CHAPTER 17: PRELIMINARY INVESTIGATION OF LAKE SEDIMENTS FROM THE MACHAIRS OF THE OUTER HEBRIDES

K R Hirons (1986)

17.1 INTRODUCTION

Studies in the chronology and development of the west coast machair sand-dune systems of the Outer Hebrides have concentrated on organic materials from inter-tidal areas and archaeological sequences stratified within the blown sand (Elton 1938; Ritchie 1966; 1979; 1985; Simpson 1966; 1976; Evans 1971; Crawford & Switsur 1977). Other deposits which may provide complimentary evidence of the development and environmental history of the machair and adjacent 'blacklands' are deposits preserved beneath the sand plains (eg Ritchie 1968) and lake sediments from lochs within the area of blown sand (see Brayshay & Edwards 1996). There are two types of lake; machair lochs, here defined as lakes formed directly by the choking effect of encroaching sand (not necessarily equivalent to a limnological definition of Waterston *et al* 1979) and lakes confined by basins in rock or glacial deposits situated beyond the machair itself.

This project was undertaken to ascertain the usefulness of studying machair development and the environmental history of the blacklands/machair ecotone using sediments from lake deposits. The sites chosen were bog and former lake deposits near Balemore in North Uist and a core from Loch na Cuithe Moire, a rock-basin lake near Askernish, South Uist (Figure 92).

17.2 RESULTS: ASKERNISH

The small, *circa* 200 m diameter bog to the north-west of Loch na Cuithe Moire, near Askernish, South Uist lies at approximately 2–3 m OD, 1.2 km from the coastal dune system and behind a wet machair grassland. The site is in a basin in the Lewisian gneiss. The local vegetation was one of *Phragmites* and *Scirpus* spp. with *Menyanthes trifoliata*, *Myriophyllum alterniflorum* and *Potamogeton* spp. in the remaining shallow pool. The site was cored at its deepest point near the centre and somewhat to the north of the small area of open water. A 2.5 m core of peat, detritus mud, sand and clay was recovered using a narrow-bodied Russian-type corer (Jowsey 1966). The Askernish site is 6.25 km south-west of the pollen site on the island of Calvay and 9.5 km south/south-west of the peat sites at Stoneybridge studied by Heslop-Harrison and Blackburn (1946).

The stratigraphy of the core was examined in the laboratory and is recorded in Table 47.

17.2.1 Sediments

Sediment density, water content and loss on ignition (Figure 96) outline a trend of gradually increasing organic matter content up the core. Five layers are superimposed on this trend; a surface sandy layer, inorganic layers at 160–170 cm, 180–190 cm and 210–235 cm, and a basal gritty layer. High temperature loss-on-ignition (HT-LOI) is generally low (<15%) but suggests that some carbonates are present in certain parts of the core (0–15 cm, 25–30 cm, 45–100 cm, 151–180 cm and 220–240 cm). Askernish pH profiles show peaks in three portions of the core; 0–10 cm, 80–180 cm and 200–230 cm.

On the basis of these results the Askernish core has been divided into nine sediment units for ease of description and as a basis for further analyses. The units are numbered 1–9 starting from the base of the core (Figure 96).

Two samples for total elemental analysis were taken to represent the variability of each of these sediment units. Results are plotted with depth in the core in Figure 97 on both a total sediment and mineral matter basis. Results of these analyses and duplicate analyses from one sand sample supplied by Mr J Barber are also presented in Table 47. One sample was chosen from each of units 1–5 for preliminary numerological analysis in order to further characterise these basal layers. Samples were labelled A–E from the base of the core upwards and their depths were : A, 245–250 cm; B, 220–225 cm; C, 207–209 cm; D, 200–203 cm; E, 162–166 cm (samples for total elemental and mineralogical analyses are indicated on Figure 96).

Initial differential thermal analyses (DTA) of the untreated coarse fractions (<63) of samples A, B, and E (Figure 98a) do not show the characteristic calcite or dolomite peaks at around 910 ^{0}C as might be expected from the HT-LOI; they have been swamped on the silt-fraction DTA trace by other minerals. Samples B and E exhibit broad endothermic reactions in the region of 250–500 ^{0}C region, both with double peaks. The initial suggestion is that these endortherms may be produced by dehydration reactions of iron oxide minerals or amorphous ferric oxide gels (MacKenzie 1957).

