Lower Strathearn carselands show it to be generally absent. Cullingford *et al.* (1980) obtained radiocarbon dates from the top and bottom of the peat bed (Table 15.1).

The estuarine clays (bed 4) are bluish-grey when freshly dug, but quickly turn brown on exposure to the air. There is, in general, no distinct stratification, and stones are absent except occasionally near the rising ground at the edge of the carselands. There are occasional thin layers and lenses of sand. Plant remains, chiefly of reeds, are common throughout the deposit and are often fetid. No shells of estuarine molluscs have been recorded in the carse deposits of Lower Strathearn, though they occur in the Carse of Gowrie, where a sparse estuarine microfauna has also been identified (Paterson *et al.*, 1981).

Detailed pollen and diatom analyses have been carried out at Carey by P. Gotts (unpublished data). The pollen record established by analysis of samples at 0.01–0.02 m intervals throughout the peat and the upper 0.07 m and lower 0.06 m of underlying and overlying estuarine sediments predominantly reflects local vegetation changes, but does also have regional indicators. High values for Gramineae occur in the lower peat coincident with the macroscopic remains of *Phragmites*, accompanied by even higher values for Cyperaceae, thus representing a typical reed-swamp environment. Grass pollen is dominant throughout most of the peat, with very few other herb taxa represented. At the lower transition there are continuous curves for Cruciferae and *Filipendula* and occasional grains of aquatics, such as *Alisma*, *Lemna* and *Equisetum*, but very little unequivocal evidence of vegetation succession from saltwater to freshwater environments. At the upper transition to the carse silts and clays there is more evidence for the rising water table with a peak for *Typha latifolia*, but overall there is the same lack of variety in taxa indicative of changing hydroseral communities. At the peat/sand transition, dated to 9640 ± 140 BP (I–2796), there is a peak in *Betula*, with continuous curves for *Juniperus* and *Salix*. This slightly late date for the presence of juniper suggests that in the birch woodland which characterized eastern Scotland in the early Holocene, juniper was able to survive in marginal environments, as at Carey. With the immigration of hazel, demonstrated in almost all pollen diagrams in Scotland as a significant rise in *Corylus/Myrica* pollen, juniper disappears. This is dated to 8740 ± 55 BP (SRR–1392), which agrees well with other dates for this event (Huntley and Birks, 1983). Locally, close to the peat, hazel would have taken advantage of the marginal drier environment, with the occasional presence of birch and *Salix* on the slightly wetter margins. Elements of mixed oak forest are only represented to any extent in the peat/silt–clay transition and in the carse clay itself. It seems likely that oak woodland would have been present in Strathearn before 7600 BP, and the pollen record probably represents the local exclusion of pollen of mixed oak forest provenance by the surrounding hazel. With the change in sedimentary environment this pollen was then brought to Carey in the estuarine clays.

The diatom assemblage of the basal 0.12 m of carse clays and silts is dominated by several species of *Fragilaria*, averaging over 70% of the total count (1000 valves). Diatoms are abundant only within and above the peat/silt–clay transition, and the micaceous sand deposits contain only small numbers, which include both marine and brackish-water taxa.

Interpretation

It may be inferred from the sedimentary and palaeobotanical information above that the abandonment of the buried beach deposits by the sea was followed without a significant break by the colonization of their surface by terrestrial vegetation, which eventually took the form of a peat bog. The top of the peat in turn represents a former land surface that was gradually inundated by rising estuarine waters in which the silt and clay deposits accumulated.

The base of the peat (altitude 3.2 m OD) at two locations along the Carey exposure has been radiocarbon dated at 9640 ± 140 BP (I–2796) and 9524 ± 67 BP (SRR–72) (Cullingford *et al.*, 1980), giving the approximate date of initiation of peat growth following the withdrawal of the sea. As the Carey exposure is located close to the buried shoreline (altitude 3.2 m OD), the radiocarbon dates must relate closely to the abandonment of the latter. The buried shoreline is believed to correlate with the Main Buried Shoreline of the Forth Valley, which has been similarly dated at about 9600 BP (Sissons, 1983a). The top of the peat at Carey (present altitude 3.8 m OD) gave radiocarbon ages of 7605 ± 180 BP (NPL–127) and 7778 ± 55 BP (SRR–71), dating the onset of peat burial beneath the silt and clay. Use of peat-top dates in constructing a relative sea-level curve requires account to be taken of the peat compaction that accompanied and followed burial by the carse deposits, and a method for estimating compaction was employed at Carey and other sites in Lower Strathearn (Cullingford *et al.*, 1980).

A recently published account of a site nearby at Wester Rhynd (Cullingford *et al.*, 1989a) has further enhanced the importance of Lower Strathearn for sea-level studies in eastern Scotland. The results have suggested 8765 ± 75 BP (GU–1250) as an approximate date for the abandonment of the local equivalent of the Low Buried Beach of the Forth Valley, and have also demonstrated the presence of two brief marine incursions shortly after 8565 + 85 BP (GU–1518) and between 8485 ± 80 BP (GU–1517) and 8510 ± 85 BP (GU–1516), which are consistent with storm surge or tsunami events (Cullingford *et al.*, 1989a). The latter are earlier than the widely recognized event at about 7000 BP in eastern Scotland (Smith *et al.*, 1985a; Dawson *et al.*, 1988; Haggart, 1988b; Long *et al.*, 1989a) and raise the possibility that the record of high-magnitude events is more detailed than previously recognized. Dawson *et al.* (1989) suggested that the 7000 BP event might be represented by a layer of fine silty sand at the base of the carse deposits at Wester Rhynd, but Cullingford *et al.* (1989b) argued that this layer was of very limited extent and that the 7000 BP event might be represented by a sand layer higher in the carse deposits in the Carse of Gowrie on the north side of the Tay Estuary. Further work in Lower Strathearn and the Carse of Gowrie should help to clarify the sequence and depositional environments of these high-magnitude events.

Lower Strathearn is important for studies of relative sea-level change in eastern Scotland, and evidence from the area, including Carey, has allowed the construction of relative sea-level and uplift curves for the Lateglacial and early Holocene (Cullingford *et al.*, 1980; Paterson *et al.*, 1981).

A Lateglacial and early Holocene phase of generally falling relative sea level was punctuated by stillstands and/or transgressive episodes resulting in the formation of now buried estuarine flats (buried beaches) in descending order of age and altitude, the abandonment of the flats being followed by the growth of vegetation, including peat. Later, relative sea level rose again, causing the progressive burial of successive peat-covered flats by the carse deposits, and culminating in the formation of the extensive carseland surface visible today (see also Western Forth Valley). The Carey exposure has afforded vital evidence in dating and elucidating the nature of the environmental changes that accompanied these relative sea-level changes, and is still the only known site in eastern Scotland where exposure of the peat-covered Main Buried Beach deposits occurs close to the former shoreline, allowing accurate dating of the latter. With its thick sub-carse peat and clearly displayed sequence, the Carey site is of great value for demonstration purposes, and it is likely that, with improved analytical techniques in the future, it will have an important research role to play in the further study of Holocene relative sea-level changes.

Conclusion

The sediments at Carey provide important evidence for interpreting the sequence of sea-level changes that occurred during Holocene times (the last 10,000 years) in eastern Scotland. In particular, it allows a rare opportunity for dating the early Holocene Main Buried Shoreline (about 9600 years ago). In addition, subsequent changes in the coastal environment during the middle Holocene have been revealed by detailed pollen, diatom and sediment analyses. Carey is therefore an integral component of the network of reference sites for sea-level history.

SILVER MOSS
D. E. Smith

Highlights

The sub-surface deposits at Silver Moss include a sequence of estuarine and buried peat sediments which provide a detailed and dated record of sea-level and coastal changes during the Holocene. They are particularly significant for studying the Main Postglacial Transgression and a major coastal flood which occurred in eastern Scotland during the middle Holocene.

