Chapter 18 Recent and Pleistocene

Mainland, Muckle Roe and Papa Stour

Introduction

Though Shetland, like the rest of Scotland, must have been covered by ice during all four glacial maxima of the Pleistocene period, it is probable that the glacial deposits and features now seen are largely attributable to the last (Weichselian) maximum. It has long been accepted (Peach and Horne 1879; Finlay 1926b, p. 180) that the Shetland Islands were at some stage covered by ice, which had reached the area from the east and is thought to have originated in Scandinavia. After the connection with the eastward moving Scandinavian ice had ceased to exist the islands were covered by a local ice-sheet which spread out seawards in all directions from the central range of Mainland (Robertson, Geological Survey records 1935; Flinn 1964, p. 338; Hoppe and others 1965, p. 110). This may have involved a series of advances and retreats. The final episode in the glacial history of Shetland was a period of corrie glaciation during which local glaciers were confined to relatively small corries and poorly defined nivation hollows (Charlesworth 1956, pp. 887–91). Only the corries of Foula form marked topographical features (pp. 4 and 171).

In West Mainland of Shetland the westward and north-westward movements of the ice-sheets have produced a less pronounced smoothing-out of the relief than in other parts of Shetland. In the northern parts of the Walls Peninsula, Muckle Roe and the adjoining islands the craggy topography shows some effects of glacial moulding, such as north-west trending ridges and intervening glacially-gouged depressions. The glacial scouring has produced numerous hollows, most of which now form small inland lochs. These are particularly abundant in Northmaven and the northern half of the Walls Peninsula. In the southern half of the Walls Peninsula, where the only recognized ice movement was to the south-west, glacially moulded features are less prominent.

The glacial deposits of Western Shetland consist largely of grey to brownish, generally sandy, clay with abundant stones. This drift occupies many hollows and fills some possible pre- or inter-glacial valleys (p. 272), but appears nowhere to attain a thickness greater than 30 ft (9 m). Ice-transported boulders indicating a west to north-westward ice movement are common in the northern part of the Walls Peninsula, Papa Stour, Muckle Roe and Northmaven. On the island of Papa Stour the remnants of a possible terminal moraine are preserved (p. 272, (Plate 30B).

The evidence for more than one period of glaciation, separated by an interglacial period of milder climate, is at present confined to one section on the west coast of the Walls Peninsula, where boulder clay is locally underlain by a deposit of sand and gravel which fills a pre- or inter-glacial depression and contains a bed of peat (p. 273) up to 18 in (45 cm) thick.

Features and deposits formed by glacial meltwater during the ablation of the ice (pp. 277–8) are sparse.

Raised beaches are not present in the Shetland Islands, and submerged peat deposits have been recorded at depths of up to 30 ft (9 m) below High Water Mark (pp. 280–1). The coastline of Shetland with its long, gentle-sided voes has the characteristic features of a submerged landscape, and a detailed study of the submarine topography around Shetland by Flinn (1964) suggests that in this area submergence may have continued since the last glacial maximum. During the last 6000 years, the sinking of Shetland seems to have been more rapid than in most of the remainder of Britain and it is thought that this may have been, in part, isostatic (pp. 281–2).

Glacial deposits

Boulder Clay

Rather less than half the area of Western Shetland is covered by a thin irregular layer of fairly sandy and generally stony drift (Figure 28). In the northern and central parts of the Walls Peninsula and in the western parts of Muckle Roe and Northmaven, drift deposits are confined to small irregular patches filling depressions between rocky and, in places, ice-moulded hillocks. The drift cover is more continuous in the less rugged terrain along the eastern margin of the sheet, on the relatively flat 'plateaux' of Sandness and Papa Stour, and in the lower ground along the western and south-western coasts of the Walls Peninsula.

Except on the Island of Papa Stour (p. 272) and on the north and west slopes of Sandness Hill (p. 271) where there are morainic mounds and ridges, the drift deposits form thin sheets with a relatively smooth surface and 'feather-off' against the hillsides. The thickness of drift is in most cases less than 10 ft (3 m) and the maximum recorded thickness is 25 ft (7.5 m) (p. 272). The deposit is fairly homogeneous throughout the area and it has not been possible to differentiate between deposits of different ages as has been the case in Northmaven (Chapelhow 1965, pp. 65–6). The matrix of the boulder clay consists of a greyish brown sandy clay, with up to 40 per cent of sand grains set in a clayey base. The deposit is everywhere very stony, with a high proportion of pebbles less than 3 in (8 cm) in diameter, though larger boulders are locally abundant. The pebbles are never well rounded and are seldom strongly striated. Both the matrix and pebbles vary in texture and composition according to the underlying bedrock.

There is invariably a high content of pebbles derived from rocks exposed a short distance to the south-east or east, and in a number of drift sections the debris of the immediately underlying rock is confined to the basal 3 ft (1 m). Thus in the drift-filled hollow cut in rhyolite at Geubery Head on the east shore of Papa Stour, the upper 10 ft (3 m) of the sandy boulder clay contains a high proportion of pebbles of hornblende-schist, vein-granite and sandstone, some of it of Walls type. Local rhyolite clasts are confined to the basal 3 ft (1 m) of the section.

Sections in the sandy boulder clay are seen in a number of roadside pits and in a limited number of coast sections, most of which are not easily accessible. The following were the best and most easily accessible drift sections at the time of writing:

1. Large quarry in drift (50 x 30 yd; 45 x 27 m) on west side of road 2000 yd (1800 m) NE of Bridge of Walls Hotel [HU 277 524]

The quarry is situated near the western edge of a sheet of blanket-drift which occupies the low ground containing the Loch of Murraster and thins out westwards on the slopes of the Hill of Murraster. A section of up to 18 ft (5.5 m) of drift is exposed. The matrix is ochre-brown, composed of 35 per cent sand grains of fine to medium grade set in a clayey base. Of the abundant pebbles, 80 per cent are less than z in (15 mm) in diameter and are composed mainly of grey and purplish sandstone and felsite with rarer clasts of vein quartz, basic lava, black shale and siltstone. The larger pebbles range up to 3 ft (90 cm) in size, and are subangular to subrounded with rare smoothed and striated surfaces. Most of these are of Walls Sandstone; the remainder are, in order of abundance: felsite, porphyry and quartz-porphyry, mica- and staurolite-schist, amphibolite, calcareous mudstone. In the topmost 4 ft (1.2 m) of the exposure only sandstone, microgranite and vein quartz have been recorded.