Depth (cm)	Description
0–3	Fibrous, peaty mud, + sedge fragments with some sand
3–8	As above but with higher sand content
8–11	Fibrous, sedge peat
11–12	Sand layer
12–50	Sedge peat with occasional Phragmites rhizomes
50–70	Coarse, amorphous detritus mud
70–78	Fine, detritus mud
78–100	Coarse detritus mud, some of sedge fragments
100–104	Fine detritus mud, some of sedge fragments
104–107	Pale, fine detritus mud with some clay content
107–121	Fine detritus mud; some cf. sedge fragments
121–125	As above but with some clay content
125–135	Fine detritus mud with few cf. sedge fragments
135–185	Fine gytta, darker colour than above
185–187	Organic–clay layer
187–195	Fine gytta
195–208	As above but with sand increasing down the core
208–210	Whitish clay–rich layer
210–213	Transition to fine organic gytta, clay reduced
213–216	Organic gytta layer, clay still present
216–222	Clay layer. 222–229 Organic gytta with clay
229–234	Transitional layer, clay increasing
234–243	Clay, very small organic faction
243–250	Sandy clay with angular, gritty fragments

Table 47. Askernish. Stratigraphy of core

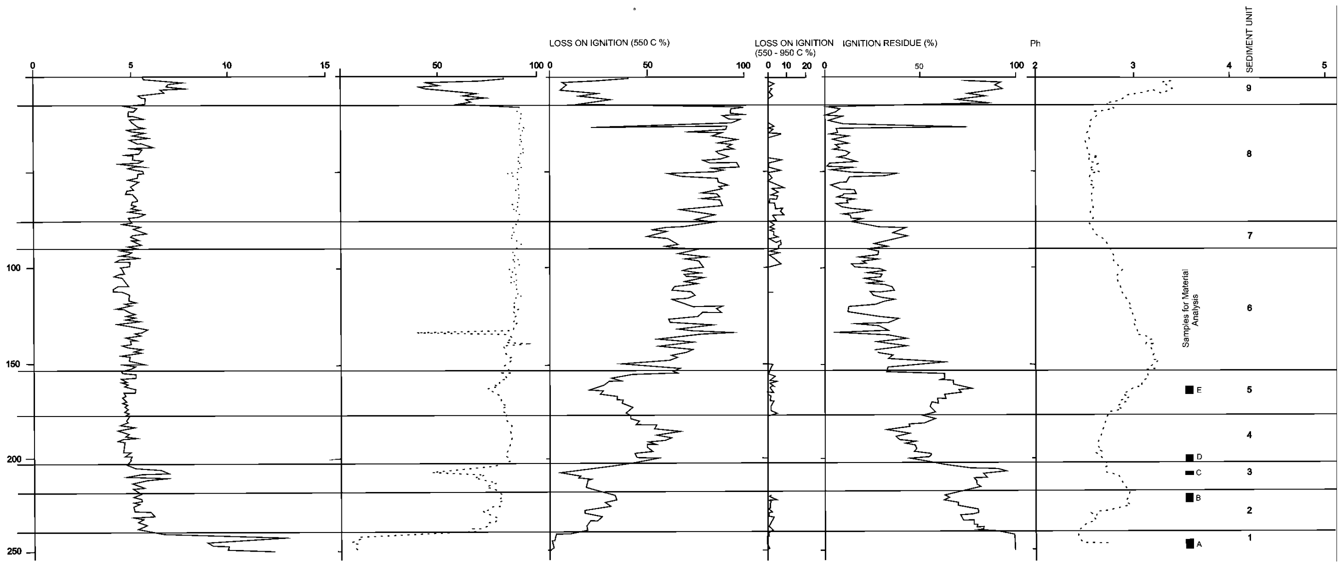

Figure 96. Askernish; sediment characterisation

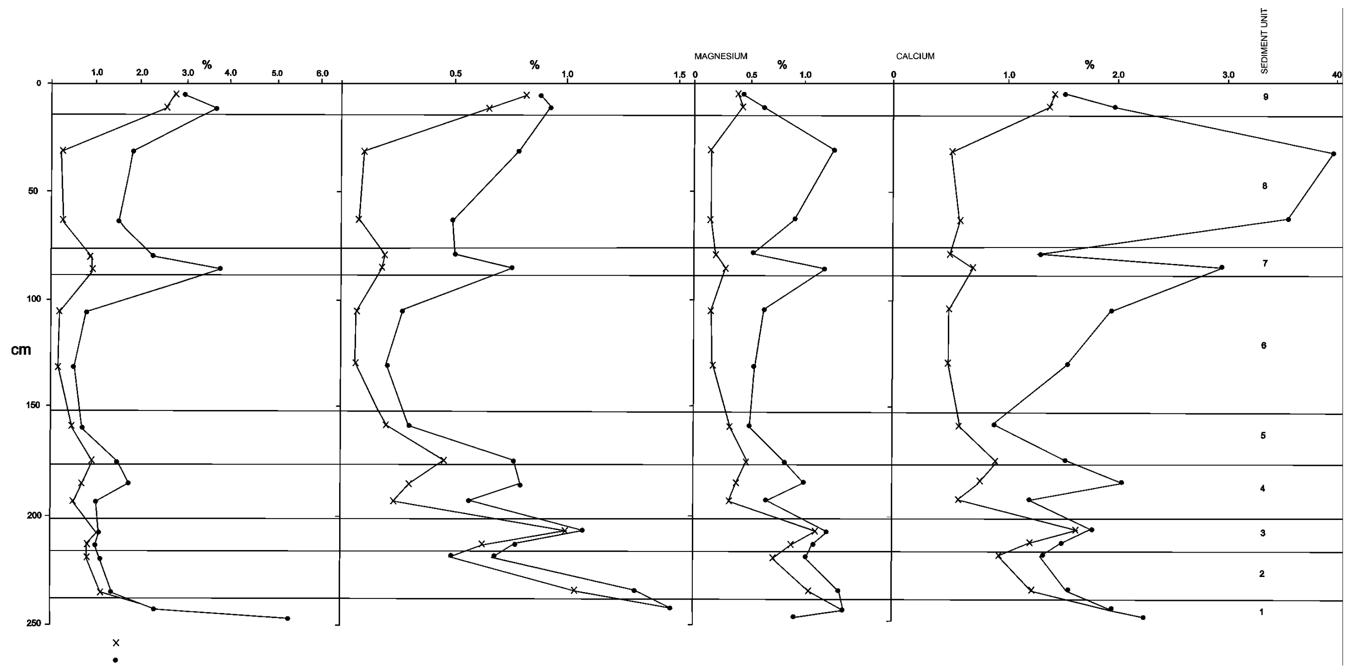

Figure 97. Askernish; chemical analysis

Further analyses were carried out on the clay-sized fraction after ammonium acetate extraction.

The mineralogical analyses distinguish between sediment units 1, 2 and 4 (samples A, B and D, Figure 98b) and 3 and 5 (samples C and E, Figure 98c). The difference may be the result of weathering processes and the different nature of iron deposition which is possibly related to erosional intensities or to a particle size effect causing a sorting of mineral assemblages.

17.2.2 Pollen analyses

