Chapter 10 Old Red Sandstone: Melby Formation

Introduction

The rocks of the Melby Formation occupy an area of approximately one square mile (2.6 sq. km) in the north-west corner of the Walls Peninsula ((Plate 12), (Figure 16)). They are separated from the sediments of the Sandness Formation and the Walls Peninsula metamorphic rocks by the north-east trending Melby Fault. For part of its course at least, this fault is a reversed fault. It is inclined at 600–70° to the south-east at Hesti Geo, where it is bounded on its northwestern side by a 300-yd (270-m) wide zone of intensely folded, sheared and somewhat indurated sediment. The possible transcurrent nature of this fault is discussed in Chapter 17.

Though there are a number of gaps in the shore section along the north coast both west and east of Ness of Melby, there is sufficient evidence (p. 147) to support the conclusion reached by both Finlay (1930, p. 676) and Knox (Summ. Prog. 1934, pp. 72–3) that the rocks cropping out north-west of the Melby Fault form a single structural and stratigraphic unit. If the large-scale faulting within the outcrop of the formation is confined to the narrow zone bounding the Melby Fault the sequence within the Melby Formation must be similar to that as shown in (Figure 17). This suggests that the total exposed thickness may be about 2500 ft (760 m). At the top of the formation there appear to be two groups of flows of silicified rhyolite or ignimbrite, the lower of which thins out southwards. It is possible, however, that the two outcrops of rhyolite are parts of the same group of flows repeated by a fault trending sub-parallel to the Melby Fault.

The lower part of the sequence contains two thick bands of pale grey sandy siltstone and shale with carbonate-rich ribs and nodules, which have yielded fish remains and abundant plant fragments and are known as the Melby fish beds. Though Knox (Summ. Prog. 1934, p. 73) considered that only one fish bed is present in the Melby area, the field evidence leaves no doubt that there are two fish beds separated by just over 300 ft (90 m) of predominantly arenaceous sediment. Watson (1934, pp. 74–6) compared the fish from Melby with the Middle Old Red Sandstone fish faunas of Orkney, Caithness and other parts of Scotland and concluded that one of the Melby genera, *Pterichthyodes,* occurs elsewhere only at the Achanarras horizon of Caithness and in the Stromness Beds of Orkney which contain the Sandwick Fish Bed (Wilson and others 1935, p. 14). Most of the other forms found at Melby are also present at these horizons. The Melby fish beds have thus been roughly equated with the Sandwick and Achanarras fish beds, which are thought to be of basal Givetian age (Weston 1937, p. 38; 1951, table iii; Waterston *in* Craig 1965, p. 291).

Both Finlay (1930, p. 676) and Knox (Summ. Prog. 1934, pp. 72–3) believed that the two groups of rhyolite flows exposed at Melby are the equivalents of the rhyolites of Papa Stour and that the Melby sandstones are stratigraphically below the Papa Stour volcanic rocks. Flinn and others (1968, p. 15) have, however, suggested that such a correlation is not justified and that there may be no stratigraphic connection between Papa Stour and the Mainland. The present author believes that the correlation of the Melby and Papa Stour volcanic rocks is a reasonable one.

The small islands in the Sound of Papa, Holm of Melby and Forewick Holm, are formed of sediments and igneous rocks which are considered by the author to belong to the Melby Formation. Forewick Holm consists of two flows of rhyolite separated by tuffaceous sandstone and is described in the chapter dealing with Papa Stour (p. 169). The Holm of Melby is formed of flaggy, in part calcareous sandstones, pebbly tuffaceous sandstones and one lenticular flow of basalt (p. 153). There is no direct evidence bearing on the stratigraphical relationships between these beds and the rocks of Papa Stour and Melby. They may form a link between the basalts and tuffaceous sediments underlying the Papa Stour rhyolites and the sediments below the Ness of Melby rhyolites.

Stratigraphy

The sediments below the Melby rhyolites can be divided into the following two lithological groups (Figure 17):

1. A lower group approximately 600 ft (180 m) thick. This contains the two fish beds in a predominantly arenaceous, fluvial, sequence which was deposited by currents from the west or west-north-west.

2. An upper group containing some thick beds of pinkish feldspathic sandstone with clasts of pink rhyolite and many plant fragments, as well as thick beds of purplish sandy siltstone. This group appears to have been deposited by currents from the east-north-east.

The two groups are separated by a gap in the shore exposures 610 yd (570 m) NE of Huxter. South-west of Huxter the boundary between the two groups is taken at the top of the Upper Melby Fish Bed.

Strata below Lower Melby Fish Bed

The strata below the Lower Melby Fish Bed are exposed in an excellent, easily accessible section on the shore north of Huxter, between the Ayre of Huxter and Lang Rigg. The sequence is shown graphically in (Figure 18). Two units are present as follows:

The Lower Unit

The Lower Unit is 65 ft + (20 m +) thick and composed of soft reddish brown-weathering medium-grained feldspathic sandstone with thin subordinate siltstones. The cross-bedded sets in the sandstone range in thickness from 2 to 10 ft (0.6–3 m). Cross-bedding is predominantly planar and most foresets are inclined to the east-south-east (Plate 16A). Trough-cross-bedded sets are rare but such as there are have a marked ESE–WNW alignment of trough axes. The foresets are strongly laminated, with individual laminae etched out by weathering and emphasized by the presence of thin pale greenish bands. Carious weathering is well seen at certain horizons. Ripple-marked fine-grained sandstones and siltstones with sand-filled sun cracks are rare. The only thick bed of fine-grained sediment occurs 45 ft (14 m) below the top of the unit and consists of a pale purple siltstone up to 2 ft 2 in (0.67 m) thick, which has an irregular eroded top and is overlain by 1 ft (0.3 m) of intraformational conglomerate. The greater part of this unit consists of medium- to coarse-grained channel-fill sandstone, beds of finer-grained sediment, probably representing overbank deposits, having been largely removed by channel scour.

Upper Unit

The reddish sandstone passes abruptly upward into pale buff, ochre-weathering medium- to coarse-grained calcareous sandstone. At the Ayre of Huxter the latter is 30 ft (9 m) thick and contains planar cross-bedded sets ranging in thickness from 2 ft 6 in to 7 ft (0.75–2.1 m). The cross-bedding near the base and top of the unit is contorted with the lamination in the upper third to half of the set forming semi-recumbent convolute folds with sharply crested anticlines and rounded synclines. These folds are invariably overturned to the east. The cross-bedded sandstone passes up into finer-grained, generally unlaminated, sandstone alternating with thin beds of silty shale and sandy siltstone with ripple cross-lamination, ripple-marked bedding planes and some thin beds with convolute lamination, which in some cases is truncated by the overlying planar-bedded sediment. The outcrop of the Upper Unit is repeated on the shore at Lang Rigg, where there is a marked increase in the number of siltstone partings and where sets with disturbed cross-bedding are rare.

Lower Melby Fish Bed

Though there is considerable lateral variation within the Lower Melby Fish Bed, which crops out at the Ayre of Huxter and at Lang Rigg, the following three lithological units can be recognized throughout (see (Figure 18)):

1. A lower unit, 9 to 10 ft (2.773 m) thick composed of evenly laminated pale grey siltstone and silty mudstone with thin sandy ribs, particularly at the base. This is characterized by the abundance of sand-filled desiccation cracks. Plant remains are present at Lang Rigg.
2. A central unit 10.5 ft (3.2 m) thick composed of pale to dark grey or black, locally bituminous, fissile shale alternating with unlaminated mudstone with irregular carbonate-rich ribs and nodules. Nodules are up to 1 in (25 mm) high and 3 in (75 mm) long. Ribs do not exceed 1.4 in (35 mm) in height and are up to 6 ft (2 m) long. The shale passes down into silty shale with fewer dark carbonate-rich ribs. The sediment throughout is intensely sheared and jointed, and a number of joint planes contain a black bituminous substance. Plant remains are abundant throughout this unit, fish remains are mainly from the calcareous nodules. Thin veinlets of fibrous carbonate traverse the lower part of the

sequence.