Introduction

Silver Moss (NO 450233) is a small peat bog in St Michael's Wood, 8 km north of St Andrews, in Fife. It occupies a gully which once formed a narrow embayment in the coastline when relative sea level stood at the Main Postglacial Shoreline in that area. Silver Moss contains a sequence of deposits which record the culmination of the Main Postglacial Transgression, together with a unique coastal flood, possibly a storm surge or tsunami. The site was first investigated by Chisholm (1971), and later studied by Morrison *et al.* (1981).

Description

In East Fife, the lower ends of the valleys of the Motray Water, Moonzie Burn and River Eden are occupied by extensive areas of raised estuarine sediments, which extend northwards towards the Tay estuary and southwards towards St Andrews, and which continue beneath coastal sand dunes to the east. These sediments, the local equivalent of the carse of central Scotland, consist of grey silty clay or clayey silt with lenses of sand. They underlie a remarkably flat surface which contrasts sharply with the rising ground inland. From the fossil content of these sediments (Chisholm, 1971) it is evident that they accumulated in a marine/estuarine environment. The break of slope at their inland limit is taken to mark a shoreline, which lies between 7 m and 9 m OD (Cullingford, 1972).

Towards the northern region of this carse area, near Craigie (NO 453243), the rising ground inland consists of Late Devensian raised beaches which are dissected by a number of gullies leading eastwards. These gullies reach the edge of the carse, and in the lower ends of some of them small peat bogs occur. The largest of these is Silver Moss, which lies in a gully draining through St Michael's Wood. From boreholes made near the mouth of the gully, Chisholm (1971) showed that the raised estuarine (carse) sediments to the east of the gully mouth continued into it to form a layer within the peat (Figure 15.3). He noted that east of the gully mouth the carse sediments include a sand layer, which appears at the base of the carse within the gully. He also identified a sand bar at the mouth of the gully (Figure 15.3), which appears to have formed contemporaneously with the carse deposit when the gully was an arm of the sea. Chisholm obtained radiocarbon dates on two 6 in. (0.15 m) thick samples of peat: the upper sample (above the clays and silts) gave 5830 ± 110 BP (St–3062) and the lower sample (below the sand at the base of the clays and silts), 7605 ± 130 BP (St–3063). He concluded that the clastic sediments in Silver Moss had accumulated between those dates, but did not exclude the possibility that the clays and silts east of the gully mouth and sand bar may have continued to accumulate for some time after the younger date.

Morrison *et al.* (1981) later undertook further stratigraphical investigations of Silver Moss. They were able to trace the inland limit of the clays and silts, which form a tapering wedge within the peat (Figure 15.3). They also proved the extent of the sand, which they described as a grey, micaceous, silty fine sand. They found that it occurs within the clays and silts east of the gully but forms a separate, tapering wedge below the clays and silts within Silver Moss (Figure 15.3). Within the peat the sand extends over 250 m farther up the gully than does the wedge of clays and silts, eventually reaching a higher elevation than the latter (Figure 15.3).

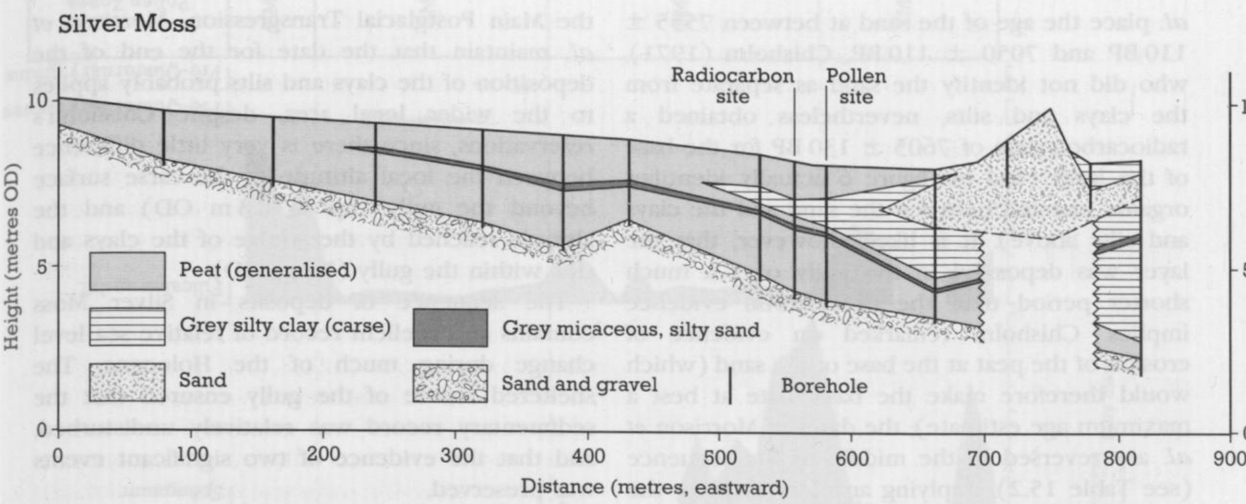


Figure 15.3 Silver Moss: section along the gully showing the sequence of sediments (from Morrison *et al.*, 1981).

Morrison *et al.* carried out pollen analysis through the sequence of deposits and also obtained further radiocarbon dates. From the pollen evidence, they found that peat had begun to accumulate in the early Holocene. The pollen sequences identified (Figure 15.4) were found to be similar to those of other Holocene coastal sites in eastern Scotland (Smith *et al.*, 1982, 1983). The gradual changes in the pollen record suggest that no breaks in sedimentation are present. High values of *Pinus* and *Quercus* pollen coincide with the wedge of clays and silts (Figure 15.4). Such increases, however, are common in marine sediments (Traverse and Ginsberg, 1966), and the presence of Chenopodiaceae in this layer is characteristic of a marine environment. However, Morrison *et al.* could find no changes in the pollen spectrum based on samples from the grey, micaceous, silty fine sand layer. The radiocarbon dates obtained by Morrison *et al.* (1981) are listed in Table 15.2.

Interpretation

The gully in which Silver Moss lies had probably been formed before the early Holocene, when the peat began to accumulate. It seems possible that the gully may have been cut during the Late Devensian under periglacial conditions, in a similar manner to other gullies in raised marine deposits in central Scotland (Sissons *et al.*, 1965). As the peat of Silver Moss accumulated, the lower end of the gully became inundated by a marine transgression, and a sand bar began to form at its mouth. During this time, the prominent layer of grey, micaceous, silty fine sand was deposited.

The radiocarbon dates obtained by Morrison *et*

Table 15.2 Radiocarbon dates at Silver Moss (from Morrison *et al.*, 1981)

Sample	Altitude (m) OD (surface = 8.30 m)	Date (^{14}C years BP)	Laboratory number
Bottom 0.01 m of surface peat	7.23–7.24	5890 ± 5	SRR–1331
Top 0.01 m of peat beneath grey silty clay ('carse')	6.75–6.76	7310 ± 100	SRR–1332
Bottom 0.01 m of peat above grey, micaceous, silty fine sand	6.38–6.39	7050 ± 100	SRR–1333
Top 0.01 m of peat below grey, micaceous, silty fine sand	6.19–6.20	7555 ± 110	SRR–1334

al. place the age of the sand at between 7555 ± 110 BP and 7050 ± 110 BP. Chisholm (1971), who did not identify the sand as separate from the clays and silts, nevertheless obtained a radiocarbon date of 7605 ± 130 BP for the base of the layer (and his figure 6 actually identifies organic material between the sand and the clays and silts above). It is likely, however, that the layer was deposited in the gully over a much shorter period than the radiocarbon evidence implies. Chisholm remarked on evidence of erosion of the peat at the base of the sand (which would therefore make the basal date at best a maximum age estimate); the dates of Morrison *et al.* are reversed in the middle of the sequence (see Table 15.2), implying an older date for the base of the peat above the layer. Elsewhere, in eastern Scotland, a similar bed of sand in a similar stratigraphic position has been found at a number of sites (see Western Forth Valley, Maryton, Dryleys and Barnyards) (Smith *et al.*, 1985a). At each of these other sites the bed appears to have accumulated rapidly, probably over a period of much less than 100 years. The radiocarbon ages at these sites range between 6900 and 7200 BP. Given the radiocarbon dates at Silver Moss, it seems likely that the sand at this location correlates with these other sand beds. It was originally thought that they are the deposits of a major storm surge in the North Sea which was particularly effective for having occurred at a time of rapidly rising relative sea level (Smith *et al.*, 1985a; Haggart, 1988b), but a recent interpretation suggests that they relate to a tsunami associated with a major submarine slide on the Norwegian continental slope (Dawson *et al.*, 1988; Long *et al.*, 1989a). It is interesting to note that a similar sand layer has been found quite close to Silver Moss, near Craigie (Haggart, 1978), though this has not been dated.