Pollen data from Askernish are plotted in the form of a percentage pollen diagram with a column showing the boundaries of the sediment units (Figure 99), and a pollen concentration diagram including selected taxa only (Figure 100). No attempt has been made to zone the Askernish pollen diagram at this preliminary stage. The pollen data are discussed in terms of the depths of pollen spectra.

240–195 cm; The five basal spectra are dominated by Gramineae (17–53%), *Rumex* (5–25%) and *Empetrum* (1–26%). *Salix* is initially high (34%) but falls, whilst Cyperaceae increases from 2% at the base to 43% in the fifth spectrum. *Juniperus* has a peak (16%) at 112 cm.

195–145 cm; Betula increases to 10–16%, *Juniperus* pollen becomes continuously higher here (7–10%) and pollen of *Plantago maritima* becomes more frequent. In contrast, *Empetrum* and *Rumex* pollen is reduced and *Lycopodium selago* and *Polypodium* spores become less frequent.

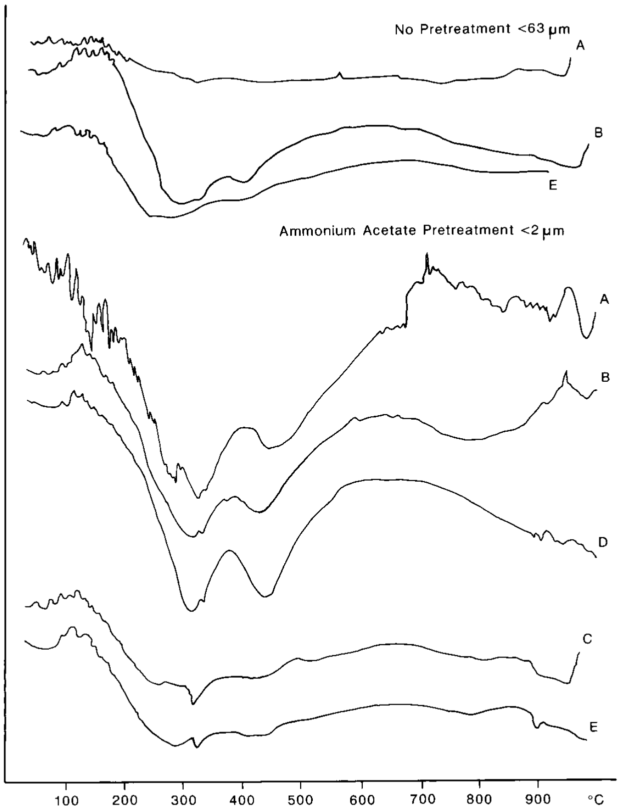

Figure 98. DTA (differential thermal analyses) traces: a) Samples A, B, and E; untreated coarse fractions (<63); b) Samples A, B and D after ammonium acetate extraction; c) Samples C and E after ammonium acetate extraction

145–65 cm; Calluna pollen percentages increase here to a peak of 24% and pollen of Coryloid, *Fraxinus*, *Alnus*, *Quercus* and *Ulmus* either make their first appearance or become more frequent. Gramineae and Cyperaceae pollen percentages are reduced and then *Betula* and Coryloid percentages expand and *Calluna*, *Empetrum*, *Plantago maritima* and *Rumex* become less frequent. Above 84 cm *Betula* and Coryloid decline whilst Gramineae, Cyperaceae and *Calluna* increase again. The charcoal curve becomes continuous above 150 cm and shows a major peak between 138–142 cm.