3. The upper unit is up to 15 ft (4.5 in) thick and has a variable lithology composed mainly of interlaminated siltstone, sandy siltstone and, near the base, mudstone and silty mudstone. There are also lenticular masses of sandstone and sandy siltstone. Certain horizons contain finely disseminated plant debris and some plant stems aligned in an E20°S direction.

The lithological pattern within the Lower Melby Fish Bed shows some resemblance to the pattern within the lacustrine phases of the cycles in the Stromness Flags of Orkney (Fannin 1970) and the Caithness Flagstones (Crampton and Carruthers 1914, pp. 91–7). No strict parallels can however be drawn. The sun-cracked, laminated sediments of the lower unit appear to represent shallow-water mud-flat deposits which were periodically exposed to the atmosphere and dried out. The base of the central unit may mark the sudden onset of deeper water lacustrine conditions, when thinly laminated sediments with alternating carbonate-rich and bituminous laminae were laid down. Deposition may have taken place in a lake with temperature distribution and water circulation controlled by a tropical climatic regime (see Rayner 1963; Fannin 1970, pp. 228–31; Bradley 1929). The carbonate concretions which enclose many of the fish remains at Melby are, however, less common in the Orkney and Caithness fish beds. The upper unit with its thin lenticular masses of sandstone, which may represent small sand-filled channels, may indicate a period when the lake was again becoming shallower and the influx of elastic material brought into the lake by river and stream deltas was on the increase.

At the Ayre of Huxter the Lower Melby Fish Bed is affected by a number of minor east-north-east trending folds, which vary from open synclines at the north-eastern end of the exposure to recumbent folds locally passing into small thrusts. There are also a number of minor north-north-east trending vertical faults and some thrusts along the bedding planes.

Strata between Lower Melby Fish Bed and Upper Melby Fish Bed

West shore

The 270 to 300-ft (80–90-m) of predominantly arenaceous beds between the lower and upper fish beds are exposed in the cliffs between Quilva Taing and Pobie Skeo. Four groups of strata with distinct characteristics have been recognized:

The lowest group consists of about 45 ft (14 in) of flaggy sandstone with fairly closely spaced siltstone partings and some thick intercalations of siltstone and sandy siltstone. At Quilva Taing the 6 ft (2 m) of strata just above the fish bed are convoluted into semi-recumbent folds which are up to 3 ft (0.9 m) high, have north-west trending axes and are overturned to the north-east. South of Quilva Taing the flaggy beds pass upwards into fine-grained sandstone with posts 2 to 3 ft (0.6–0.9 m) thick separated from each other by thin purplish siltstone partings. A number of these sandstone beds are partially reddened. Convolute lamination is common in the finer-grained sediments of this group.

The second group consists of about 180 ft (55 m) of reddish brown, medium-grained sandstone with fairly thick predominantly planar cross-bedded sets, and relatively few siltstone partings.

The third group is 50 to 55 ft (15–17 m) thick and consists mainly of buff medium- to fine-grained generally planar-bedded sandstone. This contains some sets with planar cross-bedding, in which the foresets dip consistently towards the east to east-north-east sector. In the lower part individual sets are separated by lenticular beds of purple siltstone and silty mudstone, some of which reach a thickness of 4 ft (1.2 m).

The highest group is 15 ft (4.5 m) thick and is composed of flaggy sandstone interbedded with finer sediment. Ripple cross-lamination is common throughout. Beds of siltstone and shale up to 2 ft 6 in (0.75 m) thick contain calcareous nodules similar to those in the overlying fish bed. Near the top of the unit small near-horizontal sand-filled tubes are present in certain sandy siltstone laminae. Individual tubes are round in cross section, approximately 2 mm wide, straight or slightly curved, and up to 20 mm long. These tubes may have been formed by burrowing invertebrates.

North shore

On the north coast, between. Lang Rigg and Humabery, the Lower Melby Fish Bed is overlain by an incomplete sequence approximately 250 ft (75 m) thick, composed mainly of medium-grained brownish-weathering sandstone

interbedded at intervals with thick beds of siltstone and flaggy sandstone. Near the middle of the sequence these fine-grained sediments contain macerated plant debris. They are generally poorly laminated. Some beds have ripple-marked surfaces, convolute lamination and local signs of bioturbation. Beds of sandy siltstone with ripple cross-lamination and convolute lamination are also present at the base of the sequence. A feature of the sandstones is the gradual increase in the percentage of feldspar grains as the sequence is ascended. Trough- and planar-cross-bedded sets up to 2 ft (0.6 m) thick are scattered throughout this predominantly planar-bedded sequence. The cross-bedding suggests that current directions were still predominantly from the west.

The beds in the northern outcrops have the following features which are not seen further west:

1. A slightly higher proportion of fine-grained sediment, but a complete absence of red siltstone and mudstone partings.
2. A higher proportion of pink feldspar grains in the sandstones.

Upper Melby Fish Bed

The Upper Melby Fish Bed is almost continuously exposed along the cliff-top between Foglabanks and Rotten Craig. The fish-bearing carbonate-rich shales and flags exposed on the south shore of Matta Taing, 1600 yd (1460 m) SW of Huxter, appear to be the most southerly representatives of this fish bed. The sequence of the fish bed at Pobie Skeo is as follows (see (Figure 18)):

	feet	inches	metres
Flaggy sandstone with siltstone partings	—	—	—
Silty shale, pale grey, evenly bedded with carbonate-rich ribs and nodules. Fish remains in calcareous bands	4	0	1.22
Shale, dark grey, thinly bedded, somewhat contorted; some calcareous bands are nearly black and slightly bituminous; carbonate nodules with fish remains throughout	1ft 6 in to 2	0	0.45–0.6
Siltstone and sandy siltstone, slightly calcareous with thin ribs and elongated nodules of carbonate	5	0	1.52
Shale and silty shale, dark grey, calcareous, with ribs of limestone	1 ft 6 in to 2	0	0.45–0.6
Siltstone, pale grey, evenly bedded, slightly calcareous	6 in to 0	9	0.15–0.22
Flaggy sandstone with thin bands of sandy siltstone with ?invertebrate burrows (p. 145)	—	—	—

As in the lower fish bed this sequence varies somewhat along the strike, and lenticular masses of sandstone are locally present.

Strata above Upper Melby Fish Bed

The sequence of strata above the Upper Melby Fish Bed cannot be readily determined. Along the south crop between Matta Taing and Hesti Geo the strata are cut by a number of minor faults and close to Hesti Geo they are affected by intense irregular folding and faulting. On the north shore between Lang Rigg and Ness of Melby there is a 60 yd (55 m) wide gap in the shore section at the probable horizon of the Upper Melby Fish Bed. This gap may contain one or more faults. It is not possible to correlate the northern and southern exposures of this group.

South crop

The strata exposed between Matta Taing and Hesti Geo consist almost entirely of brownish feldspathic medium- to fine-grained sandstone with some large-scale cross-stratification in its lower part. On the east face of The Hus a 5 to 6 ft (1.5–1.8 m) thick bed of grey, probably calcareous shale and siltstone is interbedded with the reddish sandstone. As the Melby Fault is approached the sandstone becomes progressively more indurated and, close to the fault, the bedding is largely obliterated. As this shore section is virtually inaccessible, no plant remains or rhyolite fragments have been recorded.

North crop

Between the gap in the exposures along the north coast, 600 to 650 yd (550–600 m) NE of Huxter, where the Upper Melby Fish Bed would be expected to crop out, and the point where the Melby Fault cuts the coast, 700 yd (640 m) E of Melby, the exposed section of sediments and rhyolites has two major gaps, breaking the exposed sequence into three blocks (Figure 16).

Humabery shore

The most westerly block is exposed over a distance of 430 yd (400 m) along the coast at Humabery. It contains a lower group of relatively soft pebbly sandstones and an upper mixed group.