The clays and silts (carse) continued to accumulate after the sand was deposited but, as relative sea level fell, peat began to form on the surface. The radiocarbon dates obtained by Morrison *et al.* below and above the wedge of clays and silts in the gully probably embrace the culmination of this marine transgression. The date for the base of the layer may well be younger than 7310 ± 100 BP (SRR–1332) in view of the age reversal referred to above; the age for the top of the layer, at 5890 ± 95 BP (SRR–1331), agrees well with Chisholm's date of 5830 ± 110 BP (St–3062) at the same horizon. These dates indicate that the event involved was the Main Postglacial Transgression. Morrison *et al.* maintain that the date for the end of the deposition of the clays and silts probably applies to the wider local area, despite Chisholm's reservations, since there is very little difference between the local altitude of the carse surface beyond the gully (up to 8.3 m OD) and the altitude reached by the wedge of the clays and silts within the gully (7.9 m OD).

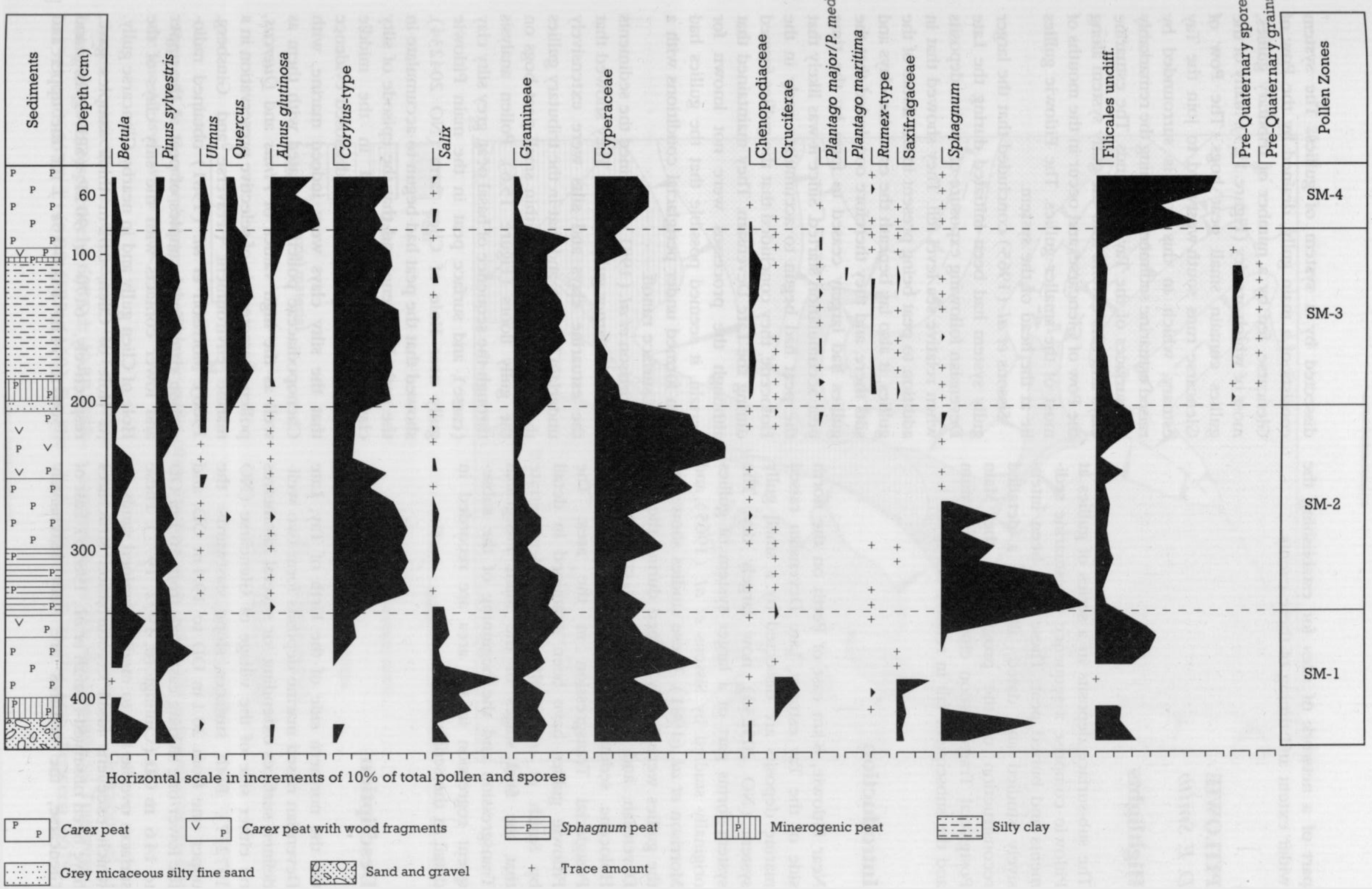
The sequence of deposits in Silver Moss contains an excellent record of relative sea level change during much of the Holocene. The sheltered nature of the gully ensured that the sedimentary record was relatively undisturbed, and that the evidence of two significant events was preserved.

The deposits which record the culmination of the Main Postglacial Transgression at this site will repay further study; notably, additional dating will contribute towards a better understanding of the wider pattern of diachroneity of the Main Postglacial Shoreline in Scotland. The grey, micaceous, silty fine sand layer is remarkably extensive in the moss, and provides an opportunity for reconstruction of the details of the event which led to its deposition. The layer can be identified so widely in the moss that its altitude and inland limit can be studied in great detail, and will provide evidence for the 'run-up' of the wave from which it was deposited. This should, in turn, provide evidence for the magnitude of the tsumani waves as anticipated in Bugge (1983) and discussed in Long *et al.* (1989a).

Conclusion

The deposits at Silver Moss provide a detailed record of sea-level changes during the Holocene (the last 10,000 years). In particular, they are significant for studies of the Main Postglacial Transgression (an encroachment of the sea on to the land that occurred around 6000 years ago as ice age glaciers in North America and Scandinavia melted away releasing large volumes of meltwater into the oceans) and a major coastal flood that occurred about 7000 years ago. Silver Moss forms

Figure 15.4 Silver Moss: relative pollen diagram showing selected taxa as percentages of total pollen and spores (from Morrison *et al.*, 1981).


Sediments
Depth (cm)
Betula
Pinus sylvestris
Ulmus
Quercus
Alnus glutinosa
Corylus-type
Salix
Gramineae
Cyperaceae
Chenopodiaceae
Cruciferae
Plantago major/P. media
Plantago maritima
Rumex-type
Saxifragaceae
Sphagnum
Filicales undiff.
Pre-Quaternary spores
Pre-Quaternary grains
Pollen Zones
SM-4
SM-3
SM-2
SM-1
60
100
200
300
400
Horizontal scale in increments of 10% of total pollen and spores
Carex peat
Carex peat with wood fragments
Sphagnum peat
Minerogenic peat
Silty clay
Grey micaceous silty fine sand
Sand and gravel
+ Trace amount

part of a network of sites for establishing the wider extent and timing of these events.

PITLOWIE

D. E. Smith

Highlights

The sub-surface deposits in a series of gullies at Pitlowie comprise a sequence of estuarine sediments and buried peat. These have been intensively studied and dated, allowing a detailed reconstruction of the progress of the Main Postglacial Transgression close to its maximum and the subsequent fall in relative sea level.