65–0 cm; The three uppermost assemblages are dominated by the pollen of Gramineae and *Potentilla*, with some Cyperaceae and *Calluna*. Charcoal frequencies are very high in all three spectra.

17.2.3 Discussion

More detailed pollen work is required for definitive correlations and therefore conclusions reached here are tentative. The grass-sedge assemblages with *Salix*, *Empetrum*, *Rumex* and *Lycopodium selago* and the double *Juniperus* peak are similar to assemblages interpreted as late-Devensian from Mainland Orkney, Skye and Mull (Moar 1969; Birks 1973; Walker & Lowe 1982) but are not readily correlated with presumed late-glacial spectra from St. Kilda (Walker 1984).

On this basis the late to post-glacial climatic amelioration of *circa* 10,200 bp (Walker & Lowe 1982) may occur between 200 and 210 cm, at the beginning of the second expansion of *Juniperus*. Species of open ground and heathland were frequent below 150 cm at Askernish, especially *Empetrum nigrum* with *Rumex* spp., *Thalictrum*, *Urtica* and *Epilobium*. *Lycopodium selago* was also present suggesting the availability of local bare-rock substrates. *Juniperus* scrub increased for a brief period, was reduced and then recovered possibly replacing *Empetrum* and *Rumex* spp. as a scrubby heath. *Filipendula,* Ranunculaceae and *Plantago maritima* became more frequent, possibly as members of a tall-herb grassland community. Ferns were present, including *Polypodium*, as was *Sphagnum* witnessing the base-poor status of the local bedrock and substrates from the earliest postglacial birch pollen values of about 10–16% suggest a local presence of scrub *Betula* in sheltered habitats (cf Birks & Madsen 1979).

The pollen assemblages from 150 cm to the base of the Askernish core encompass sediment units 1–5. Chemical analyses indicate that the mineral matter found in the three sediment-units with low LOI values, units 1, 3 and 5 are all essentially similar and probably resemble local substrates. There is a general downward trend in elemental concentrations probably reflecting the onset of weathering processes and the loss of these relatively mobile elements by leaching. Results of mineral analyses support these conclusions with sample A having the most complex mineralogy, whereas C and E are considerably less complicated. An interesting feature of the Askernish core is the third inorganic layer, sediment unit 5, which occurs in the postglacial and suggests a return to an erosional regime for some reason during the *Juniperus* assemblages. Spores of Filicales and *Polypodium*, which are often present in terrestrial soils, increase in frequency at this time.

The increase in *Calluna* pollen at the expense of *Juniperus* at 145 cm is similar to the boundary between zones LLR1b–1c at Little Loch Roag, there dated to approximately 7700 bp. However, the Coryloid and *Alnus* curves begin together at Askernish unlike several local sites; Little Loch Roag, sites from the Inner Hebrides and sites on Western Mainland Scotland (Birks 1977; Birks & Williams 1983; Walker & Lowe 1985; Birks & Madsen 1979). In combination with stratigraphic changes and suddenly increased frequencies of pollen of aquatics and of charcoal, a gap in sedimentation suggesting either erosion of sediments or an hiatus of deposition is indicated. This probably occurred from before the *Juniperus* decline and Coryloid rise dated to 7,900 bp at Little Loch Roag to after the *Alnus* expansion there dated to around 6000 bp. At Askernish, *Calluna* heath replaces *Juniperus* and herbs of open and broken ground, *Plantago maritima*, *Rumex* spp., grasses and sedges. Pollen concentration data indicate that *Empetrum* and *Salix* were also reduced. These events in the pollen record, reflecting the change to more organic sediments after unit 5, suggest a stabilisation of soils occurred, after which soils were rapidly acidified and *Calluna* heath became established.

Attention may be drawn to the correspondence of increased frequencies of *Calluna*, *Melampyrum*, Rosaceae and *Plantago lanceolata* at the time of the major increase in charcoal content of the sediment. In combination these may suggest an early phase of open and broken ground and increased incidence of fire, showing similarities to periods of inferred anthropogenic activity.