1. The lower group is approximately 270 ft (80 m) thick and is made up of feldspathic sandstone with a matrix of ochreous or purple clay. The sandstone contains pebbly bands and lenses with clasts of pink rhyolite and some quartz, and chips of greenish siltstone and mudstone. The pebbly beds are most abundant in the lowest and highest 70 ft (20 m) of the sequence. Near the top, the sandstone contains some thin pink tuffaceous laminae. Plant fragments are present throughout, and are particularly abundant near the base of the group where they are preserved as coaly ribs up to 4 in (10 cm) long and three-eighths in (10 mm) wide. Cross-bedded sets up to 3 ft (0.9 m) thick are common throughout the sequence and their foresets dip consistently to the west to south-west. Sets with disturbed cross-bedding occur near the middle of the sequence and there are a number of irregular dome-shaped structures which may have originated as sand volcanoes.
2. The upper mixed group of sediments is approximately 250 ft (75 m) thick, and contains beds of reddish purple siltstone and silty mudstone with irregular sandy laminae. These beds are 20 to 30 ft (6–9 m) thick, and they alternate with beds of pink to reddish purple, fine-grained, predominantly planar-bedded sandstone. Pebbly sandstones containing scattered pebbles of rhyolite are present at a number of horizons. There are vague suggestions of bioturbation in some of the purple sandy siltstones and fiaggy sandstones. Convolute lamination is present in some of the purple siltstones.

Ness of Melby and Djubabery

The Ness of Melby Rhyolite is underlain by the sediments which form the reefs at Djubabery. Approximately 350 ft (100 m) of strata are exposed, and the sequence is as follows:

	feet	metres
Irregular base of Melby Rhyolite		
7. Sandstone, grey, micaceous, predominantly ripple-laminated, with lenses, up to 4 in (10 cm) thick, of pebbly sandstone with rhyolite clasts		

6. Purplish brown sandy siltstone with disturbed laminae, ?bioturbated		
5. Sandstone, grey, predominantly planar-bedded, with scattered pebbles of pink rhyolite and lenses of rhyolite grit. Some silty laminae with symmetrical ripple marks		
4. Purplish brown sandy siltstone with highly disturbed laminae of fine-grained sandstone and siltstone. The sandstone laminae have lobate bases and there are detached tubes of sandstone in the siltstone (Plate 16B), (Plate 16C). These structures may be invertebrate burrows		
3. Flaggy sandstone, consisting of alternate bands of sandstone and sandy siltstone 2 ft (60 cm) thick. Small-scale cross-lamination throughout	30	9
2. Purple sandy siltstone, evenly bedded, composed of alternate laminae of purplish grey, fine-grained sandstone and deep purple silty shale	25	7–5
1. Sandstone, hard, fine- to medium-grained with pebbles of rhyolite up to 4 in (10 cm) in diameter and pebbles of basic lava	40	12

Melby Rhyolites

Ness of Melby

The base of the rhyolite forming the Ness of Melby is highly irregular and the underlying sandstone is distorted by blocks and tongues of rhyolite which have pushed downwards into unconsolidated sediments for distances of up to 2 ft (60 cm). The basal 15 to 20 ft (4.5–6 m) of the rhyolite is brecciated, consisting of rhyolite blocks up to 2 ft (60 cm) long, set in a pink rhyolite matrix. Both the breccia and the overlying rhyolite contain irregular cracks and cavities filled with a greenish sandy sediment. The estimated maximum thickness of the Ness of Melby rhyolite is 230 ft (70 m), and there is some inconclusive evidence that it may consist of several flows. The rhyolite is purple when fresh and pale pink, greenish, brownish ochre or mottled on weathered surfaces. It contains relatively sparse pink euhedral phenocrysts of feldspar and, in many exposures, is strongly banded, the banding being in many instances near-vertical and perpendicular to the inclination of the flow. The top 10 to 12 ft (3–4 m) of the rhyolite consist of breccia composed of fragments and blocks of rhyolite ranging up to 3 ft (0.9 m) in size set in a sandy matrix. In its upper 5 ft (1.5 m) the rhyolite contains numerous small vesicles lined with crystalline quartz and a dark green mineral and filled with calcite.

Only a few feet of sediment are exposed above the Ness of Melby rhyolite. These consist of fine- to medium-grained planar-bedded sandstone with scattered rhyolite clasts up to 0.5 in (12 mm) in diameter.

Melby Church

The shore exposures north of Melby Church are composed entirely of strongly banded, variably porphyritic rhyolite. As there is no indication of the dip of this rhyolite no estimate of its thickness can be made. In a number of exposures the rhyolite has a pyroclastic aspect, with small rounded clasts of darkish rock set in a rhyolitic matrix.

Fauna

Additional fish remains to those recorded by Watson (1934) were collected from the Melby Fish Beds by Mr. P. J. Brand in 1966. Some of the original specimens and the later collection have been identified by Dr. R. Miles who recorded the following forms:

Upper Melby Fish Bed

Matta Taing, 1540 yd (1400 m) S37°W of Huxter [HU 166 561] : *Cheiracanthus* sp., *Coccosteus cuspidatus* Miller *ex.* Agassiz M.S., *Gyroptychius?, Mesacanthus* sp.

Coast north of Matta Taing, 1140 yd (1035 m) S42°W of Huxter [HU 167 563]: *Coccosteus cuspidatus, Mesacanthus* sp.

Pobie Skeo, 810 yd (610 m) W40°S of Huxter [HU 168 567]: *Cheiracanthus* sp., *?Coccosteus cuspidatus, Homostius miller* Traquair.

Lower Melby Fish Bed

Quilva Taing, 450 yd (410 m) W6°N of Huxter [HU 171 572]: *Coccosteus cuspidatus, Dipterus valenciennesi* Sedgwick and Murchison, *Gyroptychius agassizi* (Traill).

Ayre of Huxter, 290 yd (265 m) W16°N of Huxter [HU 173 573] : *Coccosteus cuspidatus, Dipterus valenciennesi, Glyptolepis* cf. *leptopterus* Agassiz, *Gyroptychius agassizi.*

Lang Rigg, 490 yd (440 m) N34°E of Huxter [HU 177 576]: *Coccosteus* sp., *Pterichthyodes* sp.

Dr. Miles agrees with the conclusion reached by Watson (p. 139) that this fauna can be equated with that of the Sandwick Fish Bed of Orkney and the Achanarras Limestone of Caithness. The age of this part of the Melby Formation is thus most probably basal Givetian.

Petrography

Sandstones

The sandstones of the Melby Formation are poorly graded arkoses which contain up to 40 per cent feldspar clasts, a small, but variable proportion of lithic clasts and, in most cases, virtually no detrital matrix.

Lower Group

The reddish brown sandstone below the Lower Melby Fish Bed (Figure 18) is a relatively soft, poorly graded arkose (S49338) [HU 173 575], (S50674) [HU 174 574], (Plate 17), fig. 1) composed of laminae of coarse-grained relatively quartz-rich sandstone alternating with laminae of finer-grained, feldspathic sandstone. The former have a strongly bimodal grain-size frequency, with large rounded grains within the size range 1.3 to 0.5 mm, composed of 80 per cent quartz and 20 per cent feldspar grains, set in a groundmass of smaller angular grains averaging 0.15 mm in size. The medium-grained sandstone and the finer laminae which alternate with laminae of coarse-grained sandstone are composed of subrounded to subangular grains, ranging from 0.6 mm to 0.07 mm in diameter with a quartz-feldspar clast ratio ranging from 60:40 to 50:50. As in the case of all other sandstones of the Melby Formation the feldspar clasts contain a high proportion of slightly cloudy to fresh untwinned potash-feldspar, up to 20 per cent sodic plagioclase, a small proportion of very fresh microcline and subordinate microperthite. There appears to be no significant variation in the percentage distribution of the various types of feldspar in the sandstones throughout the group. Lithic clasts form 5 to 10 per cent of the total volume and are composed mainly of unstained silicified felsite and altered basic lava. Heavy mineral grains are never abundant. They include garnet, which is always present, apatite, tourmaline, zircon and allanite. The matrix is composed of a thin film of limonite-stained argillaceous material which incompletely mantles the grains.