The lower part of the section exhibits rudimentary stratification and contains indistinct layers of large pebbles with long axes inclined at 25° to the east, which suggests that the ice movement was to the west.

2. Small quarry in drift close to east shore of Seli Voe 200 yd (180 m) NE of Setter [HU 294 483]

The quarry is cut in stony drift which fills irregularities in the rock surface and a section of up to 10 ft (3 m) is exposed. The matrix is of grey silty clay in which there are pebbles up to 1 ft 6 in (45 cm) in diameter of sandstone, dark grey siltstone, and black microfolded shale. There is no indication of stratification and no obvious pebble alignment.

3. Drift sections in road cutting 800 yd (720 m) N of Hestinsetter [HU 290 464]

The cutting exposes 4 to 6 ft (1.2–1.8 m) of stony drift resting on granite. The matrix is ochre-brown silty clay and the clasts range up to 3 ft (90 cm) in diameter. All the larger angular blocks are granite and diorite of the Sandsting Complex. Sandstone pebbles, with some ice-polished faces, form up to 20 per cent of the clasts. Pebbles of metamorphic rock, particularly feldspathized hornblende-schist and amphibolite, are scattered throughout.

4. Quarry at roadside, 550 yd (500 m) ENE of Huxter [HU 180 573]

This small quarry is excavated in stony blanket drift up to 5 ft (1.5 m) thick which overlies Melby Sandstone. The matrix contains a fairly high proportion of sand grains in a clayey base. The clasts range up to 2 ft (60 cm) in diameter and consist of equal proportions of Walls Sandstone and reddish purple siltstone and shale of the Melby Formation. Rhyolite and rhyolitic breccia of local derivation are also common and there are a number of pebbles of metamorphic rock, particularly hornblende-schist, feldspathized hornblende-schist and vein quartz. All of these types are common in the metamorphic rocks of the Walls Peninsula.

Morainic mounds and ridges

North slope of Sandness Hill

A series of small morainic mounds and sinuous ridges are developed on the lower slopes of Sandness Hill [HU 196 564]. The mounds, which occupy the higher ground around the 250 ft (82 m) contour, are up to 300 yd (275 m) long and 150 yd (135 m) wide and are mostly elongated in a north-westerly direction. The ridges, which appear to be the downstream continuations of these mounds, are sinuous and, in some cases, branching, 10 to 20 yd (9–18 m) wide and up to 250 yd (230 m) long. Both mounds and ridges project less than 10 ft (3 m) above the surface of the surrounding drift and one branching ridge partially encloses a kettle hole. The material forming both mounds and ridges is pale brown unsorted gravel with only a slight clayey admixture. The included pebbles are all angular, up to 15 in (37 cm) in diameter, and composed entirely of grey and reddish sandstone. It is significant that pebbles of metamorphic rock, which crops out a few hundred yards to the east, are absent and there is thus little doubt that these deposits are the englacial and sub-glacial deposits of a late local glacier occupying the north slope of Sandness Hill, which had a drainage in a north-westward direction (p. 276).

West Slope of Hill of Melby

On the west slope of the Hill of Melby [HU 174 557] there are two small converging dry channels which are up to 15 ft (4.5 m) deep, with intakes which commence as a number of small depressions (Plate 30C). Immediately below the exits of these channels there is a system of very small highly sinuous ridges and mounds up to 7 ft (2.1 m) high, composed mainly of sandstone debris. It is thought that this small system of channels and ridges may have been formed by sub- and englacial streams within a small residual glacier. The streams were erosive in their upper part where they formed sub-glacial chutes, but deposited their load as eskers in crevasses within the lower part of their course in the ice.

Papa Stour

A north-north-east trending belt of morainic mounds extends across the centre of the island of Papa Stour from Sholma Wick [HU 162 618] in the north via the ground between Dutch Loch [HU 162 607] and Gorda Water [HU 167 607] to the eastern shore of Hamna Voe [HU 166 604] (Plate 30B). The moundy belt is up to 500 yd (460 m) wide and can be traced for over a mile (1.6 km) along its length. Individual mounds have a north–south elongation and vary in size from 30 x 50 yd (27 x 45 m) to 100 x 400 yd (91 x 365 m). Most have a slightly steeper slope facing east than west. The mounds are composed of sandy unbedded drift, which contains some large boulders of sandstone, and the whole morainic belt is covered with scattered blocks of sandstone, conglomerate and rhyolite. It seems possible that this belt is a terminal moraine, marking the position of a halt during the eastward recession of the ice or the westward limit of a local re-advance of the ice sheet centred on Mainland, but the form of the mounds is unusual and in some cases reminiscent of drumlins. Much additional work would, however, be necessary to determine if this deposit can be separated from the 'blanket drift' and if there is any justification for its possible correlation with the drift overlying the peat-bearing gravel of Sel Ayre.