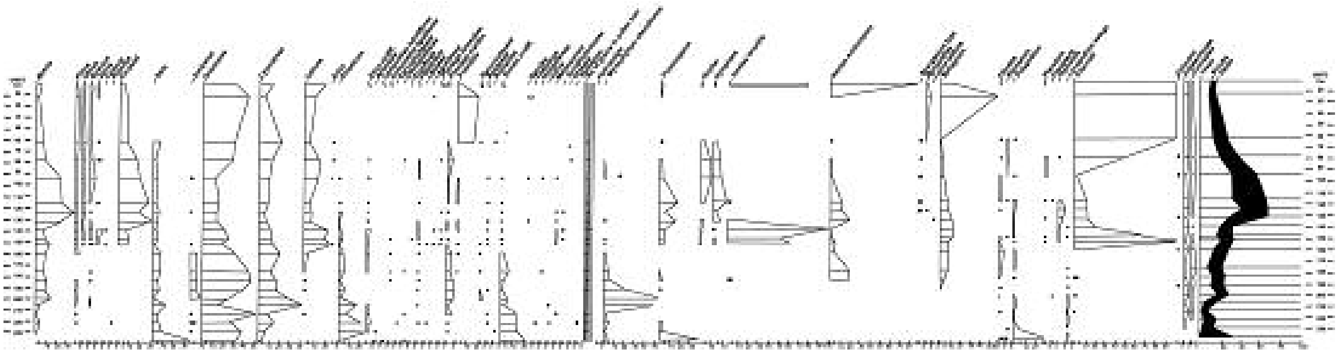

Figure 99. Askernish; pollen percentage diagram

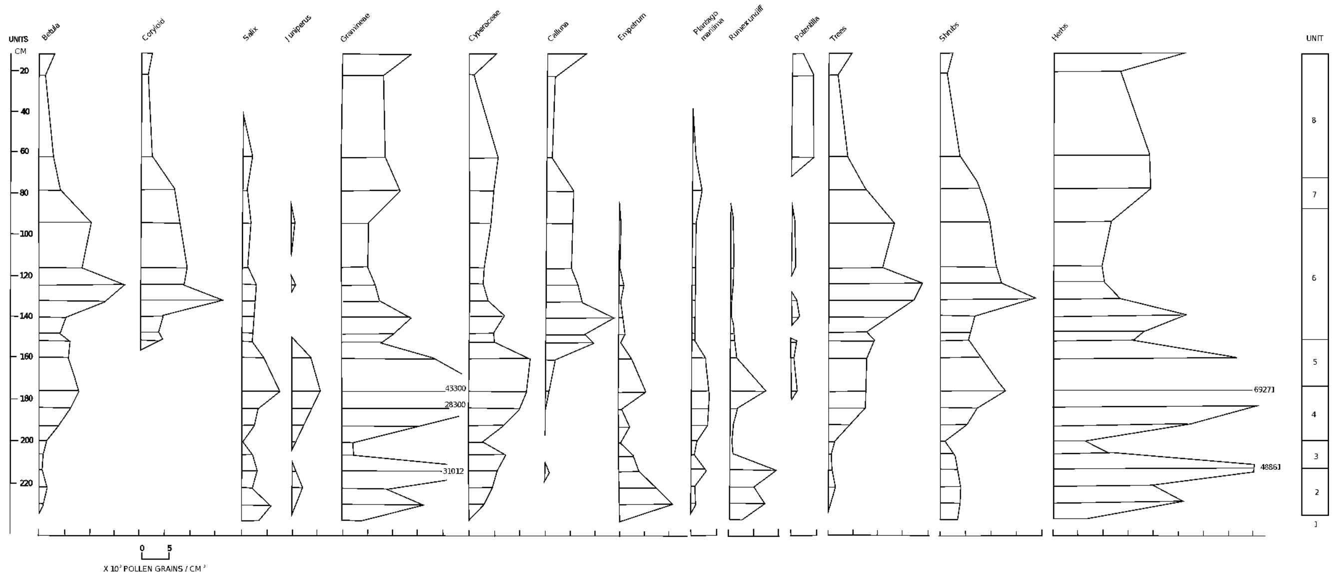

Figure 100. Askernish; pollen concentration diagram

The pollen of *Alnus*, *Ulmus*, Coryloid and *Fraxinus* first appears at 142 cm and *Pinus* and *Quercus* pollen is also present. Pollen of all these tree taxa is found in such low quantities that it is, perhaps, best explained as having been derived from trees present on the Inner Hebrides or the mainland. The expansion of Coryloid and *Betula* to a total in excess of 50% of total tree pollen between 84–132 cm almost certainly indicates a local expansion of birch-hazel scrub. This appears to have taken place at the expense of Gramineae, Cyperaceae, and *Calluna* all of which show a real reduction in concentration terms. *Betula* may have expanded to colonise damper, more acidic areas perhaps with *Osmunda regalis*, *Pteridium aquilinum* and other ferns with *Filipendula*, *Succisa pratensis* and *Rumex* spp. forming an open-herb community. *Corylus* scrub possibly colonised drier or less acidified soils and heath with *Calluna vulgaris, Potentilla* and *Melampyrum* completing the possible vegetation mosaic.

Sediment unit 7 is an inorganic layer which occurs at the time of a reduction in *Betula* and Coryloid percentages where first Gramineae and then *Potentilla* expand. Similar effects might be caused by clearance of birch and hazel and local agricultural activity which could result in the inwash of mineral material into the lake. The chemical data show an important change in the nature of the sedimentary mineral matter towards higher K, Na, Mg and especially Ca above 100 cm, despite the fact that organic matter values increase above *circa* 75 cm. One explanation for this paradox is the possibility that above about 100 cm the loch at Askernish came under the influence of greater aeolian sand and seaspray inputs. Hydroseral changes probably led to the increase in sedge content of the loch-mud and the increased organic content. Although lower in overall concentration, the mineral content is of a different nature to that found in the lower clay and sandy layers being much enhanced with respect to calcium but not potassium.