The buff-coloured sandstone (S50673) [HU 175 575] which lies between the reddish brown sandstone and the Lower Melby Fish Bed does not have the alternating coarse and fine laminae of the underlying sandstone. It is a relatively

well-graded arkose with subrounded to well-rounded grains and a grain diameter ranging up to 0.8 mm. The quartz-feldspar ratio is 60:40, with quartz forming most of the larger grains. Muscovite is abundant and 5 per cent of the clasts are composed of fine-grained argillaceous sediment. The other lithic clasts are silicified felsite.

Of the sandstones between the two Melby Fish Beds only two thin sections have been examined (S51501) [HU 168 567], (S49339) [HU 165 562]. Both specimens are medium- to fine-grained arkose (quartz-feldspar ratios 50:50 and 60:40) with grains ranging from 0.45 to 0.1 mm. Grains are predominantly subrounded in (S49339) [HU 165 562] and angular in (S51501) [HU 168 567], and in both cases there is slight induration with grain margins in places interlocking. In both cases matrix is virtually absent.

Upper Group

The sediment above the Melby Fish Bed exposed on the coast north-east of Huxter is characterized by the presence of pebbly bands with clasts of fine sediment and pink felsite. The thin section examined (S50672) [HU 178 575] is a medium-grained poorly graded, but not bimodal, arkose, in which the larger grains are well rounded and the smaller grains angular. Grain size ranges from 0.7 to 0.14 mm. The quartz-feldspar ratio is 55:45 and most quartz grains contain liquid inclusions similar to those in the quartz of the Sandsting Granite. Lithic clasts form approximately 20 per cent of the total and are composed of unstained felsite and fine-grained sediment. Of accessory minerals well-rounded grains of garnet are relatively abundant; tourmaline and apatite are rare. As in the underlying sandstone detrital matrix and cement are virtually absent. The sediment is fairly indurated and some grains have serrate margins.

The sandstone exposed along the south-west coast between Matta Taing and Hesti Geo (S52744) [HU 166 587] shows evidence of induration as well as mechanical deformation. The quartz grains have undulose extinction and irregular conchoidal cracks and adjacent quartz grains have serrate margins. The quartz-feldspar ratio of this sandstone is 65:35 and there is a higher proportion of microperthite grains than in the other sandstones of the Melby Formation. Lithic clasts, mainly of felsite, form up to 10 per cent of the total volume, and large garnet grains are relatively abundant. As in the other sandstones of the Melby Formation the argillaceous matrix forms only a minute portion of the total volume.

Rhyolites

The petrographic characters of the rhyolites from Melby have been referred to by Flinn and others (1968, p. 16) who state that they show vague signs of being an accumulation of fragments of welded tuff and that in one specimen there are abundant quartz phenocrysts, which are rare in the rhyolites of Papa Stour. They also mention one specimen, which, they consider, might be an altered and reddened very fine-grained andesite.

Only a small number of rhyolites have been examined by the author, and no assessment of the mode of formation of the entire thickness of the two 'flows' can thus be made. Only the specimen collected from the lower part of the Ness of Melby Rhyolite has the vitroclastic texture of welded tuff (S54285) [HU 185 580]. This rock contains abundant phenocrysts of euhedral patchily red-stained potash feldspar as well as subrounded xenoliths of non-silicified rhyolite and baked sediment, set in a matrix composed of only partially flattened glass shards, many with a characteristic Y-shaped outline, and some larger pumice fragments. The latter contain spherical or slightly flattened vesicles ((Plate 17), fig. 3). Under crossed polars the matrix is completely silicified into a fine mosaic aggregate of silica. Axiolitic and spherulitic textures are absent. In addition to the silicified pumice fragments there are also a number of highly elongated fragments, up to 10 mm long, of less silicified pumice, many of which have the ragged, serrated outlines characteristic of 'fiamme'. The subangular xenoliths of red-stained rhyolite are not completely silicified, but do contain irregular patches of silica. They are irregularly banded and contain an anastomosing network of opaque microlite rods.

The specimens from close to the top of the Ness of Melby Rhyolite (S29972) [HU 187 580],(S30582) [HU 187 580] have no vitroclastic textures. They are in part strongly porphyritic with patchily red-stained euhedral to subhedral phenocrysts of potash feldspar. Quartz phenocrysts have not been recorded. The matrix consists in one case (S30582) [HU 187 580] of strongly flow-aligned microlites of hematite-dusted feldspar, together with irregular patches composed of a fine-grained mosaic of quartz. Though the rock appears to be spherulitic in hand specimen, there are no true spherulites made up of radiating fibres. The spherical red-stained masses have no consistent internal structure and they are separated from

each other by irregular sheaths of mosaic-quartz.

A specimen from the Melby Church outcrop (S29971) [HU 192 578] contains both feldspar and quartz phenocrysts set in a partially silicified matrix, which contains no textures that would suggest a welded tuff origin. Many of the quartz crystals are partially corroded.

Conditions of deposition

The sediments of the Melby Formation appear to be predominantly of fluvial origin. In the lower half of the sequence, up to the Upper Melby Fish Bed, the foresets of most planar cross-bedded sandstones dip predominantly to E10°S and there is a marked east-south-easterly trend of the axes of trough-crossbedded units. This suggests a prevalent current direction from the west or west-north-west. In the upper part of the sequence the pebbly sandstones have cross-bedded units with an equally consistent dip of foresets to the west-south-west, suggesting that the direction of the currents depositing these sediments was from the east-north-east. The change in current direction coincides with the appearance of abundant pebbles of pink rhyolite and rarer pebbles of basic lava in the sediment, and it is suggested that the topography and drainage pattern of the area was suddenly altered by outpourings of volcanic rocks and by associated earth movements which created an area of high relief to the east-north-east.

A high proportion of the sediment below the Upper Melby Fish Bed consists of medium-grained, predominantly planar-cross-bedded sandstone with a uniform inclination direction of the foresets and a low percentage of fine-grained sediments. The sedimentary structures and petrographic characters (pp. 141–5) of the sandstones suggest that they were largely laid down in the channels of straight or braided rivers (Allen 1965, pp. 164–5). Most of the original overbank deposits appear to have been eroded by the migrating channels, leaving only thin lenticular masses of purple siltstone, but providing material for the isolated lenses of intraformational conglomerate and the scattered siltstone clasts within the sandstones. The strata just below both fish beds and a proportion of the beds between them are fine-grained flaggy ripple-marked sandstones interbedded with siltstones and shales. These beds were laid down by relatively slow-moving currents, probably in river channels and crevasses and as overbank deposits on an alluvial plain.

The two fish beds show some resemblances to the lacustrine phases of the Orkney (Fannin 1970) and Caithness (Crampton and Carruthers 1914) flagstone cycles (see p. 143) and they were probably deposited in shallow, but extensive lakes. Fannin (1970) has shown that the lacustrine beds of the Sandwick Fish Bed Cycle are very much thicker than the equivalent beds within the other cycles in the Stromness Flagstones of Orkney and that in western Orkney the Fish Bed lake may at one stage have had a depth of 164 ft (50 m). The Sandwick Fish Bed therefore represents a major transgression and it is just possible that one of the Melby fish beds was laid down in the same extensive lake as the Sandwick and Achanarras Fish Beds. Such a concept assumes that the lower members of the Melby Formation are river deposits laid down near the north-western margin of the flat depositional basin which, towards its centre, contained the Orkney–Caithness lakes. The implications of this concept have a far-reaching effect on our understanding of the structural and palaeogeographical relationship of the Melby Sandstone to the other Old Red Sandstone deposits in the Shetland Islands. This relationship is discussed in Chapter 17.