Interglacial deposit

An exposure of bedded sand, gravel and peat, overlain by boulder clay, occurs at the top of a cliff, approximately 350 ft (107 m) above sea level, at Sel Ayre [HU 177 541]. The sand and gravel, which appears to dip gently to the. north-east and of which up to 25 ft (7.6 m) are exposed, fills an east-north-east trending drift-filled valley. The junction between the gravel and the overlying boulder clay is more or less horizontal. The sequence is as follows:

		feet	inches	metres
10	Peat	1	0	0.3
9	Boulder clay, with clayey matrix and angular to subangular pebbles and boulders of Walls Sandstone and rare basic lavas	9	0	2.7
8	Gravel, well-bedded with predominantly angular pebbles set in a silty to clayey matrix	6	0	1.8
7	Sand, pale brown with patchy brown iron staining. Sparse pebbly bands up to 9 in (23 cm) thick, more common at sides of channel	4	6	1.4
6	Sand, black to dark brown, limonite-impregnated and peaty	0	1	0.025
5	Sand, pale ochre-brown, pebbly, locally bleached white; patchily ochre-stained at base	1	4	0.4
4	Peat with scattered round grains and some sandy lenses.	up to 0	1.5	0.038
3	Soft pale clayey sand with thin laminae of clay and peat.	9 in to 0	10	0.23–0.26
2	Peat with scattered sand grains in lower part. Passes laterally into sand with thin peat bands and thickens to 1 m	1	6	0.45
1	Sand with scattered pebbles, base not seen	1	4+	0.4+

It is not known whether the sand and gravel of this exposure is underlain by a lower boulder clay.

The only other recorded peat bed underlying boulder clay in the Shetland Islands occurs at Fugla Ness [HU 312 913] on the north-west coast of North Roe, where peat, up to 5 ft (1.4 m) thick, occurs between two layers of boulder clay, the upper of which is 17.5 ft (5.3 m) thick (Chapelhow 1965, pp. 65–8). The detailed pollen analysis of this peat by Birks and Ransom (1969, pp. 777–96) has shown that it was probably formed during the Hoxnian interglacial stage. The Sel Ayre peat deposit differs from that of Fugla Ness in that it underlies a thick bed of sand and gravel. The overlying boulder clay contains pebbles of basic lavas as well as sandstone and must have been derived from a southeasterly direction, and not from the late local ice centre around Sandness Hill which lies to the north-east. This suggests that the Sel Ayre sand, gravel and peat may also be part of an interglacial deposit. Samples of the peat have been examined by Dr. Birks, who has suggested that the samples are interglacial. They contain large amounts of Ericaceae pollen and several oceanic genera like *Osmunda, Ilex* and *Polypodium.* There is also pollen of *Picea,* a tree not native in Britain today. The pollen analytical similarities between the Sel Ayre and Fugla Ness deposits are very strong and it is possible that both are of Hoxnian age. However, as there are no other interglacial deposits within a few hundred miles, any correlation must be very tentative.

Radiocarbon dates from material collected from the Fugla Ness and Sel Ayre peats have been provided by Dr. D. D. Harkness of the Scottish Reactor Centre. These are as follows :

SSR 59 Fugla Ness (wood within peat):	40 000 + 2000/–1600 BP
	$\delta^{13}C$ = –26.4%.
SSR 60 Sel Ayre (peat):	36 800 + 1950/–1560 BP
	$\delta^{13}C$ = –25.7%.

The date from the Fugla Ness wood is in rough agreement with the dates obtained from this deposit by the Radiological Dating Laboratory, Trondheim (Page 1972, p. 136). These are T—1092 (wood within peat): +900/–800 BP and T—1093 (peat): 37 000 +1200/–1100 BP.

Evidence for directions of ice flow

The information regarding the directions of ice flow has been obtained from the orientation of glacial striae, roches moutonnees, drumlins and other glacially moulded features (Plate 30A), as well as from the distribution of those drift pebbles and erratic blocks whose source can be located with reasonable accuracy. Striae are abundant and well preserved in the northern half of the Walls Peninsula, on Vementry Island, Papa Stour, Muckle Roe and North-maven. They indicate that in these areas the ice moved to the north-west, with local swings to north-north-west and, in Northmaven, to the west (Figure 29). In the southern and western parts of the Walls Peninsula striae are much less abundant. They show that the last ice moved to the south-west in the area extending from Skelda Ness to Gruting Voe and to the west-south-west to south-south-west sector in the ground between Vaila Sound and Wats Ness.

The direction of ice-movement as indicated by striae appears thus to have been not only westward but radially outward from the land area, with ice crossing the present coastline more or less at right angles. The 'ice-shed' between north-west and south-westward moving ice appears however to have lain somewhat south of the centre of the peninsula, more or less along a line extending from Garderhouse in the east *via* the centre of Gruting Voe and Walls, to Setter in the west. The south-west trending striae could be due to a later or local period of ice movement. The absence of any trace of north-west trending striae in the southern part of the peninsula, however, makes this unlikely.

The west and north-westward direction of ice movement in the greater part of the area is amply confirmed by the distribution of drift pebbles and erratics. Blocks of schist and Walls Sandstone from the Mainland are common on Papa Stour. Clousta conglomerate is abundant on Vementry Island and Braga Ness. Serpentine from the outcrop at Houlland at the eastern margin of the area is common in the drift immediately to the north-west and staurolite-schist from the Scallafield Ridge, located just east of the present area, occurs on the west side of Aith Voe. Pebbles of the porphyritic epidote-bearing granite, which crops out east of the Walls Boundary Fault from Aith southwards, are commonly found throughout the eastern part of the Walls Peninsula.

The evidence within the area under description does not give any definite indication of more than one direction of ice-movement. No crossing striae, or striae showing marked divergence within a limited area, have been recorded. Nor is there any indication of two widely distributed boulder clays overlying each other. In some areas, however, the direction of the most likely source of stones and erratics within the drift does not match with the direction of ice-movement deduced from striae. Thus the drift from quarries near Huxter contains pebbles and boulders of hornblende-schist and metamorphic rocks, which crop out east and north-east of their present position, whereas the direction of striae in the area indicates ice-movement from the south-east. The divergence between ice-movement directions deduced from striae and drift content is, however, nowhere greater than 30° and can be explained by possible local topographically controlled variations in the ice-movement or by possible local differences in the direction of movement of various levels within the ice-sheet. Local re-advances of the ice-sheet, such as that which may have given rise to the possible moraine belt of Papa Stour (p. 272) may also account for such variations in the direction of the ice flow.