In sediment units 7 and 9 the chemical data show a closer affinity with the basal clay layers suggesting that these horizons relate to erosional episodes where predominantly till or bedrock substrates have been recruited to the sediments. These conclusions are supported by HT-LOI data which suggest that the major phase of carbonate deposition in the loch was between 45–100 cm, with some evidence for episodic input above this.

The suggestion that aeolian sand was present nearer the site as indicated above 100 cm might have led to a reduction in *Betula* and Coryloid by, perhaps, causing changes in the water table. It is possible that the *Potentilla* increase represented the increased frequency of *P. anserina* a co-dominant or very frequent member of machair peatland or dune-slack communities (Dickinson & Randall 1979). The alternative explanation, that man may have been responsible for the *Betula*-Coryloid reduction is feasible but there are no

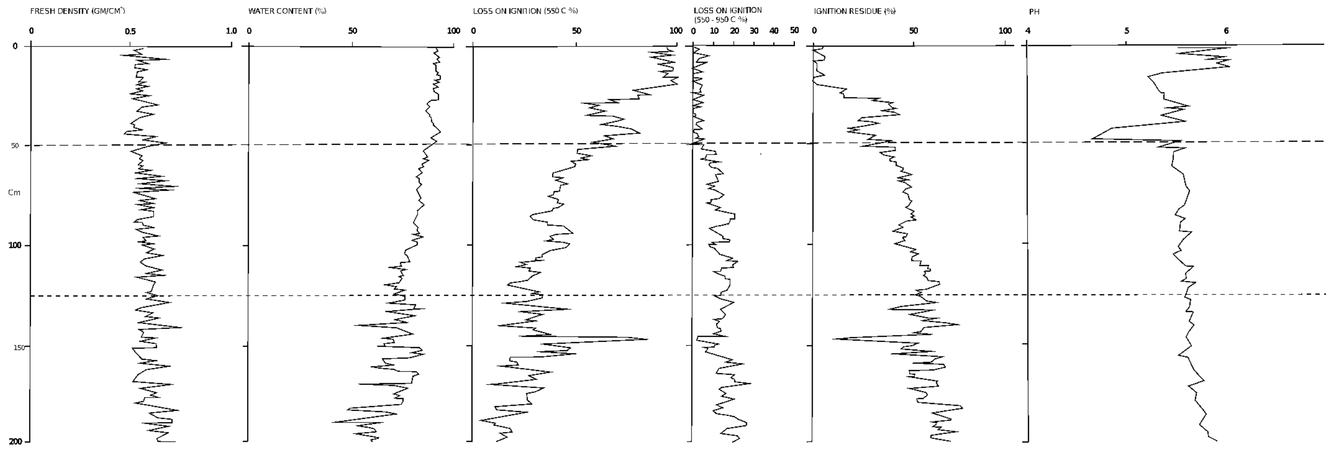

Figure 101. Balemore; sediment characterisation

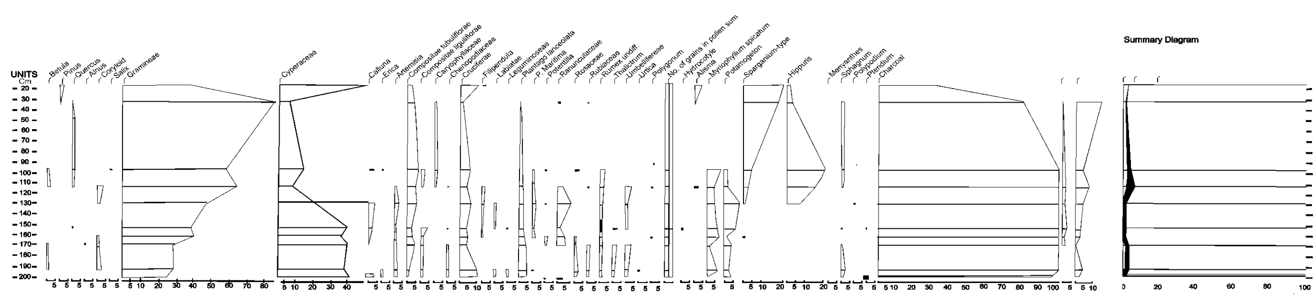

Figure 102. Balemore; pollen percentage diagram

definitive indications of man's impact in the pollen diagram other than, possibly, the charcoal evidence.

Rather similar pollen changes, dated to *circa* 5200 bp, are reported from Loch Cleat, Skye and there are also similarities with evidence from Little Loch Roag after *circa* 5000 bp. Although the causal factors for this change at Askernish cannot yet be determined and correlation with other sites is only tentative, it is interesting to note that Ritchie (1979) considers the major primary deposition of sand to have occurred before *circa* 4500 bp and that redeposition of this material inland took place after *circa* 3500 bp. Independent dating evidence from the Askernish site may be able to tie in this major deflation period for one area of South Uist and provide a link with dated archaeological deposits. On the basis of the data accumulated so far there is no evidence to support the suggestions of several major episodes of sand instability each followed by stabilisation (Ritchie 1979).