The higher sediments of the Melby Formation exposed along the coasts of Humabery and Djubabery differ from those below the Upper Melby Fish Bed in that the sandstones contain pebbly beds with clasts of acid and basic lavas, abundant chips of siltstone and large fragments of coaly plant material. The sandstones are interbedded with considerable thicknesses of reddish brown sandy siltstones, some of which show evidence of extensive disturbance, either by burrowing animals or by the mechanical break-up and foundering of sandy laminae. If the beds cropping out on this shore are the equivalents of those exposed along the west coast between Matta Taing and The Hus, there is also a considerable lateral facies change within the group. These data suggest that the rivers which deposited the sandstones were fairly short and had relatively steep profiles. They carried angular clasts of the newly erupted lavas and deposited them in alluvial fans near the foot of the volcanic hills which appear to have lain to the north-west of the present area. Such hills may have been formed by the earliest members of the extrusive rocks which later formed the Papa Stour–Eshaness Volcanic Series. The formation of this high ground could be responsible for the diversion and possible ponding of the old established drainage system, and the thick beds of purplish brown siltstone and sandy siltstone may

have been laid down either as overbank deposits or in ephemeral lakes within the ponded areas. The presence of large pieces of plant debris in the pebbly sandstones could suggest that the newly formed volcanic areas provided a fertile environment for the growth of large Old Red Sandstone plants.

Holm of Melby

The Holm of Melby (Figure 19) is a small island in the Sound of Papa, 650 yd (590 m) NE of the Ness of Melby, with a geological structure which does not tie in with the structural pattern of the sediments and lavas of the Melby area. It may be separated from the latter by an east–west trending fault.

The sequence, as seen on the west and north coasts of the island, consists of a basal series of pale flaggy sandstone interbedded with and underlain by beds of pale grey carbonate-rich siltstone and silty mudstone. This is succeeded by a series composed mainly of tuffaceous sandstone with scattered clasts of acid lava and with thin lenses of rhyolitic agglomerate and lapilli-tuff. The tuffaceous sandstone contains several thin flows and one fairly thick (up to about 35 ft [10 m]) lenticular flow of basic lava. The latter forms a prominent west-north-west trending ridge in the centre of the island but thins out south-eastwards. In the upper part of the sequence the tuffaceous sandstone becomes reddish brown, fine-grained and in part thinly bedded with reddish silty laminae.

The lapilli-tuff bands within the tuffaceous sandstone are water-deposited and usually have strongly erosive bases. They consist of clasts of pink to purplish felsite or rhyolite, up to 0.5 in (12.6 mm) in size, together with rarer clasts of dark fine-grained or glassy lava and greenish-weathering fine-grained sediment. The clasts are, in some cases, strongly imbricated and are invariably set in a matrix of fine-grained greenish sandstone, which normally forms less than 20 per cent of the total volume.

The tuff bands and igneous clasts become less abundant and largely disappear south-eastward along the strike, indicating that the source of igneous material must have lain to the north or north-west. It is possible that the upper part of the Holm of Melby sequence is the stratigraphic equivalent of the basalt and tuffaceous sandstone underlying the rhyolites of Papa Stour (p. 158), and the pebbly sandstone beneath the rhyolite of Melby.

The sediment exposed along the north-east side of the Holm of Melby is folded into a series of gentle folds plunging gently to the north-north-west (Figure 19).

Petrography

The lapilli-tuff (S54286) [HU 186 579] is composed of subrounded clasts of pink to purplish acid rock, ranging up to 0.5 in (12.7 mm) in length, with subordinate clasts of altered fine-grained basic lavas, set in a matrix which does not exceed 20 per cent of the total volume. The matrix is composed in part of calcite, and, in part, of fine-grained sandstone with angular quartz grains. The acid clasts are composed of rhyolite and sub-acid lavas, with a very wide range in texture and grain size. The finest grained and most common types are flow-banded patchily silicified, red-stained, sparsely porphyritic rhyolite containing very fine aggregates of feldspar microlites and minute rods of iron ore. Many of the rhyolite clasts are partly or completely silicified and a number have spherulitic texture. Some rounded clasts are single spherulites of red-stained rhyolite. Less abundant clasts include microgranite composed of feldspar laths set in a clear quartz matrix, sub-basic lava composed entirely of flow-orientated feldspar laths set in a turbid matrix, and altered basic lava.

The basic lava (S30602) [HU 191 586], (Plate 17), fig. 2) is a fine-grained strongly ophitic pyroxene-andesite, composed of closely spaced highly ophitic augites commonly about 0.8 mm in diameter but reaching 1.5 mm. The pyroxenes enclose laths of calcic andesine, which occupy 40 per cent of the volume of the rock. The latter average 0.17 mm in length and show a vague fluxion banding. Outside the pyroxenes the plagioclase needles are embedded in a deep olive-green structure-less base containing abundant grains of pyrite. In the altered vesicular lava (S30601) [HU 191 585] fresh pyroxene is not preserved. The vesicles are lined with chlorite and filled with calcite, sometimes containing a central mass of chlorite.

