Chapter 17 Major transcurrent faults

The faults described in this chapter are the Walls Boundary Fault, which forms the eastern boundary of the area described in this memoir, and the Melby Fault which separates the Melby Formation from the Walls Sandstone. Both faults may have had considerable post-Devonian dextral transcurrent movement along them and these movements may explain the present close juxtaposition of the Melby Formation, the Walls Sandstone and the East Shetland Old Red Sandstone, which not only differ from each other in age, but have such diverse sedimentological, volcanological and structural histories that it must be assumed that each evolved in a separate depositional and structural province.

Walls Boundary Fault

The Walls Boundary Fault is a complex, locally branching, dislocation zone, which separates two areas of widely differing lithology and structural trends. It has a complex geological history, having been involved in at least three phases of movement (pp. 263–5). Flinn (1961, p. 589) has suggested that it may be the northward continuation of the Great Glen Fault.

In the Walls Peninsula the fault is accompanied by a crush belt of considerable width, but the actual fault plane is everywhere narrow and clearly defined. Fault-bounded enclaves of rock derived from opposite sides of this fault plane have, however, been recorded within the shatter belt exposed on the west shore of Aith Voe. In the area north of Papa Little the fault splits into a number of branches which enclose a complex dislocation zone. This zone was developed during two phases of dislocation long before the final brittle transcurrent fault movements took place.

Outcrops of fault

Southern end of outcrop: Roe Ness, Rea Wick and Sand peninsulas (Plate 12)

Though the actual fault plane is not exposed where it crosses the shore at the head of Sell Voe, there are excellent sections of the shattered and faulted rock around the coasts of the Roe Ness and Sand peninsulas. West of the fault there is a 1.25-mile (2-km) wide zone in which the sandstone, granite and diorite have been affected by intense brittle shattering which has produced closely spaced faults and joints and has made the rock very friable. The faults in this zone include a number of major sub-parallel N10°E to N30°E trending dislocations which appear to be branches of the Walls Boundary Fault. Some north-north-west trending belts of mylonite are present on the coast between 600 and 1200 yd (550 and 1100 m) N of Rea Wick [HU 328 448]. These belts are scapolitized and they do not have the same trend as the crush belts associated with the Walls Boundary Fault. It is thought that their formation may have preceded the brittle movements along the fault (see pp. 236–7, Mykura and Young 1969, p. 3).

East of the Walls Boundary Fault, a 0.75-mile (1.2-km) wide belt of shattered schist is exposed just east of Kirka Ness [HU 337 464] along the south shores of the Sand peninsula. The rock is here composed almost entirely of soft micaceous fault-gouge derived mainly from mica-schist with fault-bounded lenses of shattered quartzite which form the headlands.

The soft and friable nature of the crush rock suggests that in this area the movements within the fault-zone took place at a high tectonic level. There is here no evidence of earlier shear or thrust movements along the line of the fault.

Bixter Voe

On the shores of Bixter Voe [HU 336 506] and [HU 337 513] the fault plane is clearly defined and inclined at 85° to the west. The zone of intense shearing within the Walls Sandstone immediately west of the fault is only 200 yd (180 m) wide, though the sandstone is shattered for a further 70 yd (65 m). East of the fault the zone of shearing is well defined and 150 to 160 yd (140–150 m) wide. The sheared rock is again very friable and cut by many small closely spaced faults which are sub-parallel to the main fault, as well as by many irregular shear planes which are variable both in direction and inclination. As in the area further south, there is no mylonite or compact crush rock which can be attributed to earlier movement within the fault zone. All the dislocation may thus have taken place at a high tectonic level. W.M.

West shore of Aith Voe (Plate 9)