17.3 RESULTS: BALEMORE

The reedswamp at about 15 m OD west of Balemore is about 1.2 km inland of the Rubna Mor dunes on North Uist (Figure 92). The site was found to comprise up to 2 m of sediment overlying a base of calcareous sand. The bog was cored approximately at the centre. It is about 300 by 200 m in size and lies south of a road running from the Balemore settlement across the machair. The site is one of a series of lochs and bogs occurring on the seaward flank of a north-west/south-east trending ridge of periodite intrusion running from Craig Hasten through Balranald at the landward edge of the Paible machair. Ritchie (1968) records evidence of recent sand-blowing from south to north in the form of partly-healed blowout scars on the south facing coast at Rubh Arnal. Other evidence for severe sand movements in the area come from accounts of arable farming on machair from Kirkibost Island, in the Statistical Account of 1837 and of large areas of sand lost from the south and west of Rubh Arnal (ibid). At the time of coring there was no open water at the sampling site and the vegetation consisted mainly of *Phragmites* and *Scirpus* reedswamp together with *Iris pseudacorus*. Caird (1979) provides evidence showing that arable agriculture has been important in the machair here since at least 1799.

The stratigraphy of the core was examined in the laboratory and is recorded in Table 48.

17.3.1 Sediments

The core recovered from Balemore can be roughly divided into three sections for the sake of discussion (Figure 101).

i) 0–50 cm. Sediment with the highest LOI of > 50% but lowest HT-LOI (<10%). there is a layer of reduced organic content between about 20–38 cm.

ii) 50–125 cm. Organic matter gradually declines in this part of the core (67 – minimum of 17%) whilst HT-LOI increases to fluctuate between 8–21%.

Depth (cm)	Description
00–50	Coarse sedge peat becoming finer towards the base
50–60	Fine detritus mud
60–90	Fine detritus mud as above with some whole shells and many shell fragments
90–112	Fine detritus mud with some sand, fibres and many shells after 105 cm
112–121	As above but with more shell fragments and whole shells (large whole shell at 120 cm)
121–134	Fine detritus mud with a few cf. sedge fragments, some clay and sand content with shells throughtout but increasing after 125 cm (large shell at 134 cm)
134–140	As above but gradually increasing proportions of whole shells and sand
140–184	Sandy gytta with increased sand content and some cf. sedge detritus. (large whole shells at 147, 148, 163–4, 168, 178 and 184 cm)
184–185	Sand layer
185–198	Sandy gytta with increased sand content and some cf. sedge detritus. Paler in colour below 190 cm
198–200	Almost pure sand with humus

Table 48. Balemore. Stratigraphy of core

iii) 125–200 cm. LOI fluctuates considerably in the bottom 75 cm of the core (5–90%), probably due to the increased incidence of shells and shell fragments. There is a slight increase in HT-LOI, but again the range is large (2–30%).

There is considerably more sand in the Balemore sediments than at Askernish, as might be expected. The sediment changes around 50 cm probably represent the encroachment of macrophytes and the change from open-water to reedswamp.

17.3.2 Pollen analyses

The land-pollen content of the Balemore core was found to be in very low concentrations and the time available for counting only allowed for sums between 100–200. The percentage pollen diagram from Balemore is presented in Figure 102.

Although pollen of *Betula*, *Pinus*, *Quercus*, *Alnus*, Coryloid and *Salix* are present in the Balemore core, the sum of these taxa never exceeds 10% of total pollen and makes the assemblages difficult to correlate with other pollen diagrams. The high grass and sedge frequencies (together never below *circa* 60%) suggest that these assemblages may match those in the upper part of the Askernish core, say above 70 cm although much of the Balemore pollen is probably local.

The pollen data suggest that the immediate vicinity of the Balemore site has been completely open during the period of accumulation of the deposits, what little tree and shrub pollen there is present is most likely to have originated in other parts of the Hebrides or from the mainland. The pollen and stratigraphic record suggests a succession beginning with submerged macrophytes – *Myriophyllum spicatum* and *Potamogeton* spp. – a transitional phase of *Hippuris vulgaris* and finally a phase of *Sparganium* cf. *erectum* or *emersum*.

As Gramineae pollen increases then the records of many herb pollen types decline (eg *Artemisia*, Chenopodiaceae, *Plantago maritima*, *Rumex* spp., *Potentilla*, *Thalictrum*, Ranunculaceae and Umbelliferae). The increase in grass may be hydroseral and it is possible that the large amounts of Gramineae pollen may be reducing the percentages for other herb pollen taxa by swamping. The possibility that the change from Cyperaceae-Gramineae to Gramineae-Compositae tubuliforae is due to other causes such as, for example, increased sand instability, cannot be ruled out. Dickinson and Randall (1979) describe two major types of machair vegetation, a type of unstable dune almost completely dominated by *Ammophila arenaria*, other grasses, sedges and *Bellis perennis* (a Compositae tubuliflorae-type), and a more stable grassland type with much less *Ammophila* and a different range of herbs. Further work involving the differentiation of *Ammophila* pollen from that of other grasses (cf Randall 1977) could contribute to the resolution of this problem here and at Askernish.