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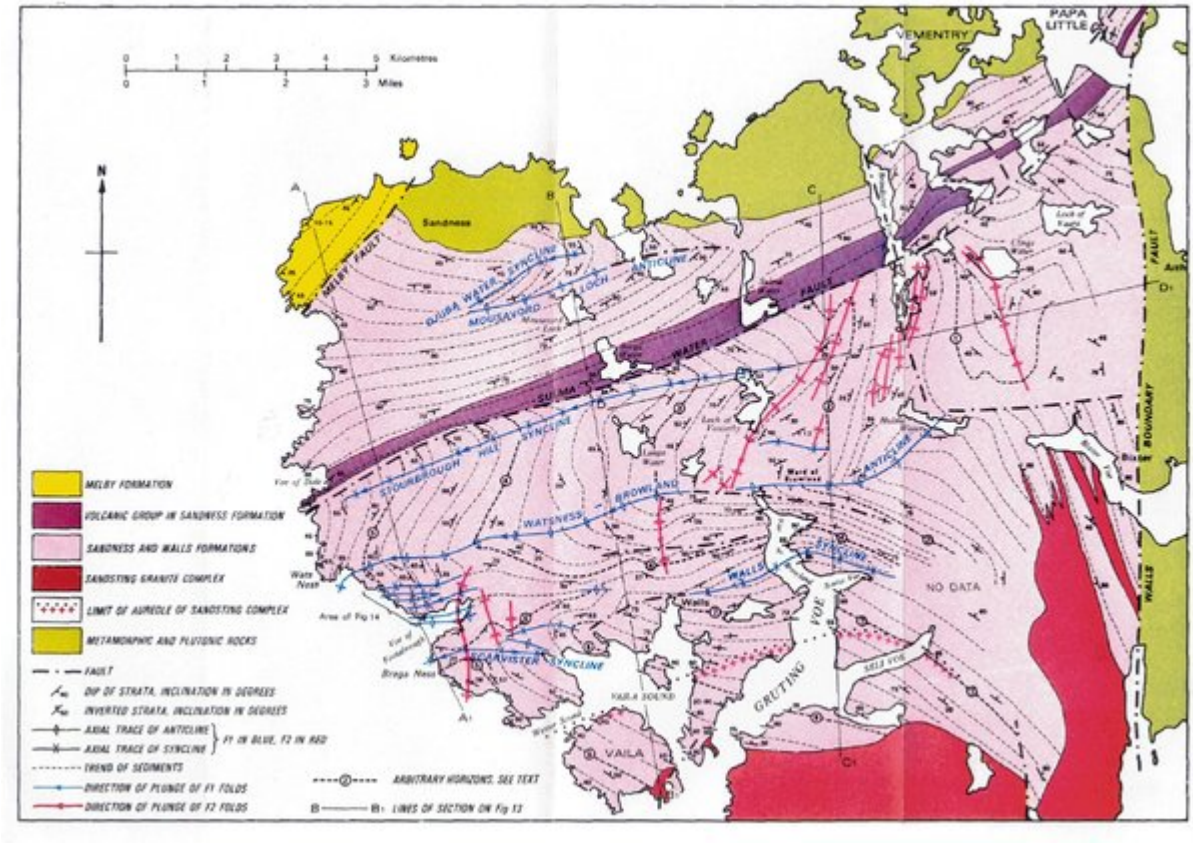
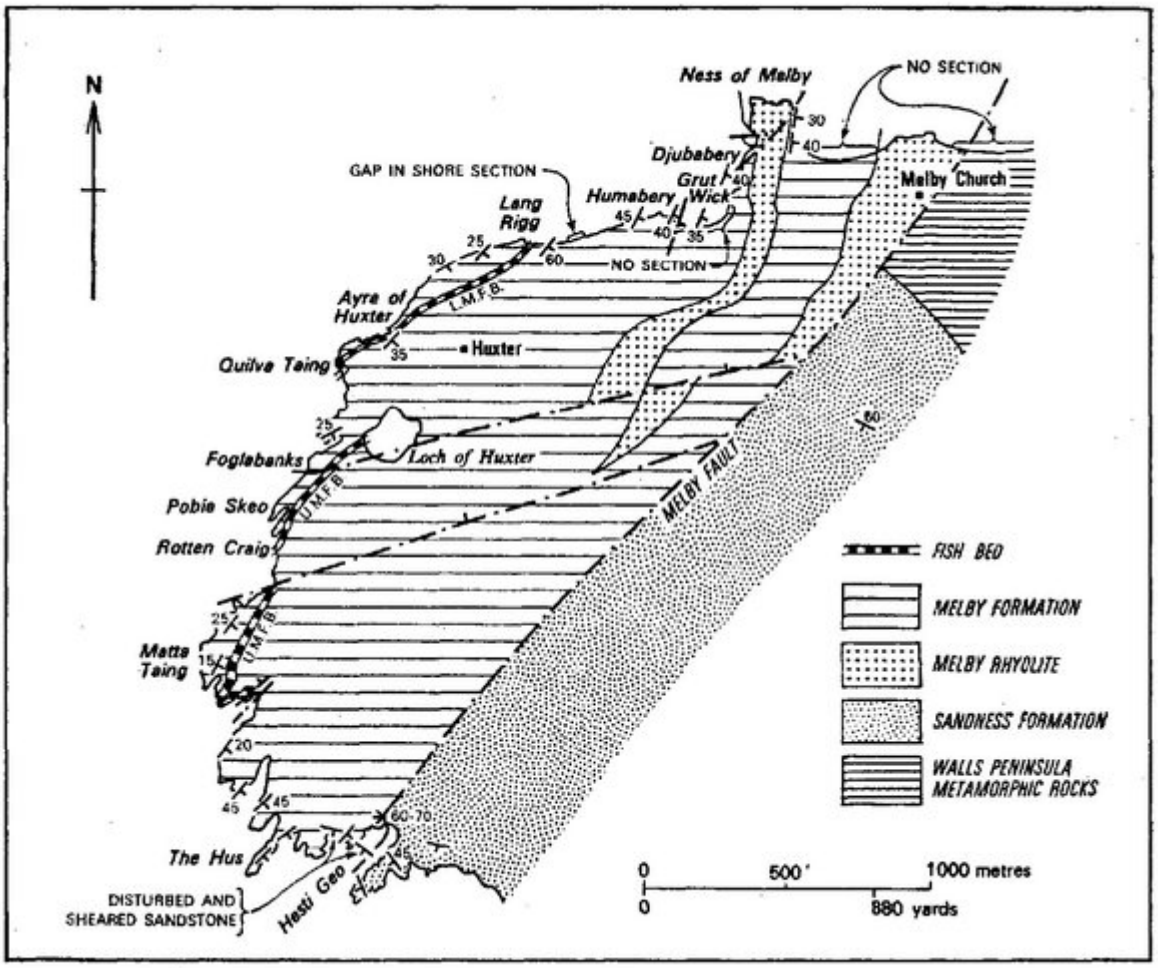
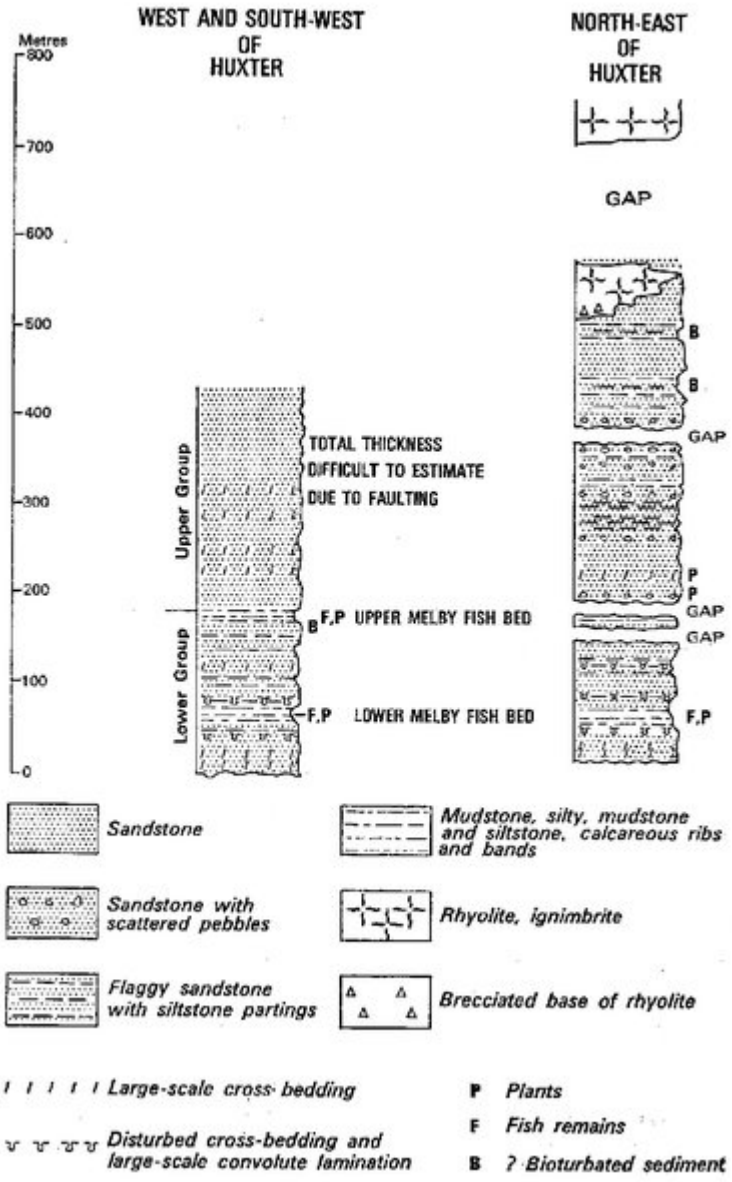