On the western side of Aith Voe the fault-zone is wedge-shaped, reaching several hundred yards in width on Aith Ness but thinning southwards towards Breawick [HU 338 577]. On Aith Ness the Walls Boundary Fault itself has two main branches which at Keen Point [HU 336 593] and the bay to the east are about 40 yd (36 m) apart. The faults are very steep to vertical. Inland, to the south, these two branches cannot readily be traced on the ground but their positions may be seen from the eastern bank of Aith Voe. At the points where the two branches of the fault crop out on the coast the rocks are seen to be much crushed. They include a rock of felsitic appearance which is found in thin section (S47940), from the coast 100 yd (90 m) S of Keen Point) to be a cataclastically deformed argillaceous feldspathic sandstone. It is a shattery streaky greenish grey sediment having numerous curved faces coated with red to chocolate-coloured iron oxide. The quartz grains are mainly 0.1 mm or less in length although occasionally much coarser. The groundmass contains abundant chloritic granules and shreds and flakes of green mica. There are plentiful heavy mineral grains, including zircon and green tourmaline, and epidote is plentiful in grains and aggregates. There is abundant actinolitic amphibole, abundant ore granules including hematite, and ilmenite rimmed by sphene. The rock is traversed by numerous veinlets along lines of movement of chlorite, calcite, hematite, and alkali feldspar showing complicated twinning or granulation. The veins show a continuation of the rock fabric transversely and sygmoidally across them; this applies to the fine detail of the fabric, although in the veins the fabric is represented by different minerals from those of the host rock. Their texture may be interpreted as being in part, at least, due to replacement following the imposition of foliation.

South of Breawick the two branches of the Walls Boundary Fault cannot readily be separated. The fracture is intermittently marked by a line of seepages and springs, and by occasional exposures of the rocks on each side.

East of the Walls Boundary Fault on Aith Ness the crushed rocks consist of schist and sandstone with a higher proportion of schist occurring nearer to Point of Sletta [HU 339 591]. Limestone bands not more than a few feet (1 m) thick crop out close to the Walls Boundary Fault on the coast and inland. The schists are variable, including semipelitic and psammitic types, garnetiferous mica-schist and hornblende-schist, with pegmatite veins and quartz veins. The strike is variable but predominantly north-easterly, and the dip is generally high. Isolated observations were made of rodding which is to the north-east at 7° and 45°.

Northerly trending faults cut the main bay and the promontory between the Loch of Aithness [HU 334 583] and Aith Voe, two of them dipping eastwards at 45°. All of the ground in this part of Aith Ness is extensively broken and crushed. The main fracture which marks the eastern boundary of this crush zone cuts the coast just north-north-west of Stiva [HU 341 575]. This fracture belt which is some 40 yd (36 m) wide may conveniently be referred to as the Stiva Branch. The rocks in this Stiva fault-belt include green and chocolate-coloured sheared and crushed quartzite and sandstone, apparently of Old Red Sandstone age, as well as schist, pegmatite and some fault-breccia. A shattery greenish rock with hematite-coated joints having some resemblance to mylonite is seen in thin section (S51266) [HU 340 577] to be a cataclastically deformed sandstone, traversed by veinlets mainly of calcite. The easterly fault bounding the Stiva Branch brings crush-rock against broken limestone 60 ft (18 m) thick. The fault plane is well exposed and dips west at 80°. Some of the faults within the Stiva fault belt are vertical or steep, but one prominently exposed fault plane is nearly horizontal and undulating. P.A.S.

The Walls Sandstone adjoining the western branch of the Walls Boundary Fault at Keen Point is hardened and colour-laminated (yellowish green, brownish purple and buff) for a distance of 30 yd (27 m) from the fault plane. Individual colour bands are 2.5 to 6 mm thick. They trend north-north-east to north-east and their inclination ranges from 73° to WNW to vertical, (i.e. sub-parallel to the main fault). Within a 15-yd (14-m) wide zone adjoining the fault the sandstone is cut by many thin 'veins' of pink mylonite, which cut and locally slightly displace the colour lamination.

The induration, colour banding and local mylonitization of the rocks within the fault zone can be attributed to one or more phases of shearing or thrusting which took place at a fairly low tectonic level and created a zone of weakness which was later utilized by the faulting along the Walls Boundary Fault Complex. The latter, with its large number of sub-parallel shear planes and shatter zones, has been formed by dislocation at a much higher crustal level.

Papa Little. (Plate 9).

The two branches of the Walls Boundary Fault cut the island of Papa Little. The western branch is exposed on the north and south shores of the island and in the Little Burn [HU 338 604]. In all these exposures it is associated with bands of pink, commonly colour-laminated, highly indurated crush rock and mylonite which in hand specimen resembles felsite. Mylonite is also developed in the schists just east of the fault plane. The eastern (main) branch of the fault is seen on the east coast, 600 yd (560 m) E of North Ward [HU 346 614]. The superimposed brittle crushing within the western fault planes is less intense than in the exposures along the shore of Aith Voe and the effects of shattering in the rocks on either side of the fault are much less extensive. W.M.