17.3.3 Discussion

The markedly different pollen records for the two sites makes comparisons of the Askernish and Balemore data very difficult. The Askernish site possibly reflects a more diverse environment at the machair/blackland transition, whilst local bog and machair grassland vegetation has dominated the pollen input to Balemore with only a limited base-poor blackland component. The much greater influence of shell sand at Balemore is evident from sediment data, especially HT-LOI, and from the aquatic pollen record.

No dating evidence is available for the profiles presented here although a crude outline chronology may be proposed for the Askernish core. Presumed late-glacial sediments at Askernish exhibit an apparently classical tri-partite lithological sequence, but without more pollen analyses these cannot be tied in to existing mainland biostratigraphic profiles. The Outer Hebrides are considered to be outwith the general area of Loch Lomond Advance Ice (Sissons 1977), thus there are no objections to the possible deposition or survival of complete late-glacial sequences in South Uist.

An inorganic layer in the early postglacial sediments at Askernish (unit 5) could relate to a change in local hydrological regime or in the balance between erosion and leaching of local soils. This feature is particularly interesting in view of the growing body of evidence for short-term climatic change in the early post-glacial which seems to be most evident in far-west European sites (Bradshaw 1985). To what extent this erosion episode relates to the postulated hiatus in sedimentation at Askernish and occurring sometime before 7,900 bp until after 6000 bp is difficult to suggest. At St. Kilda, Walker (1984) found an hiatus covering a period from the late glacial until shortly before 6000 bp.

The early phase of increased charcoal frequencies which accompanies pollen evidence suggesting possible anthropogenic activity deserves further attention. Closer pollen sampling, higher counts and secure dating are required to amplify events at that time.

After the stabilisation of soils and the establishment of birch and hazel scrub the pollen record from Askernish suggests a rich diversity of habitats along the machair/blackland ecotone. This period was succeeded by a more open environment as *Betula*, *Salix* and Coryloid pollen was reduced and grasses expanded with *Potentilla*. Changes in the sediments were also evident with a brief erosion phase (unit 7), a second major increase in charcoal frequency, and a general increase in the calcium content of the sediment mineral matter. These were suggested to relate, respectively, to possible clearance of birch and hazel with local agricultural activities initiating erosion, and to a possible movement of sand near to the Askernish site. Further work would be necessary to test the hypothesis that *Betula* and Coryloid were cleared for agriculture, but if so this might have implications for sand stability. Similar pollen changes at Loch Cleat, in northern Skye (Birks & Williams, 1983) have been attributed to clearance activities around 5000 bp, which dates them to soon after the initiation of major sand movements in the Outer Hebrides as suggested by Ritchie (1979). The sediments at Askernish are not excessively carbonate-rich, as are those at Balemore, and could be radiocarbon dated to provide an independent chronology for comparison with available archaeological dates.

Exposure and substrate instability may produce very open landscapes and a major problem of interpretation is that inferences regarding the impact of man cannot be based on the same criteria as are applied elsewhere. More information is needed on pollen dispersal (cf. Randall 1977) and critical indicator species which may reflect agricultural activities in this unique environment. For example Spence *et al* (1979) compared grazed fen and ungrazed islands at Loch Druidbeg and suggested a list of wetland species which are sensitive to grazing pressure, some of which may be useful 'negative' indicator species. Another species which is of prime importance is *Ammophila arenaria*. Its pollen is large and may be confused, on purely size criteria, with that of cereals (Andersen 1979). As *Ammophila* is a critical species in the distinction between the plant communities of stable and unstable sand environments (Dickinson & Randall 1979) distinction of its pollen in deposits from such environments may be rewarding. Preliminary observations at Balemore suggest the continuous presence of *Ammophila*-type pollen but further work is required to complete these analyses.

17.4 PROSPECT

In general the prospect is very good for the use of rock-basin sites for environmental reconstruction of the machair/blackland ecotone. Dating should be possible as the sediments were not particularly calcareous and should be amenable to radiocarbon assay. At the Askernish site, periods of local sand deflation were not immediately obvious from the sediments and were only identifiable from chemical analyses. Presumably the degree of sand-influence on sediments from such rock-basin sites will vary with local sand stability.

Machair lochs such as that studied at Balemore are possibly not so easy to find and to sample. The use of piston corers might be more successful and these might also be able to penetrate sand to sample deeper stratified peat layers (cf Ritchie 1968). The study of deeper lochs to investigate the sediment characteristics might be profitable. Dating of lake sediments from such calcareous situations by radiocarbon is probably impractical. The linear accelerator makes it feasible to consider the possibility of dating macrofossils from terrestrial species whose tissues may not be prone to producing 'hard-water' errors.