It is not possible, on the strength of local information, to draw any deductions about the effects of earlier glaciations or directions of ice movement, other than the one observed. No drift pebbles or erratic blocks which could with certainty be derived from a more easterly source than the Scallafield–Weisdale ridge of Mainland Shetland have been found in the Walls Peninsula, suggesting that all observed drift deposits and glacial features in this area were formed during the period when Shetland had its own ice-cap. This ice-cap may have been in contact with the Scandinavian Ice Sheet which lay to the east of the Shetlands. Robertson (Geological Survey records 1935) has shown that in the areas east of the Scallafield–Weisdale ridge all the available evidence indicates that the ice moved to the east, north-east, and north-north-east. The only concrete evidence for the presence of Scandinavian ice in these islands is confined to Southern Shetland where a tonsbergite boulder of a type known to occur in Norway was found (Finlay 1926b, p. 180). It is therefore, unlikely that Scandinavian ice crossed Central Mainland during the last glaciation, and the island may also have had its own ice-cap during earlier glacial maxima.

Corrie glaciation

Deposits and features which give some indication of the stages in the retreat, re-advance, and eventual break-up of the Shetland Ice-Cap, as well as the location of the last local glaciers, are extremely scarce in Western Shetland. Charlesworth (1956, p. 890) suggests that residual glaciers may have existed at the following localities :

1. The north side of Sandness Hill.
2. On the east side of Sandness Hill in the valley between the Burns [HU 204 552] and Trona Scord [HU 210 558] (corrie glacier).
3. The south-west side of Sandness Hill and in Deepdale [HU 184 549] (corrie glacier).
4. The north-west side of the Hill of Melby [HU 180 560] (corrie glacier).
5. The north-west side of Stourbrough Hill [HU 213 527].
6. The north-west side of the Ward of Browland [HU 267 516].
7. The west side of Twatt Hill [HU 289 519] (uncertain).

In the author's opinion, the only areas where the presence of late local glaciers is substantiated by visible features and deposits are the north slope of Sandness Hill and the west slope of the Hill of Melby. In the former area late local ice has left a series of morainic mounds and ridges (p. 271) and in the latter a system of channels and esker-like ridges (p. 272). In neither area are there features which could be compared with true corries.

Glacial retreat phenomena

With the exception of those detailed below Western Shetland is virtually devoid of glacial drainage channels and meltwater deposits which might have formed during the wasting of the last ice-sheet. During the last glacial maximum, the sea level in Shetland may have been 40 to 50 fm (75–90 m) lower than at present (Flinn 1964, p. 337) and as the products and features of ice-wastage are usually concentrated on the lower ground, it can be assumed that in Shetland these are now largely submerged. There are, however, a small number of dry valleys in the area and some of these may have originated as glacial drainage channels.

Examples are (Figure 28):

1. A 328 yd (300m) long N20°E trending peat-filled channel between Mousavord Loch [HU 225 552] and Djuba Water [HU 226 560] with its present thalweg having a gentle fall to the north.
2. A series of branching channels 1250 yd (1140 m) NNW of the Ward of Browland [HU 268 525].
3. A prominent dry curving valley which passes through the village of Culswick to the Stead of Culswick [HU 274 448]. This is about 1 mile (over 1.5 km) long and has a flat alluvium-filled base, locally up to 656 ft (200) wide.

4. A roughly horse-shoe shaped dry valley cut in rock on the eastern side of Cow Head on Vementry Island [HU 308 606]. This is over 656 ft (200 m) long and locally up to 115 ft (35 m) wide. It has an undulating floor which contains at least one small lake.

The lack of glaciofluvial deposits, and other late-glacial features in these areas, makes it impossible to use these channels in any attempt to reconstruct a sequence of deglaciation.

Periglacial and post-glacial deposits

Residual deposits formed by frost action and weathering of the bedrock, such as the block fields (Felsenmeere) on the summit plateaux of Sandness Hill and to a lesser extent on the Ward of Culswick were probably formed during the tundra regime which prevailed immediately after the retreat of the ice.

Deposits which have been formed since the final retreat of the ice include blown sand, lake and stream alluvium, peat, as well as land-slip deposits and scree.

Blown Sand

Wind-blown sand covers an area of about three-quarters of a square mile (2.19 km^2) in south-east Papa Stour and a somewhat smaller coastal strip between the Ness of Melby and the Neap of Norby at Sandness. In both areas the sand is relatively thin [probably less than 10 ft (3 m)] and in Papa Stour a number of rocky ridges and hillocks project through the otherwise smooth surface.

Lake and river-alluvium

The core sampling of post-glacial deposits of Shetland lochs by Hoppe and others (1965; pp. 5–6) has shown that the thickness of unconsolidated silts and organic mud in the three sampled Western Shetland lochs is as follows (Figure 28):

Stanevatstoe Loch [HU 216 545] 3.0 m
Upper Loch of Brouster [HU 262 520] 4.5 m
Lower Loch of Brouster [HU 260 514] 3.5 m

The sediments consist of muds and silts with a fairly high but variable organic content. Radiocarbon measurements of the basal post-glacial lake sediments have been carried out by Engstrand (1967, pp. 413–5) and the following dates were obtained:

Stanevatstoe Loch	(Altitude 80 m OD). Core sample from 382 to 389 cm below upper surface of sediment. 9725 ± 265 BP.
Upper Loch of Brouster	(Altitude approx. 3 m OD). (a) Core sample from 400 to 404 cm below upper surface of sediment. 8760 ± 250 BP. (b) Core sample from 440 to 450 cm below surface of sediment 9670 ± 540 BP.
Lower Loch of Brouster	Core sample from 345 to 350 cm below upper surface of sediment. Originally dated as 15 080 ± 850 BP, but revised by Ollson and others (1967, p. 460) to 7700 ± 600 BP and 7600 ± 600 BP (two samples).

These dates are as yet unsupported by pollen analyses or other evidence. Hoppe and others (1965, p. 111) came to the provisional conclusion that the date of the earliest lake deposits in Shetland is approximately 10 000 BP or 'a thousand or thousands of years older' and suggested that this may indicate that Shetland became free of ice during the Allerod interstadial or possibly slightly earlier. The revised age of the Lower Loch of Brouster sample and the re-dating of the C^{14} ages of other Shetland loch samples may, however, necessitate a reassessment of this estimate.