Muckle Roe–Gunnister–Sullom ((Figure 27))

In this district the Walls Boundary Fault-zone runs parallel to the east coast of Muckle Roe. The main break is hidden under the waters of Busta Voe but must lie close to that coast since the igneous and metamorphic rocks there are confusedly intermingled and are seen to be traversed at Green Taing by N–S crush-lines. North-east of Busta the fault zone comprises three main faults which diverge at small angles northwards. The rocks caught between them are in a mylonitic condition at the head of Busta Voe so that recognition of their geological group is rarely possible, but between the two eastern faults a mylonitized calcareous band allows identification with the Calcareous Group of the Lunnister Metamorphic Rocks (p. 15). On the north side of the Busta Voe–Sullom Voe isthmus the rocks are less difficult to identify and those between the western and central of the three faults are considered to belong to the complex of igneous and contact altered metamorphic rocks which form the Busta peninsula. The central fault is thus regarded as the southward continuation of the Haggrister Fault which is well exposed at the Bight of Haggrister and courses north to form the boundary between granite and the Lunnister Metamorphic Rocks along the west bank of the Loch of Lunnister up to the west end of the Loch of Burraland. The eastern of the three faults is not seen at the head of Busta Voe, but its position there is locatable within a few metres between exposures of the calcareous band referred to above and a sheared granite-schist mélange. It is recognized as the Walls Boundary Fault particularly well on the south coast of the Ness of Haggrister where its position is fixed precisely by a drift-filled vertical cleft 164 ft (5 m) wide on the east side of which are sheared migmatites of the Delting Injection Complex and on the west tightly folded micaceous and calcareous schists of the Lunnister division. The western of the three faults is regarded as a major break in a crush-zone which affects granitic, dioritic and metamorphic rocks. This zone is exposed in the cliffs and coast forming the south-east corner of Ell Wick, at the south-west end of Sullom Voe, and is comparable with that exposed along the east coast of Muckle Voe. The Mangaster Voe Fault may be a similar break.

In the area occupied by the Lunnister Metamorphic Rocks the fractures named the Bight Fault and Ness Fault on (Figure 27) are considered to be major lines of movement synchronous with the tight folding and mylonitization of these rocks and to be of earlier date than the Haggrister and Walls Boundary faults though it is possible that movement contemporaneous with the latter faults was renewed along the older lines. The Walls Boundary Fault appears to transect at a small angle the line of the Ness Fault at the Ness of Haggrister.

Many crush-belts trending NNW to NW have been noted in the igneous rocks of Muckle Roe and southern Northmaven; they have allowed easy erosion along the geos which open to the north-west. One of these crush-belts is spectacularly illustrated by the vertical-walled cleft which divides the island of Egilsay. It is likely that there are many more crush belts than are shown on (Figure 27) for their probable presence is indicated in the western part of Muckle Roe by deep valleys bounded by steep scree-coated flanks and also in the country north of lower Mangaster Voe where there are long steep features with a northwesterly trend. The crush-belts are probably later than the acid dykes of Muckle Roe for crushed and brecciated felsites have been noted by D. Haldane; there is, however, no record of crushing along any of the basic N–S dykes. Neither the amount nor the direction of displacement along the crush-zones is known. They appear to be vertical belts but in the case of a few sharp dislocations which have been mapped by D. Haldane as faults he has shown hade in both east and west directions.

In addition to the faults and crushes in the N to NW quadrant a few faults trending ENE to NE have been recorded by D. Haldane. One of these displaces the northern part of a composite acid–basic dyke eastwards for a distance less than the width of the dyke at a locality about 0.33 mile (0.5 km) W of the north end of Kilka Water.

The fan pattern formed by the faults and crushes in this area (Figure 27) is noteworthy. The Walls Boundary Fault is directed a little east from its N–S Aith Voe–Busta Voe trend but the N–S line is continued by the Haggrister Fault. West of the latter the faults and crushes have in general a more northwesterly trend the farther they lie from the main zone of translation. It appears that the crustal fracture meeting a massive block of gneiss in which old structural lines were established and which was buttressed by massive crystalline igneous rocks, had its major displacement deflected while a minor component followed old structural lines or was dissipated in the structureless igneous massif. J.P.