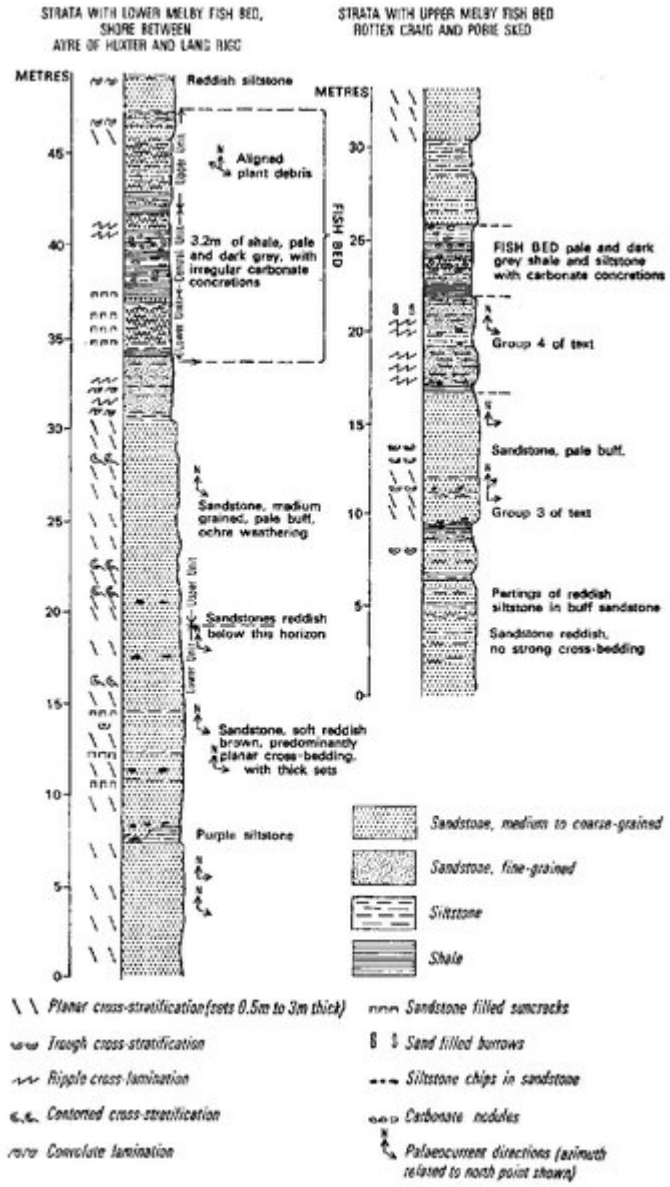
(Plate 12) Major stratigraphic and structural features of the Old Red Sandstone sediments and volcanic rocks of the Walls Peninsula.



(Figure 16) Geological sketch-map of the Melby Formation on Shetland Mainland.

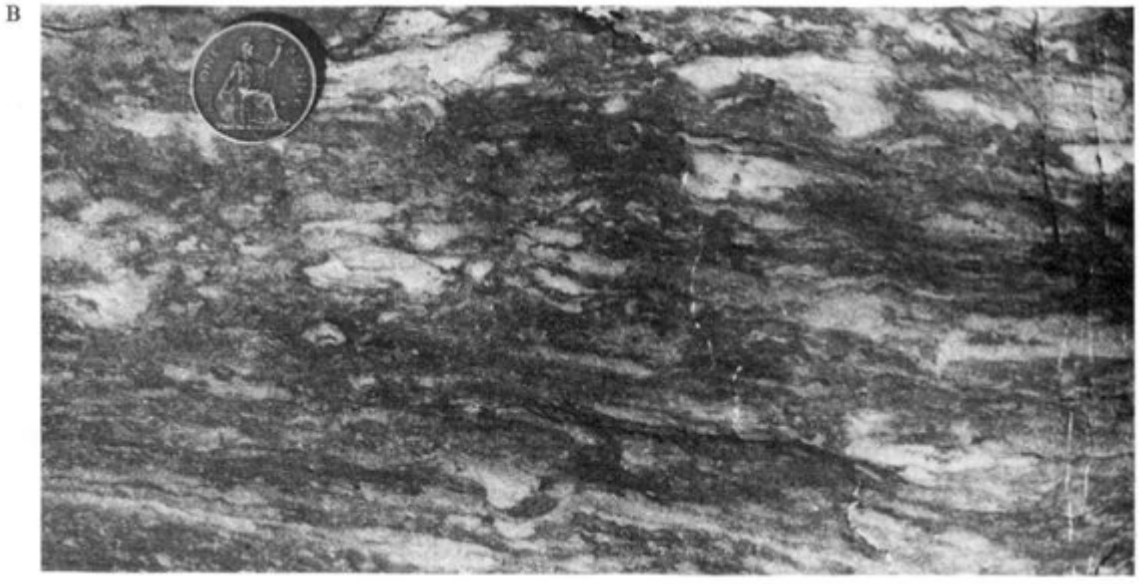


(Figure 17) Melby Formation: probable successions.

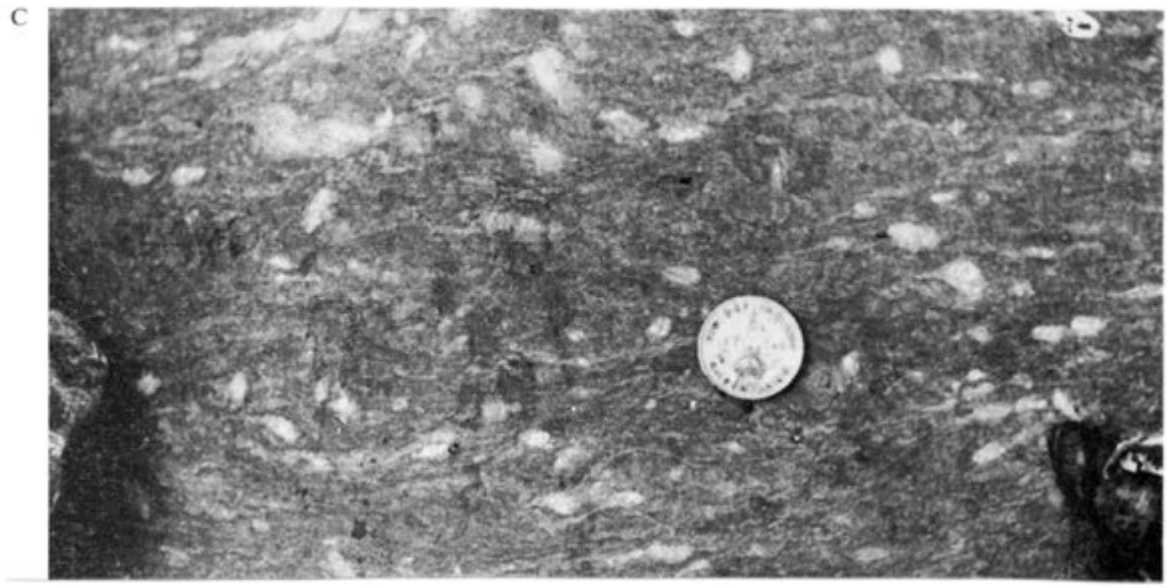


(Figure 18) Sections of the Lower and Upper Melby Fish Beds and adjacent strata.

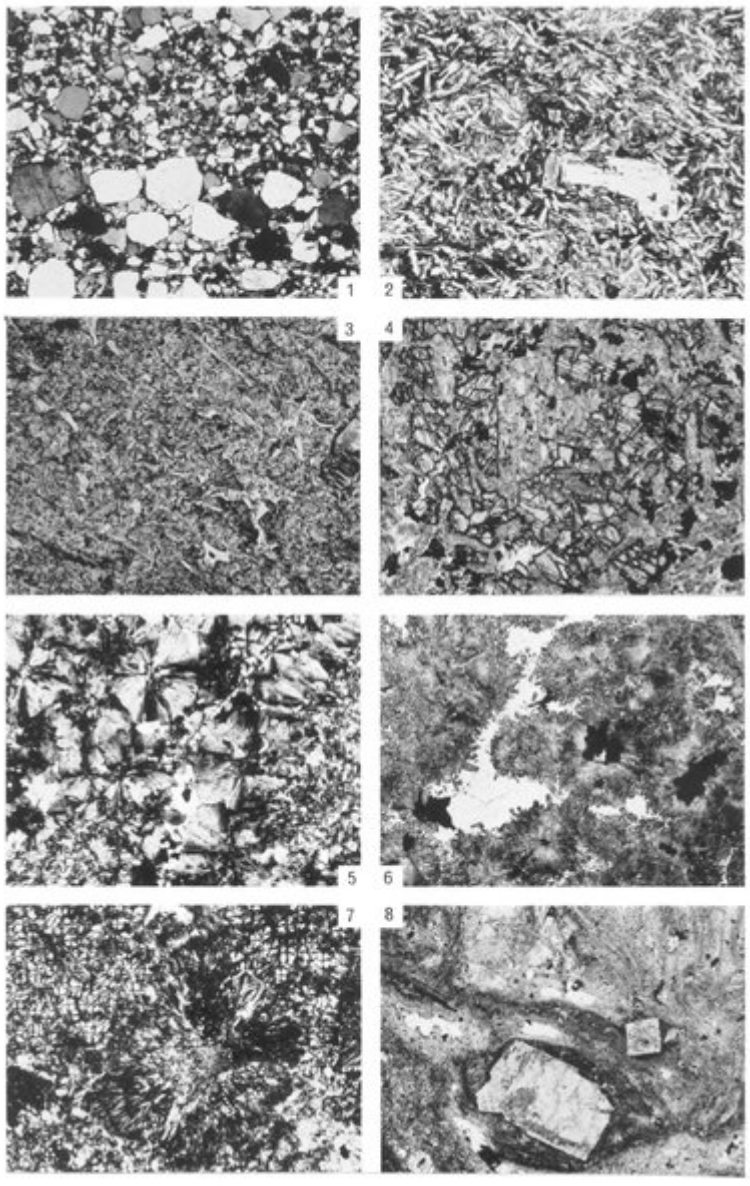
(Plate 16A) South shore of Sound of Papa, 350 yd (320 m) N5°E of Huxter [HU 175 574]. Planar cross-bedded purple sandstone underlying Lower Melby Fish Bed in Melby Formation. (D891).