Owing to the absence of any sizeable rivers in Western Shetland, fresh-water fluvial alluvium is confined to small areas flanking streams such as the Burn of Mirdesgil [HU 186 577] north of Melby, the Burn of Trona–Scord [HU 204 577], the

Burn of Turdale [HU 198 500], the Burn of Setter [HU 205 497] and the Burn of Selivoe [HU 302 489]. The valley at Culswick (p. 277), now virtually without a stream, is also floored by alluvium. No detailed examination of these sediments has been carried out.

Peat

Peat, almost entirely of the blanket bog type, covers nearly 40 per cent of the area of the Walls Peninsula, Vaila and Papa Little (Figure 28). In the part of Northmaven within the area under description and on Vementry Island it is restricted to a few areas of limited extent. On Papa Stour the thin peaty turf which once covered parts of the island has long since been completely removed for fuel.

Blanket bog covers extensive areas in the west and south-east of the Walls Peninsula. Its thickness does not normally exceed 5 ft (1.5 m), but in hollows and valleys up to 19 ft (5.8 m) of peat have been recorded. The stratigraphy and vegetational history of this peat has been studied by Lewis (1907, pp. 50–4; 1911, pp. 796–803) who established a correlation of the vegetational zones within the peat of Shetland with those in other parts of Scotland, and was able to draw a number of conclusions about the post-glacial climatic and vegetational history of the area. No recent research has been carried out on the pollen chronology of the Shetland peats and it is not yet possible to correlate Lewis's sequence with the Scottish pollen sequence.

Lewis noted that in Western Shetland the peat can be divided into the following two major groups:

1. A lower stratified peat which occurs in certain valleys and hollows and on the plateaux of the higher hills, and
2. an upper unstratified peat, which has a very much greater extent and which in many areas rests directly on weathered boulder clay.

Lewis established the following sequence of vegetational zones within the lower peat:

5	Second Arctic Bedwith *Salix reticulata* Linnaeus, *S. arbuscula* Linnaeus, *Empetrum nigrum* Linnaeus and *Betula nana* Linnaeus. Locally overlain by a bed of diatomaceous earth.
4	Lower Peat Bog, up to 7 ft (2.1 m) thick, with *Sphagnum* sp., *Scirpus caespitosus* Linnaeus, *Eriophorum vaginatum* Linnaeus, *E. angustifolium* Honckney and *Molinia caerulea* (Linnaeus) Moench.
3	Forest Bed, with remains of large trees of *Betula alba* Linnaeus and *Corylus avellana* Linnaeus. Correlated by Lewis with the lower Forest Bed of the Scottish Mainland.
2	First Arctic Bed, 1 ft to 1 ft 6 in (30–45 cm) thick, with *Salix reticulata, S. herbacea* Linnaeus and *Betula nana.*
1	Basal peat with aquatic plants including *Potamogeton pectinatus* Linnaeus, *Menyanthes trifoliata* Linnaeus, *Viola palustris* Linnaeus, *Ranunculus repens* Linnaeus and *Equisetum* sp.Thought to have formed in small marshy pools scattered over the surface of the tundra, and believed to be contemporaneous with the First Arctic Bed.

Lewis recorded remains of the Forest Bed as far west as Simli Field [HU 188 513] and Blouk Field [HU 179 536], close to the western cliffs of the peninsula, and concluded that the climatic regime at that time must have been very different from the present climate with its abundant strong westerly winds.

The upper, unstratified peat consists of the remains of *Sphagnum* sp., *Callum* sp., *Scirpus* sp.,and *Eriophorum* sp.,and Lewis believed that this has formed without interruption to the present day.

At present, peat is rapidly being eroded by wind and water. In areas with an almost complete peat cover, the peat is cut by large numbers of sub-parallel channels up to 10 ft (3 m) deep and 15 ft (4.5 m) wide, which in many cases form branching networks. Lewis has found that the upper peat is less affected by denudation than the lower peat.

The only area of peat in Shetland Mainland which has been surveyed by the Moss Survey of the Scottish Peat Committee with a view to possible commercial exploitation is the 'Kame Bog' in Pettadale, situated between Sand Water and Petta Water, 1.25 miles (2 km) ENE of Aith and outside the area described. The peat of Pettadale occupies a depression and is rather thicker than most of the blanket bog of Western Shetland, but its profile, plant associations, moisture content, degree of humification and other properties are no doubt similar.

The following description of the Kame peat is based on the account on pp. 85–100 of Scottish Peat Surveys, vol. 4 (Department of Agriculture and Fisheries for Scotland, 1968).

'The peat of Kame bog ranges in thickness from 1 in to 6 m. Like all Shetland peats it has an upper section, up to about 15 cm thick, of light brown peat which has a low degree of humification. The greater part of its profile is uniform amorphous black peat with no recognizable structure and with a high degree of humification. Wood has been recorded in the basal 0.5 to 1.5 metres of the peat in a number of sections. The unstratified peat is composed largely of the remains of bog mosses (*Sphagnum* spp.) together with (in order of abundance): cotton grass (*Eriophorum* spp.),heather (*Calluna* sp.), sedges (*Carex* spp.) and, locally, woolly hair moss (*Rhacomitrium lanuginosum* (Hedwig) Bridel). The remains of the latter are generally present in the upper 1.6 m of the peat only. They are relatively unhumified and are not a significant peat former elsewhere in Scotland. The species of wood at the base of the Pettadale Moss were not determined. The degree of humification in the bog was found to vary from H2 to close on H10, the average for the whole bog being H7. The lower values occurred near the surface and, occasionally, at the bottom of the peat. The average moisture content was estimated to be 853 g of water per 100 g solids, which is drier than might be expected in the prevalent climatic conditions and may be due to the good natural drainage of the bog. The average ash content of the bog was found to be 3.78 per cent, increasing slightly towards the base. In one borehole the peat was found to be underlain by 2 m of diatomite, some of which was also present in the basal 1 m of the peat.'