Tectonic history

Early thrusts

It is believed that the early mylonitization within the northern wedge is associated with a series of low-angled thrusts, which have been rotated by subsequent folding into a vertical position (pp. 21–23). The rather narrower mylonitized belts in Papa Little and Aith Ness may lie within the southward extension of this wedge. As no mylonite or phyllonite have been recorded along the fault south of Aith Voe, it is assumed that the early thrusting either did not extend further south, or followed planes which were not utilized by the later movements along the fault.

It is tempting to correlate this early phase of thrusting and associated mylonitization and phyllonitization with the major thrust movements postulated elsewhere in Shetland. Examples of such movements are the thrusting responsible for the first phase of retrograde metamorphism in the Valla Field Block of Unst (Read 1934, p. 650; 1937), the emplacement of the 'Nappe Complex' of Unst and Fetlar (Flinn 1958), and the major phase of dislocation which brought the East Mainland, Quarif and Lunnasting successions of Shetland Mainland into tectonic contact (Miller and Flinn 1966, p. 114; Flinn 1967, pp. 287–8). The age of all these movements has, however, been tentatively set at or before 420 m.y. by Miller and Flinn (1966, p. 114). The mylonitization along the Walls Boundary Fault, on the other hand, affects the Old Red Sandstone of Aith Ness and Papa Little, which indicates that in these areas deformation leading to mylonitization was active at some time after 360 m.y. or, at most, 370 m.y. B.P. There is, however, no evidence which could be used to prove that all the mylonitization along the Walls Boundary Fault is of roughly the same age and it is possible that there were several periods of dislocation during which mylonite was produced.

Folding

Evidence for the folding or, at least, rotation of the belts of mylonite into a vertical position prior to the final faulting has been recorded in the Lunnasting area (p. 22) and parts of Northmaven (Phemister, 1976).

Late brittle dislocation

The latest movements along the fault produced a belt of brittle shearing and shattering which contains clearly defined steep fault planes. The belt appears to be narrowest at Papa Little. It widens out southward to a width of over 2 miles (3.2 km) at the south shore of the Walls Peninsula and northwards to over 1 mile (1.6 km) at the northern margin of the Sheet. A number of branching faults splay out southwards from the main fault south of the latitude of Bixter Voe, and northwards from focal points near Aith [HU 339 564] and in Busta Voe just east of Busta House [HU 348 665]. In the most northerly splay most of the dislocation appears to have been along the most easterly branch of the fault, though some of the movement was taken up by faults branching off westward and extending into the Northmaven Granite–Diorite Complex (pp. 261–2). These faults are clearly younger than the Old Red Sandstone sedimentary and intrusive rocks of the area, but the true age of the faulting remains a matter for conjecture.

Direction and amount of movement

Both Flinn and the author have put forward evidence which supports the concept of a considerable post-Old Red Sandstone dextral transcurrent movement along the fault. Flinn (1969, p. 291) has suggested that this movement may have been of the order of 40 miles (65 km). He has based this conclusion on evidence obtained from his interpretation of the IGS geomagnetic map and has no doubt found further support from the fact that the smaller sub-parallel Nesting Fault, which lies some 6 miles (9.5 km) to the east of the Walls Boundary Fault, has a dextral displacement of 10 miles

(16 km). The author (Mykura 1972a, p. 51; 1972b, p. 30; Mykura and Young 1969, fig. 1) believes that the amount of post-Old Red Sandstone dextral transcurrent movement along the fault may have been between 35 and 50 miles (60 and 80 km). This conclusion is based on the following evidence:

1. Sodic scapolite is a common vein and replacement mineral, both in and around the Sandsting Complex of the Walls Peninsula and in the somewhat indurated sedimentary rocks of south-west Fair Isle. Fair Isle is thought to lie a few miles east of the southward continuation of the Walls Boundary Fault.
2. There is evidence for the presence of a granitic body a short distance to the southeast of Fair Isle (see Mykura 1972a, p. 51). This granite could possibly be part of the displaced eastern portion of the Sandsting Granite–Diorite Complex.
3. The sedimentary rocks of Fair Isle are of Lower and/or Middle Old Red Sandstone age and in the south-west of the island they are strongly deformed and intruded by acid and basic dykes (Mykura 1972b). The only other Old Red Sandstone rocks of similar age within the Orkney–Shetland area which are intensely folded and cut by late-Caledonian dykes are those forming the Walls Sandstone. There is thus a distinct possibility that these two sequences were deposited and deformed in the same depositional and structural basin (see p. 124) and were later separated by dextral transcurrent movement along the Walls Boundary Fault.
4. The Walls Sandstone is completely different, in age, content of volcanic and intrusive rocks and tectonic style from the high Middle to Upper Old Red Sand stone (Upper Givetian) sediments of south-east Mainland (see Mykura 1976). Both formations rest unconformably on the metamorphic basement and the two formations must have evolved in completely separate sedimentary, magmatic, and tectonic environments. Yet their outcrops are now only 7 miles (11 km) apart. This suggests that they have been brought into virtual juxtaposition by considerable transcurrent movement along the two intervening north–south trending faults: the Walls Boundary Fault and the Nesting Fault. As a dextral sense of movement can be demonstrated in the case of the Nesting Fault it is reasonable to assume that the movement along the much larger Walls Boundary Fault was also dextral.

There is inconclusive evidence that some of the branch-faults of the Walls Boundary Fault within the Walls Peninsula are tear faults with a dextral displacement. The Reawick Fault, which cuts the south-east corner of the peninsula, for instance, separates strongly folded and locally cleaved strata to the east from considerably less intensely folded strata to the west. The nearest exposures of sediments to the west of the fault belt, which are deformed to the same extent as the strata east of the Reawick Fault, are found 6 to 7 miles (9–11 km) further north.

None of the evidence so far quoted is in any way conclusive. Perhaps the strongest evidence is that provided by the presence in both Fair Isle and West Mainland of scapolite associated with a granite complex. The Fair Isle scapolite, however, could just as well be connected with a granite mass which was at the time of emplacement located well to the south of the Sandsting Complex and which may be a member of a north-south trending suite of granite masses of which the granites cropping out between North Roe and Sandsting form only a part. All the other points of evidence above can be similarly questioned. The coincidence of all these factors, however, adds up to a strong impression that the latest movement along the Walls Boundary Fault was a major dextral transcurrent displacement.

Melby Fault

The Melby Fault cuts the north-west corner of the Walls Peninsula, where it has a south-westerly trend and separates the Melby Formation in the west from the Walls Sandstone and Walls Peninsula Metamorphic Rocks in the east (Plate 12). It appears to continue north-north-eastwards across the centre of St Magnus Bay and re-appear on the Esha Ness peninsula of Northmaven, where it separates the Eshaness Volcanic Rocks in the west from the North-maven Granite in the east. The south-westward extension of the Melby Fault is uncertain. The data from Sheet 16 of the IGS Aeromagnetic Map (1968) suggest that it passes 5 to 6 miles (8–9.6 km) E of Foula.

The fault plane is well exposed at Hesti Geo [HU 172 556] on the west shore of the Walls Peninsula ((Figure 16), p. 145), where it is inclined at 60° to 70° to the south-east and associated with a 300 yd (270 m) wide zone of intensely sheared and folded strata. The intense folding is largely confined to the Melby Formation west of the fault plane and in these beds disturbance on a diminished scale can be traced for a further 200 yd (180 m) to the west as far as Pund Head. Some of the folds within the disturbed zone appear to have been affected by more than one phase of deformation and some have axes which trend almost at right angles to the Melby Fault. The fault forms a prominent feature along the north-west slope of the Hill of Melby but is not exposed on the north coast of the peninsula, just north-east of Melby Church.