(Plate 16B) South shore of Sound of Papa, 150 yd (140 m) W of Melby House [HU 184 577]. Purple sandy siltstone with irregular buff sandstone laminae with ?bioturbation structures. (W.M.).

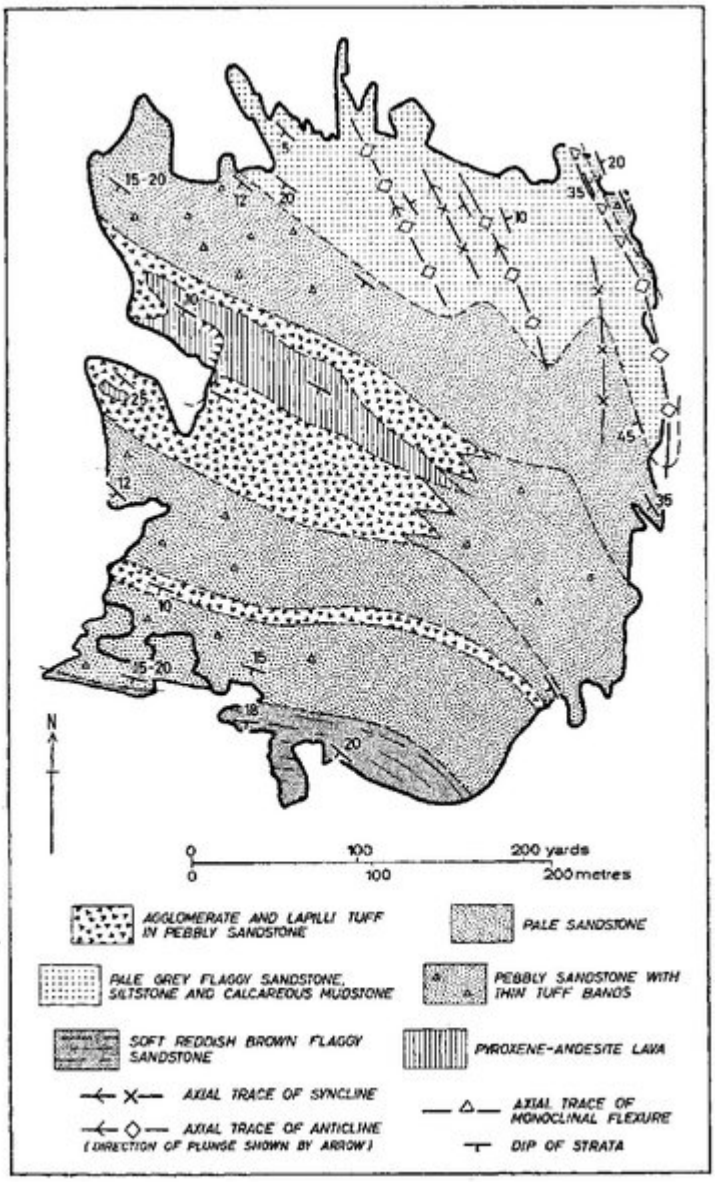


(Plate 16C) South shore of Sound of Papa, 150 yd (140 m) W of Melby House [HU 184 577]. Purple sandy siltstone with irregular buff sandstone laminae with ?bioturbation structures. (W.M.).



(Plate 17) Photomicrographs of Melby Formation and Papa Stour volcanic rocks Fig. 1. Slice No. (S49338) [HU 173 575]. Magnification × 16. Crossed polarisers. Pink medium-grained sandstone below Melby Fish Bed, Melby Formation.

Feldspathic sandstone with bi-modal grain size distribution. Quartz-feldspar ratio 70:30. Among large subrounded grains quartz predominates. Accessory grains are garnet, zircon, tourmaline and apatite. Lithic clasts are composed mainly of altered acid lava and form less than 10 per cent of the total grains. Most grains are covered by a thin reddish film of iron ore. South shore of Sound of Papa, 340 yd (310 m) N of Huxter [HU 174 575]. Fig. 2. Slice No. (S30602) [HU 191 586]. Magnification × 31. Crossed polarisers. Thin flow of basalt within tuff sequence in Melby Formation. Ophitic basalt with rare phenocrysts of sodic labradorite. Vaguely flow-aligned laths of calcic andesine are partly enclosed in ophitic augite. Matrix is a deep olive-green amorphous aggregate. Holm of Melby, west coast [HU 191 586]. Fig. 3. Slice No. (S54285) [HU 185 580]. Magnification × 32. Plane polarized light. Poorly welded or non-welded tuff near base of Ness of Melby rhyolite. Partially flattened devitrified glass shards and small potash feldspar plates and laths, set in matrix of microlite rods. North-west corner of Ness of Melby, 240 yd (220 m) NW of Melby House [HU 185 580]. Fig. 4. Slice No. (S30944) [HU 167 619]. Magnification × 31. Plane polarized light Coarse ophitic dolerite with plates of cloudy plagioclase set in ophitic pyroxene. Papa Stour, 560 yd (500 m) SSE of Skerry of Lambaness, 1850 yd (1690 m) NW of Gardie [HU 167 620]. Fig. 5. Slice No. (S30930) [HU 177 613]. Magnification × 32. Crossed polarisers. Spherulitic rhyolite. Spherulites are composed of radiating fibres of brownish-stained potash feldspar. Small patches of quartz between adjoining spherulites. Papa Stour, south shore of West Voe, 550 yd (500 m) NW of Gardie [HU 176 612]. Fig. 6. Slice No. (S30931) [HU 175 615]. Magnification × 32. Plane polarized light. Spherulitic rhyolite. Spherulites composed of tightly packed clusters of irregularly radiating laths of orange stained potash feldspar, set in large interstitial areas of clear quartz. Quartz forms a small central nucleus in some spherulites. Papa Stour, east shore of West Voe, 920 yd (840 m) NW of Gardie [HU 175 616]. Fig. 7. Slice No. (S30933) [HU 183 620]. Magnification × 31. Crossed polarisers. Spherulitic rhyolite showing two contrasting types of spherulites. The large spherulites consist of radiating fibres of quartz and potash feldspar and are set in a groundmass of small near-spherical spherulites of consistent size (with black cross). Papa Stour, Doun Helier, 1220 yd (1100 m) NNE of Gardie [HU 183 620]. Fig. 8. Slice No. (S30962) [HU 166 591]. Magnification × 16. Plane polarized light. Porphyritic rhyolite, with stumpy euhedral plates of slightly kaolinized potash feldspar, set in an irregular banded matrix of microlites of orange-stained potash feldspar and irregular patches of quartz. Papa Stour, south-west coast, close to Shepherd's Geo, 800 yd (730 m) SW of Bragasetter [HU 165 592].



(Figure 19) Geological sketch-map of the Holm of Melby.