Introduction

Near Pitlowie, 8 km east of Perth on the north side of the Tay estuary, Late Devensian raised marine deposits are dissected by a small gully system (NO 205230), now largely dry. The system forms part of a larger system of gullies originally studied by Sissons *et al.* (1965) and Morrison *et al.* (1981). These studies show that the gullies were largely formed during the Late Devensian, and that their lower ends contain Holocene sediments which record the Main Postglacial Transgression in the area. The Pitlowie gullies have been examined in detail by Smith *et al.* (1985b), who demonstrate that the final stages of the Main Postglacial Transgression and the beginning of the subsequent regression in the area are recorded in detail in the sediments.

Description

On the northern side of the Firth of Tay, Late Devensian raised marine deposits form two well-defined surfaces extending for several kilometres on either side of the village of Glencarse (NO 197217). Both surfaces slope eastwards: the upper one from 20.1 m OD to 19.4 m OD, and the lower one sloping eastwards from 16.1 m OD to 14.6 m OD (Cullingford, 1972, 1977). These surfaces overlie fine to medium-grained sands, in which excellent fossil cryoturbation structures have been observed (Smith *et al.*, 1985b). East of Glencarse, the features are very extensively dissected by a system of gullies. The system consists of a main gully, drained by the Pow of Glencarse, fed by a number of tributary gullies, most of which are dry (Figure 15.5). Many of the gullies contain small peat bogs. The Pow of Glencarse runs south-westward to join the Tay estuary, which in this area is surrounded by raised estuarine sediments forming the remarkably flat surfaces of the Tay carselands. The estuarine clays and silts extend into the gully system along the Pow of Glencarse, and occur in the mouths of most of the smaller gullies. The Pitlowie gullies lie at the head of the system.

Sissons *et al.* (1965) concluded that the larger gully system had been initiated during the Late Devensian following exposure of marine deposits when relative sea level fell. They showed that in addition to peat being present in the floors of the gullies, it also lay beneath the estuarine clays and silts there, and they therefore concluded that the gullies had largely ceased to form by the time peat accumulation started. Since it was likely that the peat had begun to accumulate early in the Holocene, they concluded that the gullies formed during the Late Devensian. They maintained that although the processes were not known for certain, it seemed possible that the gullies had been formed under periglacial conditions with a high surface runoff.

Morrison *et al.* (1981) examined the sediments within the larger gully system. They showed that the estuarine clays and silts were extensively underlain by peat, and that in the tributary gullies they formed a wedge within small peat bogs on the gully floors (Figure 15.6). Pollen analysis through the sequence of basal peat, grey silty clay (carse), and surface peat in the main Pitlowie gully near Hole of Clien farm (NO 204234), showed that the peat had begun to accumulate in the early Holocene, and that the episode of silty clay sedimentation occurred in the middle Holocene. The pollen record disclosed evidence that the silty clays were indeed marine, with Chenopodiaceae pollen associated with them as well as the high values of *Pinus* and *Quercus*, pollen characteristic of selective preservation in a marine environment (Traverse and Ginsberg, 1966). Morrison *et al.* (1981) obtained radiocarbon dates from samples of peat at the upper and lower contacts with the silty clays of the Hole of Clien gully and in nearby Glencarse gully. At Hole of Clien, 0.02 m thick samples gave, respectively, 6170 ± 90 BP (SRR–1510) and 7500 ± 90 BP (SRR–1511) for the upper and

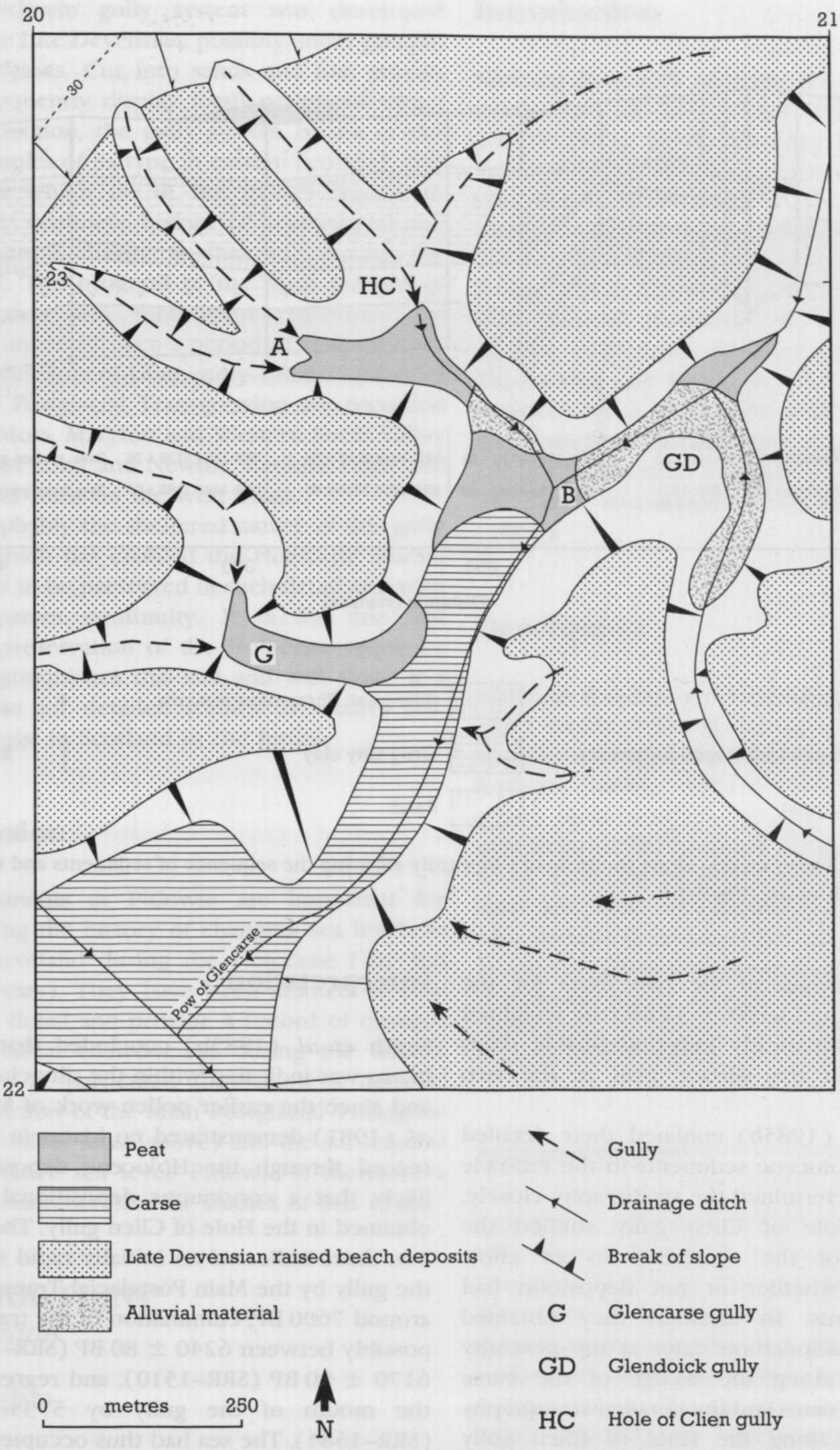


Figure 15.5 Geomorphology of the Pitlowie gullies (from Morrison *et al.*, 1981). The sediment sequence along the line AB is shown in Figure 15.6.

lower contacts. At Glencarse, 0.01 m thick samples gave, respectively, 6083 ± 40 BP (SRR–1151) and 6679 ± 40 BP (SRR–1150) for the upper and lower contacts. Morrison *et al.* concluded that the Main Postglacial Trangression had culminated in the area between 6679 ±