If the Melby Fault were a fault along which only differential vertical movement had taken place, it would be a reversed fault along which the Walls Sandstone, which is here steeply inclined to the south-west, has been thrust over the southeastward dipping Melby Sandstone. The intensity and extent of deformation in the adjoining Melby Sandstone would suggest that this was a fault with a very considerable throw. There are, however, a number of factors which suggest that the Melby Fault, like the Walls Boundary Fault, is a transcurrent fault with considerable dextral displacement. It has been argued in Chapter 10 (p. 153) that the predominantly fluvial Melby Formation may have been deposited near the north-western margin of the extensive Orkney–Caithness depositional basin and that one of the Melby fish beds might even have been formed in the same extensive lake as the Sandwick Fish Bed of Orkney and the Achanarras Limestone of Caithness. Though such a correlation must remain highly speculative there is no doubt that in its fauna, lithology and structure the Melby Sandstone bears a much closer resemblance to the Givetian sediments of Orkney than to the adjoining Walls Sandstone, which has not only been intensely folded but has been intruded by a granite complex and by suites of basic and acid dykes. If the Melby Fault were a simple reversed fault the Melby Formation would be expected to rest unconformably on the strongly folded Walls Sandstone which would have been extensively eroded before the deposition of the former. As the base of the Melby Formation is nowhere exposed, nothing is known about the rocks underlying it either in Mainland or Papa Stour. In the Island of Foula, however, there is both geophysical evidence (McQuillin and Brooks 1967, p. 15) and a certain amount of field evidence (p. 175) that the Foula sandstone rests directly on the metamorphic basement.

It is the author's opinion that the Melby and Foula formations were deposited along the north-western margin of the open Orcadian basin, in a position that was a considerable distance south-west or south-south-west of the basin in which the Walls Sandstone was laid down and that the two formations were subsequently brought together by dextral transcurrent movement along the Melby Fault. The actual amount of displacement along this fault cannot, as yet, be calculated.

Conclusion

Large post-Old Red Sandstone dextral transcurrent shifts along the Walls Boundary Fault and Melby Fault can most satisfactorily account for the virtual juxtaposition of three diverse formations of Old Red Sandstone rocks in Shetland. Each formation appears to rest directly on the metamorphic basement, but each differs from the others in its age, in its depositional and volcanological development, its tectonic history and in the extent to which it has been affected by igneous intrusions. The recognition of the presence of two major transcurrent faults also permits us to attempt a reconstruction of the Old Red Sandstone palaeogeography of the Shetland–Orkney area. Such a reconstruction assumes that there were three distinct, possibly fault-bounded intermontane basins, each of which had a completely independent evolution. The most southerly basin, which extended over Orkney and part of Caithness, was flat and open and tectonically relatively stable. In middle Givetion (?Eday) times it was affected by a phase of extrusive volcanism which was most extensive in the north (i.e. Eshaness) and became thin and intermittent at the latitude of Orkney. The central basin, in which both the thick sequences of the Walls Sandstone (pp. 123–124) and the Fair Isle Old Red Sandstone (Mykura 1972b) may have been laid down, lay within a tectonically and magmatically active belt. This basin was probably elongated in a west-south-westerly or east–west direction and was affected at the end of Middle Old Red Sandstone times by compressive forces which acted first in a north–south direction and later in an east–west direction. The most northerly basin, of which only the western marginal deposits are now seen in eastern Shetland, was probably bounded in the west by mountainous terrain carved partly in a granitic complex similar to that now exposed in Northmaven and North Roe. W.M.