Diatomite has been found elsewhere in small pockets below peat but none has so far been recorded below the peats of Western Shetland.

Post-glacial changes in sea level

Finlay (1930, pp. 672–3) referred to the continuous slope of the sea-floor to the fifty fathom contour, the lack of a submerged shore platform and the presence of peat bogs flooring the voes and shallower straits, all of which are evidence for a continuous submergence of the land in post-glacial times. He also quoted local traditions which indicate that submergence has continued during historic times. Thus the sound between Muckle Roe and Mainland, now spanned by a bridge 100 yd (90 m) long, was said to be at one time fordable at low water, and a crofter's steading on its shores is now covered by shingle.

Flinn (1964, pp. 321–39) has suggested that the Shetland Islands are the summits and upper slopes of a range of hills rising from the gently undulating plain of the North Sea floor, some 67 fm (122 m) below sea level. The present coastline of Shetland has many features characteristic of recent submergence, the most obvious being the ria-like voes which are drowned drainage basins. The abundance of spits and bars, known locally as 'ayres', in many voes (where some have cut off the head of the voe and formed a fresh-water lake) as well as between islands, is a feature of both emerging and submerging coastlines.

A characteristic feature of the sheltered shores of the voes is the presence of submerged peat, in many instances covered by a thin layer of shingle or sand. The best examples in Western Shetland occur in the bays on either side of the headland of Mara Ness, on the west shore of Gruting Voe [HU 268 495]. This peat is exposed between the high and low water marks and is partially covered by shingle.

Submerged peat has been recorded during excavations in other parts of Shetland at Lerwick Harbour (Finlay 1930, p. 673), Scalloway, Bressay, Graven (Sullom Voe) and Symbister in Whalsay (Hoppe 1965, pp. 195–7). At Lerwick Harbour peat with tree stumps occurs at a depth of 21 ft (6.4 m) below high water mark and in Symbister Harbour peat was found between 28 and 29 ft (8.6 and 8.9 m) below high water mark. Five radiocarbon dates obtained from the peat samples from Symbister Harbour (Hoppe 1965, p. 201) range from 5455 BP to 6970 BP. Hoppe considers that the Symbister peat was formed *in situ* and that some 5500 years ago sea level in Whalsay was at least 29 ft (9 m) lower than at present.

In an evaluation of published data relating to the world-wide post-glacial eustatic rise in sea level, Hoppe concludes that at 6000 BP the average sea level throughout the world was probably about 16.5 to 23 ft (5–7 m) lower than at present. The considerably lower sea level 5500 years ago in Shetland thus indicates that there has been either, (a) a eustatic rise in sea level as great as the highest recorded elsewhere, or (b) more likely, an isostatic contribution to the submergence.

The concept of the continued isostatic sinking of Shetland after 6000 BP is also favoured by Flinn (1964, p. 338). He states that the isostatic depression of Scotland and Scandinavia during the glacial maxima was probably accompanied by peripheral uplift which affected the Shetland area, as this lay between the two ice-sheets, and that part of the submergence observed in Shetland is probably due to recovery from this peripheral uplift.

Flinn (1964, fig. 1) has produced a contour map of the sea-floor around Shetland, which is based on Admiralty charts and Admiralty 'fair charts' which cover areas of limited extent and show about 100 soundings per square mile, supplemented by a number of echo traces. He has recognized the following major topographic features in this sea area (Figure 29):

1. A 45 fm (82 m) shelf which forms an extensive platform south-west of the Walls Peninsula and includes the sea-floor around Foula. It also forms a ledge extending from Papa Stour and the Ve Skerries northwards to Esha Ness, which cuts off the deep St Magnus Bay basin.
2. A 25 fm (45 m) shelf, which forms several shoals on the 45 fm (82 m) shelf and includes the bank extending from the Ve Skerries to Foula and the arcuate shelf extending for 8 miles (13 km) eastward from the latter island.
3. A 13 fm (24 m) shelf, which is generally narrow and not always recognizable on the 'fair charts'.

Though there is also a possibility that near some semi-sheltered coasts a shelf exists at 5 fm (9 m), it is probable that on most coasts the cliffs plunge at a reduced angle, but without an intervening shelf, to about 13 fm (24 m).

Flinn believes that these shelves are not drowned wave-cut platforms, as they do not have smooth upper surfaces. He concludes (1964, p. 332) that there is probably only a single surface of marine erosion formed during a lengthy period of continuously rising sea level and that the shelves may mark the existence of wave-cut erosion surfaces that were already present before the last submergence of the land took place. These shelves would have been modified by sub-aerial erosion and glaciation. Flinn tentatively suggests that platforms of this type occur also at 200 to 250 ft (60–76 m) and 500 to 550 ft (152–167 m) above the present sea level.

On the west side of the Shetland sea area, the 45 fm (82 m) shelf is bounded by a gentle slope whose margin extends along a straight line from a point 3 miles (5 km) W of Esha Ness to a position 7 miles (11 km) NW of Foula. This slope descends gently to the 80 fm (150 m) contour and then more steeply to 120 fm (220 m). Between Papa Stour and Esha Ness the 45 fm shelf is bounded on the east by a steep drop into the St Magnus Bay basin which has a maximum depth of 87 fm (159 m). This basin has steep sides between 50 and 70 fm but a more gently sloping floor below that depth. Flinn originally thought that, like the 'deep' between Whalsay and Yell, the St Magnus Bay 'deep' is the result of glacial overdeepening, but he has more recently (Flinn 1970, p. 131) considered it to be a possible meteor impact crater Flinn also recorded the presence of a number of possibly glacially overdeepened troughs just east of this basin. The Swarbacks Minn trough between Vementry and Muckle Roe is up to 50 fm (90 m) deep. Another depression in the sea-floor commences 5 miles (8 km) S of Skelda Ness (the southern tip of the Walls Peninsula). This is a N10°E trending trough, which is up to 70 fm (128 m) deep and marks the probable southward continuation of the Walls Boundary Fault along the sea-floor.