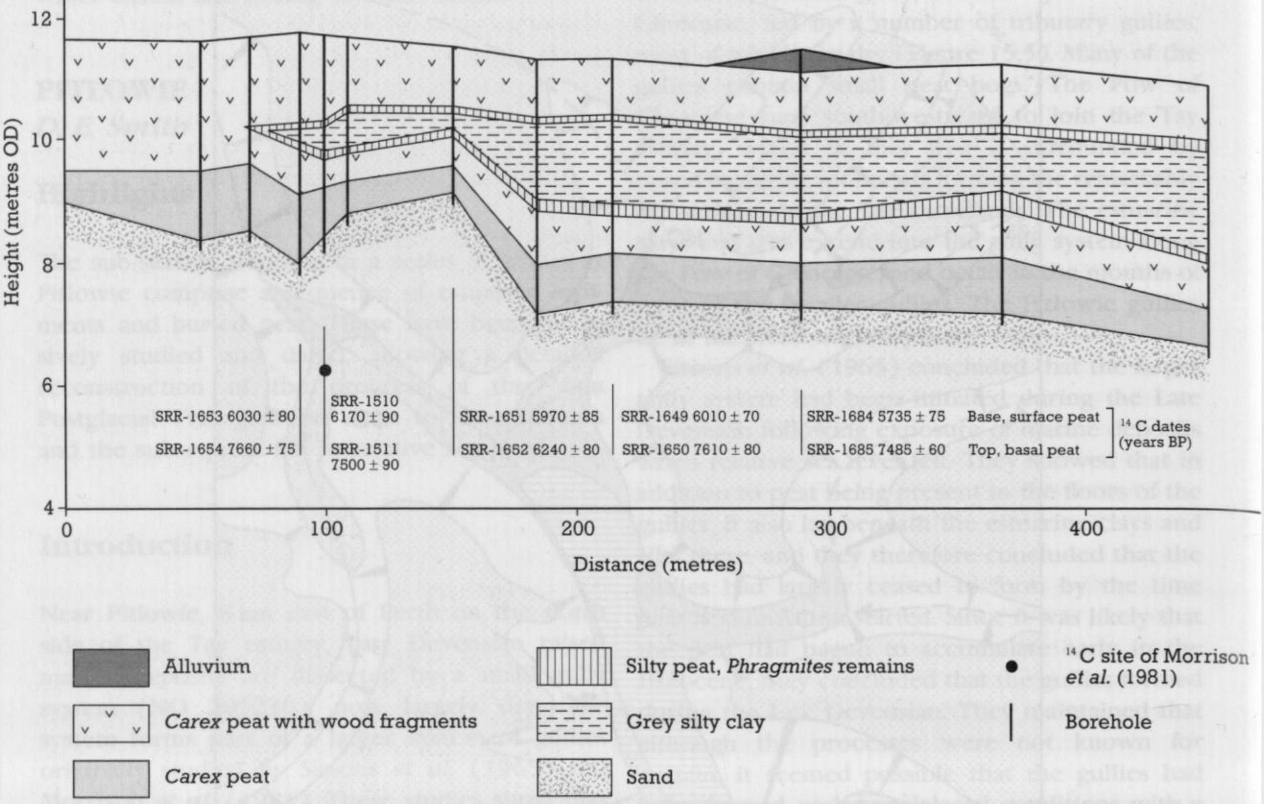


Figure 15.6 Pitlowie: section along the Hole of Clien gully showing the sequence of sediments and radiocarbon dates (from Smith *et al.*, 1985b).

40 BP (the younger of the two dates for the lower contact) and 6100 ± 35 BP (the weighted mean of the statistically indistinguishable dates on the base of the surface peat at the two locations).

Smith *et al.* (1985b) confined their detailed study to the Holocene sediments in the Pitlowie gullies. They determined the stratigraphy closely, and in the Hole of Clien gully studied the geochemistry of the sediments in an effort to determine whether or not deposition had been continuous. In addition they obtained eight further radiocarbon dates at the peat/silty clay interface along the wedge of the carse sediments. The dates and the detailed stratigraphy they obtained along the Hole of Clien gully are shown in Figure 15.6. Their studies of the geochemistry of the silty clay showed no major changes in organic carbon, $\delta^{13}C_{PDB}$, aluminium or magnesium, and they concluded that no hiatus in deposition within the silty clays was indicated.

Interpretation

Smith *et al.* (1985b) concluded that since no hiatus was indicated within the silty clays (carse), and since the earlier pollen work of Morrison *et al.* (1981) demonstrated no hiatus in the pollen record through the Holocene deposits, it was likely that a continuous depositional sequence obtained in the Hole of Clien gully. The radiocarbon dates indicated an initially rapid invasion of the gully by the Main Postglacial Transgression at around 7600 BP; culmination of the transgression possibly between 6240 ± 80 BP (SRR–1652) and 6170 ± 90 BP (SRR–1510), and regression from the mouth of the gully by 5735 ± 75 BP (SRR–1684). The sea had thus occupied that part of the gully where the silty clays occur for nearly 2000 years, yet sedimentation, though apparently continuous, was relatively slight. Little sediment was evidently derived from the land, which emphasizes the lack of gully development during that time.

The Pitlowie gully system was developed during the Late Devensian, possibly under periglacial conditions. Cut into sands and fine gravels which frequently display fossil periglacial structures in section, the gully system is one of the best examples of its type in eastern Scotland. The sediments which lie in the gullies record an apparently complete history of vegetational and environmental change in the area during the Holocene. The progress of the Main Postglacial Transgression and subsequent regression are recorded in detail over a period of around 2000 years in the Hole of Clien gully. Other aspects of the Main Postglacial Transgression are recorded at Silver Moss, Maryton and Western Forth Valley on the east coast and Newbie, Redkirk Point and Dundonald Burn on the west coast.

It is probably the sheltered nature of this gully system which has enabled the Holocene marine sediments to be preserved in such detail and with such apparent continuity. It is the fine and detailed preservation of the Holocene sequence which distinquishes this site and will make it a focal point for detailed studies of relative sea-level change in Scotland in the future.

Conclusion

The sediments at Pitlowie are important for establishing the history of changing sea levels in eastern Scotland during the Holocene (the last 10,000 years). They have been studied in considerable detail and provide a record of changes in the coastal environment during the middle Holocene. In particular, they allow a detailed reconstruction of the Main Postglacial Transgression (see Silver Moss above) and the subsequent fall in relative sea level. Pitlowie is therefore a valuable reference site for studies of this event.

KINCRAIG POINT

J. E. Gordon

Highlights

The Lateglacial and Holocene raised shorelines at Kincraig Point are notable as erosional features formed in bedrock. They form a striking sequence of landforms that contrasts with the sedimentary evidence for coastal changes recorded elsewhere in the estuaries of eastern Scotland.

Introduction

Kincraig Point (NT 465998) is a headland on the south coast of Fife, 2.5 km west of Elie. It is notable for its geomorphology, demonstrating a series of raised shorelines (shore platforms) cut into the western flank of the headland. The interest and striking appearence of those features has long been noted (Wood, 1887; Geikie, 1901; Geikie, 1902; MacGregor, 1973) and they have also featured frequently in book illustrations (Geikie, 1902, figure 66; MacGregor, 1973, figure 18; Forsyth and Chisholm, 1977, plate 1 (frontispiece); Price, 1983, plate 4.1B). The position of the shorelines in the wider regional pattern of Lateglacial sea-level changes in eastern Scotland has been assessed by Cullingford and Smith (1966).

Description

Although frequently described as beaches (Wood, 1887; Geikie, 1902; MacGregor, 1973) the raised shorelines at Kincraig Point are in fact erosional features (Geikie, 1901). They consist of four raised rock benches cut into the volcanic agglomerate of the headland at approximately 4 m, 11 m, 22 m and 24 m OD and are veneered with sand and shells (Cullingford and Smith, 1966). Also present is an intertidal shore platform. The raised shorelines at Kincraig Point are particularly prominent when viewed from the west (see illustrations in Geikie, 1902; MacGregor, 1973; Forsyth and Chisholm, 1977; Price, 1983).