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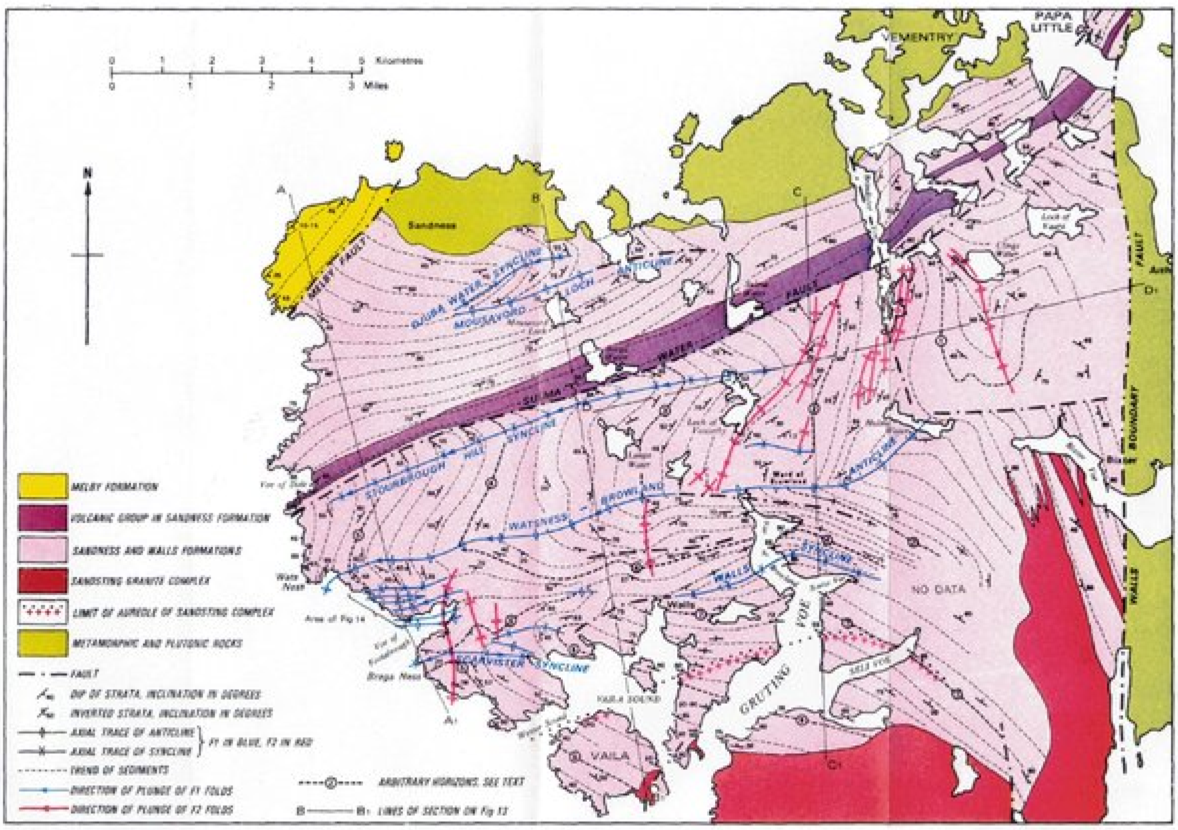
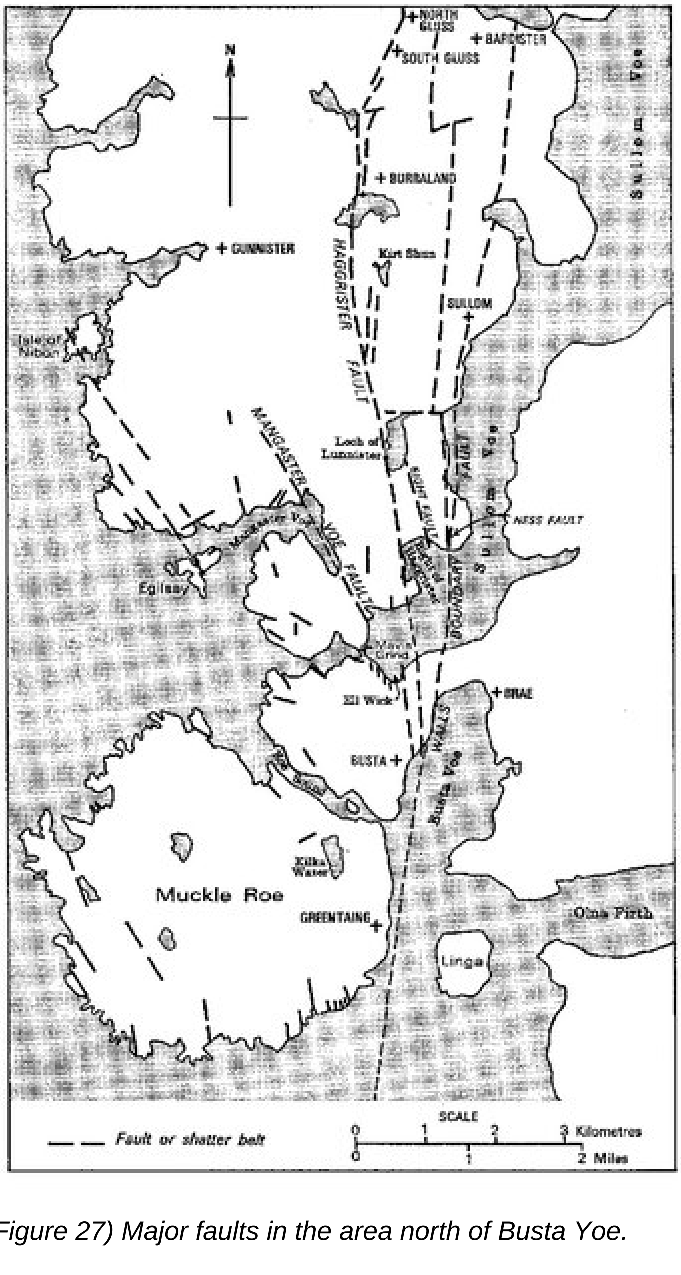
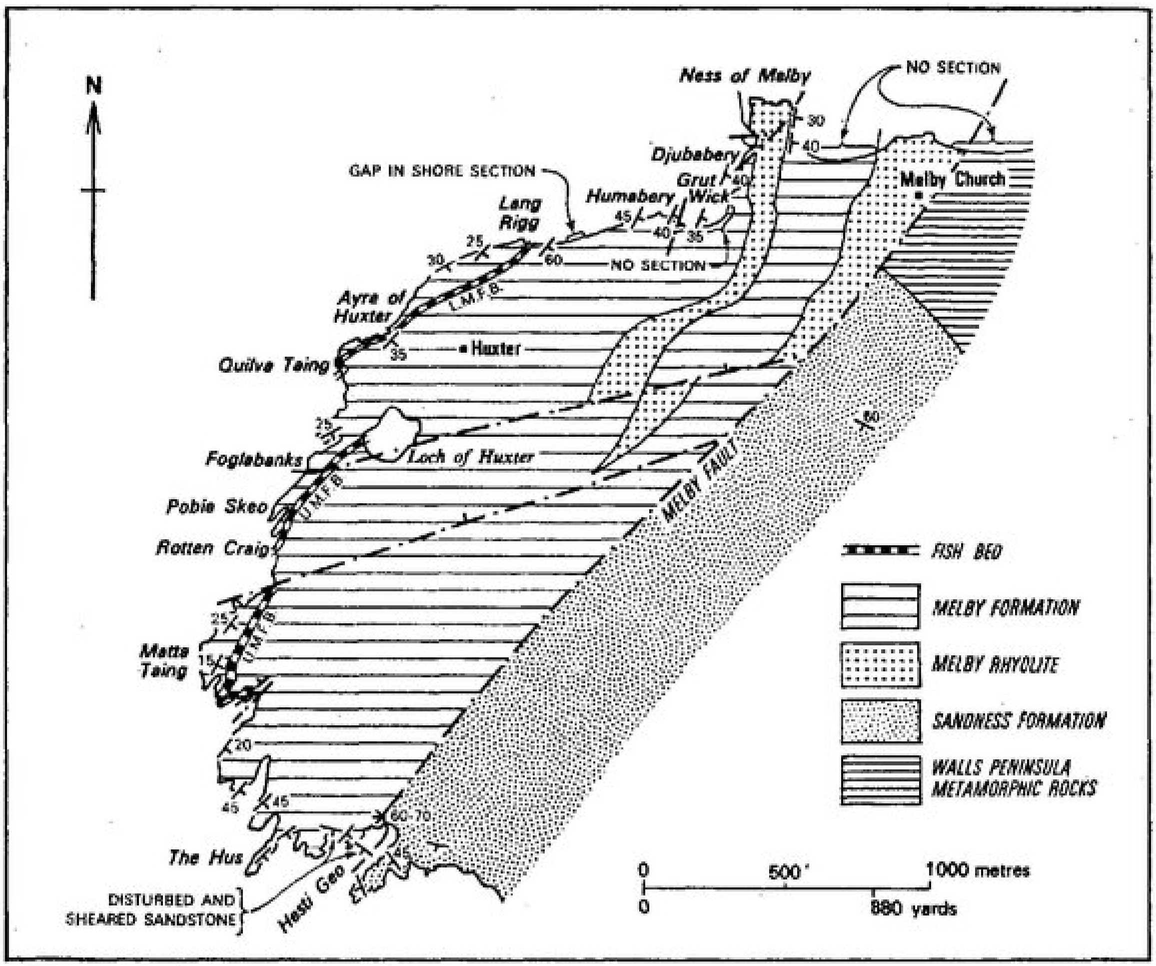


(Plate 12) Major stratigraphic and structural features of the Old Red Sandstone sediments and volcanic rocks of the Walls Peninsula.

(Plate 9) Geological sketch map of the Sandness Formation.



(Figure 27) Major faults in the area north of Busta Yoe.



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