Foula

The island of Foula has considerably greater relief than West Mainland and was probably never completely overridden by the ice from the east (Finlay 1926a, p. 564). It contains two high 'hanging' corries on the northern face of the ridge extending from the Kame *via* the Sneug to Hamnafield, and a lower corrie forming the Netherfandal just east of Wilsie. The west-north-west trending depression between Hamnafield and the Noup, known as the Daal, may be another glacially deepened valley whose corrie-head, possibly originally sited just south-west of the present shore, has been removed by the rapid retreat of the sea cliffs due to marine erosion. These corries were the sites of local corrieglaciers which flowed first in a general eastward direction and were then diverted to north-north-west or south-south-east, probably by ice approaching Foula from the east as indicated by erratics (p. 283).

Drift deposits and glacial erratics

Sandy boulder clay forms a cover of very variable thickness along the northern and eastern coastal platforms of the island. The drift blanket extends inland at Ham and along the low ground around Hametun into the floor of the Daal.

Excellent sections in the drift are seen along the north shore of the island between Ness and Logat Head [HT 959 415], on the east shore just south of Baa Head [HT 976 385] and on the north shore of Ham Voe [HT 975 388]. In the first two localities the drift rests on a rock surface with well developed striae trending W5°N to W10°N.

The section on the north shore is as follows:

	feet	metres
Fine silt, thinly bedded, dark brown, with small pebbles, probably water-deposited	4	1.6
Sandy boulder clay, reddish brown, stony	25	7.6
On striated pavement of sandstone.		

In this section, the larger boulders are almost entirely of grey and brownish sandstone. Among the cobbles up to 1 ft (30 cm) in diameter, metamorphic rocks are common. These include mica-schist, hornblende-schist, granulitized gneiss, pegmatite and microgranite. There are also small well-rounded quartz pebbles (some red and amber-coloured) derived from a pebbly sandstone. Rare pebbles of epidote-granite are present. The pebbles of metamorphic rock occur only in the lower 15 ft (4.6 m) of the section. Many deep scratches in the striated pavement taper out eastwards.

On the south-east shore of Baa Head 10 ft (3 m) of tough reddish brown sandy boulder clay are exposed. This boulder clay rests on metamorphic rocks, but in contrast to the drift seen on the north shore, its most abundant pebbles are grey and purplish sandstone. There are also numerous small rounded pebbles of orange and amber-yellow quartzite, black chert and pink microgranite derived from the local pebbly sandstone (p. 173). Pebbles of metamorphic and igneous rock, also present throughout the section, include hornblende-schist, pegmatitic granite, microgranite and greenish porphyritic epidotic granite.

Erratic blocks are abundant along the eastern and south-eastern coastal stretch of Foula. The most conspicuous are of epidotic granite, which bears a close resemblance to the Spiggie Granite which crops out just east of the Walls Boundary Fault on Shetland Mainland and forms a series of islands extending from Sandsound Voe southwards along the west coast of Shetland to Spiggie. The quartz and chert pebbles derived from the pebbly bands in the Foula sandstone are abundant on the surface of the drift, particularly in the Hametun area.

All drift deposits of Foula contain both metamorphic rocks and sandstone. As the distribution of rock outcrops on the sea floor around Foula is not known in any detail, no deduction as to direction of ice-movement can justifiably be made from the pebble content. Finlay (1926a, p. 564) suggested that the pebbles and erratics of porphyritic epidotic granite of the type found at Bixter Voe (i.e. Spiggie Granite) indicate that ice from Shetland Mainland reached Foula. The abundance of epidotic granite within the drift, however, makes it more likely that this rock was derived from an outcrop, now submerged, which is very much closer to Foula.

Corrie glaciation

The three corries in north-west Foula have more characteristic corrie shapes than any others in the Shetland Islands and were without doubt formed by local ice. The Overfandal Corrie has an arcuate terminal moraine which dams the Overfandal Loch on its hanging eastern side. A shallow north-north-west trending depression extends from Logat Head on the north coast to the shore at Hametun in the south-east and is bounded by truncated spurs and hanging corries on the west and by a series of low north-north-west trending ridges on the east. This, together with the distribution of erratics, suggests that the ice from the conies was deflected both north-westwards and southwards probably by the ice which occupied the sea area to the east of Foula.

Alluvial deposits

No alluvial sand and gravel is present on Foula, but on the low ground the boulder clay is locally overlain by a thin deposit of bedded silt, clay and sand (p. 284) which appears to be of fresh-water origin. A patch of fresh-water alluvium of considerable size is present in Hametun.

Peat

Peat covers most of the lower part of the island and a very thin peat cover is present at altitudes of up to 1200 ft (366 m). Lewis (1911, pp. 805–6) examined sections in the neighbourhood of the Flick Lochs [HT 950 402], at Bark Hill (Overfandal) [HT 957 398] and on the lower ground in the eastern part of the island. He found that the remains of birch are present in nearly all sections where the peat is more than 8 ft (2.4 m) deep. The general sequence in the peat is the same as that found in Shetland Mainland (pp. 278–9), but in a section near the Flick Lochs Lewis recorded a distinct layer containing *Juniperus commumis* in the peat between the Second Arctic Bed and the more recent peat above. This Juniper-bearing horizon is said by Lewis to occupy the same relative position as the Upper Forest (*Pinus sylvestris*)bed in the south of Scotland, and Lewis suggests that the presence of the remains of the Upper Forest bed only in Foula within the Shetland Group may possibly be attributed to the greater height of the hills in the island.

Between Ham and the Mill Loch the peat is locally underlain by a thin deposit of diatomaceous clay.