Interpretation

Cullingford and Smith (1966) regarded the upper three raised shorelines as Lateglacial in age, the lowest as Holocene. The two highest shorelines form part of the sequence of early Lateglacial shorelines in East Fife but were excluded by Cullingford and Smith (1966) from their detailed height analyses for the area because of uncertainty regarding the relationships of shore platforms to relative sea-level heights at the time of their formation.

Andrews and Dugdale (1970) originally calculated the ages of the East Fife shorelines to be between 18,250 and 15,100 BP, but more recent information suggests that they formed between *c.*

16,000 BP and 14,000 BP (Sutherland, 1991a). This revised estimate is more consistent with evidence that the last ice-sheet was at its maximum extent *c.* 18,000–17,000 BP (cf. Sissons, 1976b; Cullingford and Smith, 1980).

The third highest shoreline was interpreted as part of the Main Perth Shoreline. The latter is one of the most prominent raised shorelines in eastern Scotland, sloping E17°S at 0.43 m km^{-1}, and was formed after the East Fife shorelines at a time when the last ice-sheet had retreated west up the Forth valley (Sissons and Smith, 1965a; Smith *et al.*, 1969; Sissons, 1976b; Cullingford, 1977). The intertidal platform may be part of the platform that is extensively developed in eastern Scotland (see Milton Ness and Dunbar), and which Dawson (1980a) has correlated with the Low Rock Platform of western Scotland (see Northern Islay and the West coast of Jura).

Examples of raised shorelines are widespread in eastern Scotland, but Kincraig Point provides a particularly clear example of a suite of such features which has a very striking 'staircase' appearance when seen in profile. As erosional features they are exceptional among Lateglacial and Holocene raised shorelines in eastern Scotland (Sissons, 1967a), which typically comprise beaches or estuarine terraces. The prominence of the features at Kincraig Point probably relates to the relatively weak nature of the volcanic agglomerate into which they have been cut. As clear geomorphological features developed on an exposed headland (see also Milton Ness), the shorelines at Kincraig Point complement the interest of other sites in eastern Scotland (see Western Forth Valley, Silver Moss, Dryleys and Maryton) where the emphasis is on sedimentary and geochronological evidence for relative sea-level change in estuarine environments.

Conclusion

Kincraig Point is important for Quaternary coastal geomorphology. It is a good example of a sequence of raised shorelines eroded in bedrock following the retreat of the Late Devensian ice-sheet between about 16,000 and 13,000 years ago: each indicating a different sea level. The shorelines have a striking landscape appearance and complement the interest of sites selected for the sedimentary evidence that they provide for sea-level changes in more estuarine situations.

BLACK LOCH

G. Whittington, K.J. Edwards and P.R. Cundill

Highlights

The sediments which infill the topographic basin at Black Loch have provided a great wealth of information on the palaeoecological and palaeoenvironmental changes in eastern Scotland during the Lateglacial and Holocene. Variations with depth in pollen content and type in the sediments have been studied in considerable detail, and extensive use has been made of radiocarbon dating, so that Black Loch is an indispensable reference site for future work in this field.

Introduction

Black Loch (NO 261150) lies in the Ochil Hills of northern Fife at an altitude of 90 m OD. It has a relatively small surface area (0.015 km^2) and a maximum depth of approximately 3 m. The sediments of Black Loch have been accumulating since Late Devensian times and their pollen and spore records have proved to be of considerable interest for the vegetational history of eastern Scotland (Whittington *et al.*, 1990, 1991a). No site comparable to this has been investigated in Fife (although the detailed study at Pickletillem (Whittington *et al.*, 1991b) is worthy of note), but of greater importance than this purely regional consideration is the fact that eastern Scotland in general is poorly served by sites which can contribute to an understanding of the vegetational history on the national scale. Thus the sediments of Black Loch provide a potential link between the vegetational histories described from the areas to the north in Aberdeenshire (such as at Loch Davan and Braeroddach Loch; Edwards, 1978), the north-west in Perthshire (Stormont Loch; Caseldine, 1980a) and those to the south-east (for example, Newey, 1965b; Hibbert and Switsur, 1976; Mannion, 1978a).

Description

The sediments at Black Loch comprise a succession of clays and detritus muds (Figure 15.7). A representative relative pollen diagram showing selected pollen and spore taxa (Figure 15.7) is based on data from one of four cores, and which was 7.0 m in length taken in 3.0 m of water. There are 14 radiocarbon dates (SRR–2613 to SRR–2626) for the profile, which features both Lateglacial and Holocene age deposits. In addition there are a further eleven radiocarbon dates (UB–2290 to UB–2300) from a second core. The vegetational history is based on the information available from all four cores.

Interpretation

The basal sediments (clay) of Black Loch are not polleniferous, but at some time before 12,670 ± 150 BP (SRR–2626; determination on organic clay) pollen and spore taxa indicate the presence of a cold-climate vegetation pattern dominated by Gramineae and *Salix* with contributions from Cyperaceae, Caryophyllaceae, *Artemisia*, *Selaginella selaginoides*, and *Lycopodium clavatum*. Present also is the pollen of *Koenigia islandica*, a taxon often found in the Lateglacial deposits of sites in the west of Scotland; its presence here shows that it was probably common to the whole of Scotland at this time.

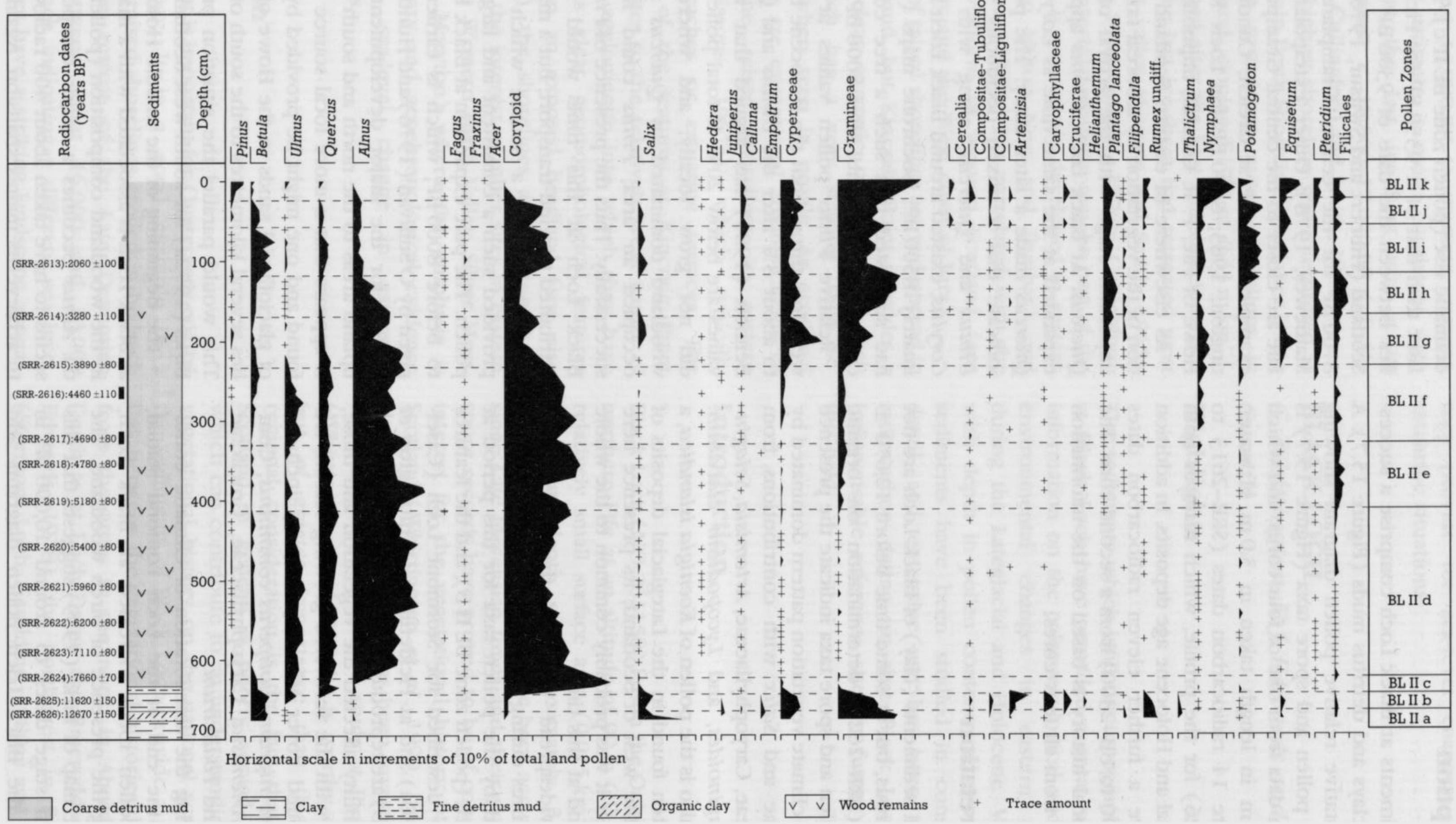
The widespread effect of the lowering of temperatures during the Loch Lomond Stadial is confirmed by the pollen taxa for this period at Black Loch (pollen zone BL II b), and the features generally described for Stormont Loch (Caseldine, 1980a) and at Pickletillem (Whittington *et al.*, 1991b) are reproduced. Conditions of extreme soil instability affected the vegetation and those, together with the restricted growing season, led to a ground cover which principally included *Empetrum nigrum*, *Juniperus communis*, Compositae, *Artemisia*, Caryophyllaceae, Cruciferae, *Rumex* and *Thalictrum*.