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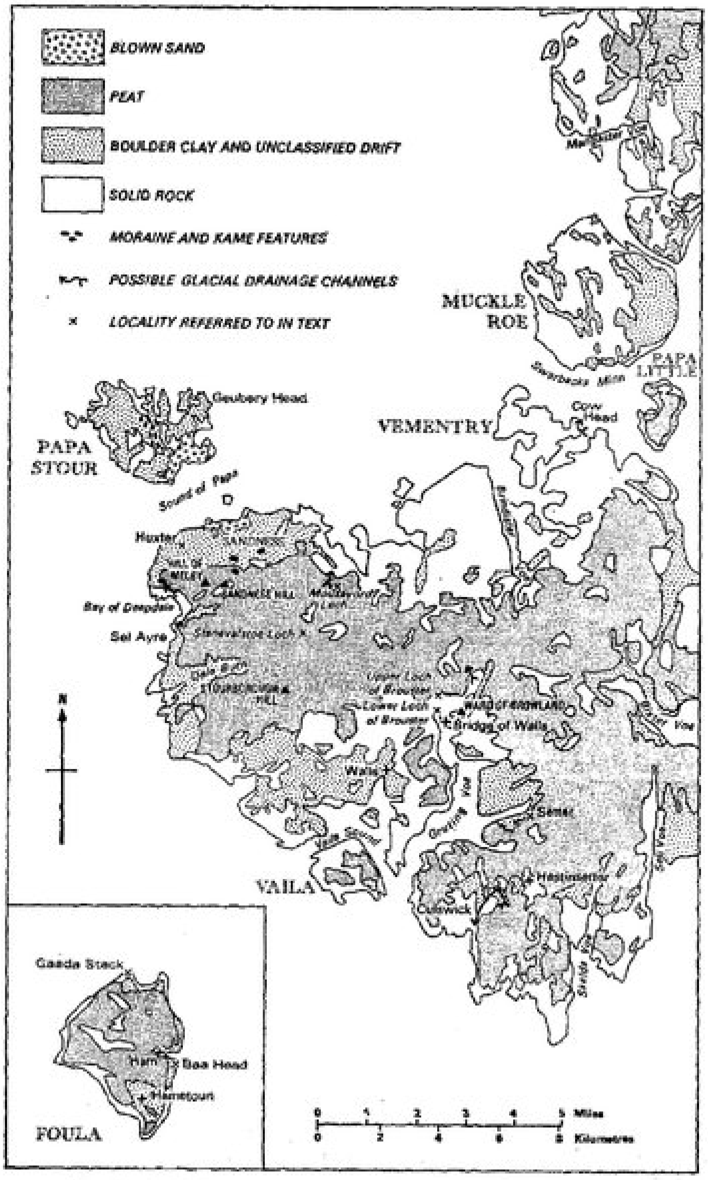
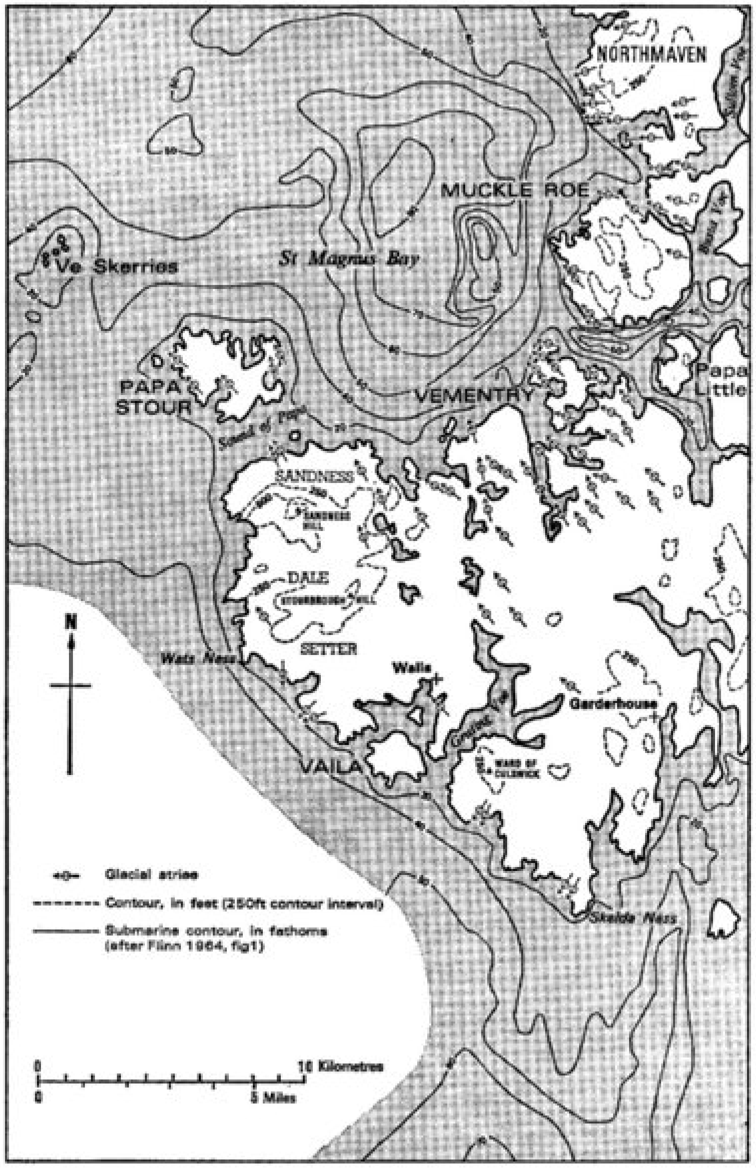
(Plate 30B) Interior of Papa Stour, looking south from hillside west of Culla Voe [HU 167 618]. Belt of morainic drift extending north-south across island from Culla Voe to Hamna Voe. Sandness Hill in background. (D931).



(Figure 28) Superficial deposits and possible late-glacial drainage features.

(Plate 30C) Western slope of Hill of Melby [HU 172 555]. Ramifying system of small meltwater channels. (D901).

(Plate 30A) Crooie Geo, north-west coast of Vementry Island [HU 286 617]. Striated and ice-moulded pavement of metamorphic rocks. Direction of ice-flow from left to right. (D916).



(Figure 29) Glacial striae in Western Shetland, also topography of land and surrounding sea floor.