Following the amelioration of climatic conditions at the end of the Loch Lomond Stadial, *Betula* pollen totals increased at Black Loch, indicating the presence of birch woodland. The isochrone map of Birks (1989) suggests that this vegetation stage dates to around 10,000 BP in Fife and the Black Loch pollen diagrams add support to this. By approximately 9000 BP the immigrating *Corylus avellana* had achieved a dramatic rise (pollen zone BL II c). This timing is later than that of *c.* 9350 BP for Pickletillem and lies between the date of 9300 BP for southern Scotland (Hibbert and Switsur, 1976) and that of 8700 BP for the central Grampians (Birks and Mathewes, 1978). Other extrapolated dates for Fife are closer to the central Grampians date (for example, 8640 BP at Creich, Cundill and Whittington, 1983; 8690 BP for Loch Rossie in the Howe of Fife, P. R. Cundill, unpublished data).

As elsewhere in eastern Scotland the domination of the vegetation by arboreal taxa reached an important stage with the arrival of *Ulmus* and *Quercus*. At Black Loch, *Ulmus* appears to have expanded at the same time as *Corylus*, whereas *Quercus* made a later entry. The pollen spectra indicate that a mixed deciduous woodland of *Ulmus* and *Quercus*, along with *Betula* and *Corylus*, existed around Black Loch from approximately 8500 BP; isochrone maps (Birks, 1989) had suggested that such a tree cover did not come into being until after 8000 BP.

Relative *Pinus* pollen values at Black Loch were low throughout the Holocene but increased to about 8% after the *Ulmus* and *Quercus* rise. Bennett (1984) has argued that where *Pinus* values are below 20% of total pollen, pine trees did not grow locally, and where deciduous woodland dominated by *Quercus* and *Corylus* occupied an area, *Pinus* could not compete successfully. Thus the presence of *Pinus* pollen at Black Loch at this time would have to be attributed to wind transport, but a major problem exists in finding a source which could have provided such a consistent and large volume of pollen. The pine expansion at Black Loch is dated to before 8000 BP, which is earlier than dates given by O'Sullivan (1976) and Huntley and Birks (1983) for the major development of pine in upland areas to the north and south of Fife. Thus it appears that a more local source needs to be found and one might be provided by the stretch of glaciofluvial sands in the Howe of Fife, which lies several kilometres to the south of Black Loch. This would parallel the situation predicated by Birks (1972a) for south-west Scotland.

The beginning of the middle Holocene period at Black Loch is associated with a marked change in the woodland composition (pollen zone BL II d). *Alnus* becomes a major component and it seems to have taken about 400 radiocarbon years to achieve its main expansion. Again, the importance of Black Loch as a source of evidence for an understanding of the vegetational history of



Radiocarbon dates (years BP)
Sediments
Depth (cm)
Pinus
Betula
Ulmus
Quercus
Alnus
Fagus
Fraxinus
Acer
Coryloid
Salix
Hedera
Juniperus
Calluna
Empetrum
Cyperaceae
Gramineae
Cerealia
Compositae-Tubuliflorae
Compositae-Liguliflorae
Artemisia
Caryophyllaceae
Cruciferae
Helianthemum
Plantago lanceolata
Filipendula
Rumex undiff.
Thalictrum
Nymphaea
Potamogeton
Equisetum
Pteridium
Filicales
Pollen Zones
(SRR-2613):2060 ±100
(SRR-2614):3280 ±110
(SRR-2615):3890 ±80
(SRR-2616):4460 ±110
(SRR-2617):4690 ±80
(SRR-2618):4780 ±80
(SRR-2619):5180 ±80
(SRR-2620):5400 ±80
(SRR-2621):5960 ±80
(SRR-2622):6200 ±80
(SRR-2623):7110 ±80
(SRR-2624):7660 ±70
(SRR-2625):11620 ±150
(SRR-2626):12670 ±150
0
100
200
300
400
500
600
700
BL II k
BL II j
BL II i
BL II h
BL II g
BL II f
BL II e
BL II d
BL II c
BL II b
BL II a
Horizontal scale in increments of 10% of total land pollen
Coarse detritus mud
Clay
Fine detritus mud
Organic clay
Wood remains
Trace amount

Scotland is underlined because the main *Alnus* rise is dated here to near 7300 BP, a date which is earlier than most others from Scotland, for example, around 6800 BP for southern Scotland (Hibbert and Switsur, 1976) and 6200 BP for western Scotland (for example, Birks, 1972a; Pennington *et al.*, 1972; Williams, 1977). The relative isolation of Fife flanked by the Firths of Forth and Tay, and the attendant widespread development of estuarine conditions, could well have encouraged an earlier migration of *Alnus* into eastern Scotland (cf. Smith, 1984) but this is difficult to reconcile with a date of *c.* 6500 BP for the main alder rise at the near coastal site of Pickletillem. Interpreting the spread of alder in the British Isles is, however, a notoriously difficult process (Chambers and Elliott, 1989; Bennett and Birks, 1990).

Signs of anthropogenic impact on the middle Holocene vegetation (Edwards and Ralston, 1985) have not been discovered at Black Loch. This was the period of densest forest cover at the site, with samples yielding non-arboreal pollen values frequently below 5% of total pollen.

Around 5180 ± 80 BP (SRR–2619) a decline occurred in *Ulmus* pollen, accompanied by the appearance of *Plantago lanceolata* and increased values for Gramineae. The dating of these events is in accordance with those to the south (for example, 5390 BP at Din Moss, Hibbert and Switsur, 1976) and to the north (for example, 5295 BP and 5105 BP, respectively at Braeroddach Loch and Loch Davan; Edwards, 1978). It is probable that human interference with the vegetation occurred at this time, a suggestion supported by the first appearance of cereal-type taxa, but natural explanations (disease, climate change) are not disproved. There is no evidence for a widespread environmental disturbance at this elm decline; the chemical and particle size analysis of the loch sediments also indicate this (Whittington *et al.*, 1991c).

Above the level of this elm decline, the pollen values for *Ulmus* and *Quercus* are reduced and Gramineae and *Plantago lanceolata* values rise (pollen zone BL II e). Taken together with an increased sediment accumulation rate (from 0.125 cm a^{-1} to a profile maximum of 0.333 cm a^{-1}) and a sharp increase in clastic inputs, there would appear to have been a period of considerable environmental disturbance around the Loch. Subsequently *Ulmus* pollen totals recovered to pre-elm decline values (pollen zone BL II f) and are matched by a decrease in sedimentation rates. This apparent return to vegetation conditions of the period before 5180 BP was brought to an end between 4460 ± 110 BP (SRR–2616) and 3890 ± 80 BP (SRR–2615), when a second major *Ulmus* decline occurred. This is accompanied in the samples by a fall in *Quercus* values, increased frequencies of herbaceous taxa (especially Gramineae, Cyperaceae, *Plantago lanceolata* and the reappearance of cereal-type pollen) and a rise in values for the spores of *Pteridium aquilinum* and *Equisetum*. (In core BL II only, a partial recovery of elm, followed by a minor decline, takes place at the 5070 BP and 4090 BP levels respectively; this event, intermediate between the two major *Ulmus* declines, is discussed fully elsewhere – Whittington *et al.*, 1991c).

Black Loch's importance as a site for demonstrating the vegetational history of this part of the Holocene is intimately bound up with the events associated with the apparent behaviour of *Ulmus*. Following the first decline of elm the area experienced vegetational disturbance, although it is unlikely, if solely of anthropogenic origin, that it was a discrete event, but rather an amalgam of different periods of human activity. The recovery of *Ulmus* pollen levels at 4690 ± 80 BP (SRR–2617) presumably indicates a reduction in cultural activity (or a cessation of natural limiting factors) which lasted until the second major *Ulmus* decline. Those events occurred at other sites in Britain and western Europe although their marked collective nature at Black Loch, as at the Welsh site of Waun-Fignen-Felen (Smith and Cloutman, 1988), puts the site in the forefront of the continuing controversy and discussion regarding the cause (or perhaps more accurately the causes) of the repeated sudden demise of *Ulmus* (Janssen and Ten Hove, 1971; Tolonen, 1980; van Zeist and van der Spoel-Walvius, 1980; Sturlurdottir and Turner, 1985; Aaby, 1986; Hirons and Edwards, 1986; Perry and Moore, 1987).

After the second *Ulmus* decline the main vegetational characteristics at Black Loch were clearly related to an intensification of human activity (pollen zones BL II g and h). Pollen of

Figure 15.7 Black Loch: relative pollen diagram at coring site BL II showing selected taxa as percentages of total land pollen (from Whittington *et al.*, 1990). *Cannabis sativa* is not represented in this diagram but in the other cores occurs in zones equivalent to BL II j.

arboreal taxa decline continuously and overall, and are replaced reciprocally by expansions, in particular, of Gramineae, Cyperaceae, *Plantago lanceolata*, and *Rumex*. The presence of the light-demanding *Fraxinus excelsior* denotes the existence of open ground and the identification of *Hordeum*-type cereal pollen is an indication of the reasons for the clearance of the woodland. Such events are usually recorded in pollen records from eastern Scotland, but the fine resolution possible due to the great depth of sediment (7.52 m after 3750 BP in the lake-centre core I) has allowed the identification of a phase of interruption in the progressive destruction of woodland. During the period that appears to correlate with the Roman incursion into Scotland (pollen zone BL II i) there was a recovery (reflected in the relative and concentration pollen levels) of *Quercus*, *Ulmus* and Coryloid, with a concomitant decline in *Calluna vulgaris*, Gramineae, *Plantago lanceolata* and *Pteridium aquilinum*. This evidence tends to confirm a similar event recorded in Loch Davan and Braeroddach Loch in Aberdeenshire (Edwards, 1978). Thereafter by 1429 BP, woodland was once more in retreat, agriculture was re-established, and the pollen spectra reveal a continuous curve for cereal-type pollen, not only of *Hordeum* type, but also of *Avena/Triticum* type. Chemical analyses of the sediments show increasing erosional activity, suggesting that the level of arable agriculture was becoming more intense.

By 1000 BP the vegetational history at Black Loch enters its final stage, but one which shows two phases (pollen zones BL II j and k). The first, approximately 1000–400 BP, continues the woodland shrinkage, apart from *Alnus* and *Salix* which survived in the carr at the edge of the loch. The pollen spectra record the strongest representation, in both relative and concentration terms, of Compositae, Cruciferae, *Plantago lanceolata*, *Artemisia*, Umbelliferae and *Calluna vulgaris*.

A feature which attests to the importance of Black Loch in tracing vegetational change in Fife in particular, and in eastern Scotland in general, occurred near the beginning of this period. There is a sudden, strong (up to 12% TLP) and maintained presence of Cannabinaceae pollen. Such pollen can be derived from *Humulus lupulus*, which occurs naturally in fenland, or from *Cannabis sativa* which appears to have been introduced into Britain by the Romans. A more secure method now exists (Whittington and Gordon, 1987) for the separation of these two taxa, and at Black Loch it is the latter which provides the majority (up to 70% at some levels) of the pollen. From around 1000 to 825 BP the growing of hemp, presumably for its useful fibres (Whittington and Edwards, 1990), must have added a distinctive aspect to the vegetation of the Black Loch area (Edwards and Whittington, 1990), providing the introduction of an alien vegetation component, to which might also be added *Juglans regia* (walnut). The growth of *Cannabis sativa* may have received encouragement from the Anglo-Norman penetration of Fife, a period which also witnessed the founding of a Tironesian abbey near Black Loch. The innovatory farming techniques of the monastic community could well have led to the intensification of arable practice, which is revealed by the strong presence in the pollen spectra of cereal-type pollen, whereas the pastoral activities probably brought about the appearance of the pollen of *Vicia cracca* and *Trifolium* types. The increase in pollen influx rates and the sediment chemistry evidence indicate that throughout this period there must have been a continuing removal of the naturally occurring vegetation species, and their replacement by cultigens and ruderals following increased ploughing activity.

In early modern and succeeding times, the agricultural modifications were maintained but appear to intensify. Again the fine resolution obtainable at Black Loch reveals quite clearly the marked impact on the vegetation engendered by changed attitudes to land management. The most striking feature lies in the re-establishment of arboreal species. The creation of coniferous plantations is marked by the sudden resurgence of *Pinus* pollen, to be followed by the appearance of such introduced species as *Abies*, *Larix* and *Picea*. The desire to beautify the landscape led to the planting of *Fagus* and encouraged a greater representation of *Ulmus* and *Fraxinus*.

In terms of unravelling the vegetational history of Scotland, the pollen spectra established from analysis of cores from Black Loch help to fill a large gap. Not only are pollen records from the Late Devensian to the present day infrequent in eastern Scotland, but the investigations undertaken at Black Loch have a base of multiple coring, frequent radiocarbon dating and sedimentological analysis; such a methodology enables corroborative checks to be made upon the representativeness of each core studied, while the differences between them provide important indications of taphonomic and spatial variability.

The findings have confirmed in some instances the results of investigation at other sites (see Din Moss, Stormont Loch and other sites mentioned above). In others they have shown that the isopollen and isochrone maps for Scotland can now be further refined; a mixed deciduous woodland was present locally for at least 500 radiocarbon years before predicted, a local source for *Pinus* is suggested, and *Alnus* expanded some 500 radiocarbon years earlier than suggested by the mapping exercises. Above all, the findings reveal new aspects of the change and development of the vegetational history in Fife, in particular, and eastern Scotland in general. Of considerable interest in this connection is the existence of a multiple elm decline, which continues to fuel the debate surrounding the frequently marked, but solitary, fall in *Ulmus* pollen values at *c.* 5100 BP, and the expansion of *Cannabis* pollen at *c.* 1000 BP, which denotes the probable cultivation of hemp within the local agricultural economy.

Conclusion

Black Loch is a key reference site, providing a record of the vegetational history in eastern Scotland from the time of melting and shrinkage (deglaciation) of the last ice-sheet (around 13,000 years ago) up to the present. Its pollen and sediments have been studied in great detail and have provided a wealth of palaeoenvironmental and palaeoecological information, supported by extensive use of radiocarbon dating. Black Loch is also an integral member of the network of sites for establishing the pattern of variations in vegetation history in eastern Scotland.