Metamorphic rocks of Shetland: east Mainland and adjacent islands

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East Mainland Succession
Geological map of Shetland east Mainland and some adjacent islands. P915596.
Most of the metamorphic rocks of Shetland Mainland east of the Walls Boundary Fault belong to the East Mainland Succession (P915596), a more or less continuous sequence of steeply inclined to vertical north to north-east trending metasediments, which may be 22 to 27 km thick. The outcrop of this group of rocks is cut by the Nesting Fault, a major transcurrent fault which may have a dextral displacement of 16 km. The succession can be divided into four main divisions, the thicknesses and lithological units of which are shown in P915570. As the thicknesses are based only on the width of the outcrops and the dip of the beds, and do not allow for the many small-scale structural complexities, they must be regarded as approximate. In spite of the paucity of way-up criteria within the beds it is believed that the oldest beds lie in the west and that the succession gets progressively younger in an eastward direction.

**Yell Sound Division**

The Yell Sound Division, which is truncated in the west by the Walls Boundary Fault, crops out along the shores of Sullom Voe and forms a narrow strip along the east coast of Aith Voe. It is also found on the east shore of Swining Voe and probably extends across Yell Sound to include the rocks of Yell. It is composed almost entirely of highly feldspathic psammites (originally arkoses or feldspathic sandstones), which have been widely but very variably migmatised. There are two or three quartzite horizons within the sequence. The junction with the Scatsta Division to the east is not clearly marked because of interbanding and the masking effects of migmatisation.
Scatsta Division

The Scatsta Division can be divided into a lower pelitic group and an upper quartzitic group. The former consists mainly of pelitic schist some of which contains large crystals of staurolite. The quartzitic group, which forms the prominent topographic ridge in central Mainland just west of Weisdale Voe and the Kergord valley, consists of pure and impure quartzites interbanded with medium- to fine-grained mica-schists. Individual bands in this group vary in thickness from a centimetre to several metres. They are highly deformed and metamorphosed and do not show any original sedimentary structures other than compositional banding. The quartzites are generally predominant but certain pelitic bands containing large staurolites can be traced for long distances along the strike.

The Yell Sound and Scatsta divisions contain a north to north-east trending, somewhat irregular belt of migmatite which has been termed the Scatsta Permeation Belt by Flinn (1954, p.187). Within this belt the mica-schists have been converted into schistose gneisses, composed of small streaks and eyes of quartz and feldspar separated by anastomosing micaceous folia. The belt is bounded by two very persistent bands, on the west by augen-gneiss and on the east by schist with large porphyroblasts of microcline. The pelitic rocks associated with the belt contain such minerals as andalusite, shimmer aggregate, sillimanite and secondary muscovite, which indicate that the formation of the gneiss was accompanied by the thermal metamorphism of the adjoining rocks.

Whiteness Division

The Whiteness Division consists mainly of flaggy micaceous quartz–feldspar–granulite (psammite) and contains four thick and several thinner bands of crystalline limestone. The psammite is characterised by the presence of micaceous laminae which are regularly spaced at intervals of a few millimetres. These laminations appear to be original features of the sedimentary rocks. The Weisdale Limestone, the basal member of the Division, is over 400 m thick and gives rise to a prominent topographic depression which can be followed from Weisdale northwards to Dales Voe. The Whiteness Limestone, which is up to 600 m thick in White Ness, thins out northwards. The Girlsta Limestone, which is persistent in the north and forms a small ridge in the Tingwall Valley, appears to lens out southwards on Trondra. All these limestones are calcite marbles which contain small quantities of epidote, zoisite, white mica and pyrite concentrated in fairly continuous layers. Epidote-rich lenses and thin semipelitic bands are present throughout the psammites of this division, but highly micaceous rocks are largely confined to one group, known as the East Burra Pelite.

The thick sequence of rocks, including the East Burra Pelite, between the Whiteness and Girlsta limestones contains a belt of migmatitic gneiss which has been termed the Colla Firth Permeation Belt by Flinn (1954). This is up to 2.5 km wide and can be traced from Swining Voe in Delting southwards to South Havra, a distance of 43 km. Its probable extension on the east side of the Nesting Fault passes through Nesting and extends from Cat Firth to Stava Ness. The gneiss contains much material of metasedimentary aspect and in most places it has retained its banded structure. The process of conversion to coarse-grained gneiss has acted very unevenly on the various rock types; psammitic and semipelitic rocks are coarser-grained than normal and contain abundant quartzo-feldspathic bands and lenses; the pelitic rocks have conspicuous micro-augen (small ‘eyes’) of plagioclase which are arranged with their long axes parallel to the schistosity, but calcareous and hornblendic rocks are preserved intact. As in the Scatsta belt the development of the gneiss is associated with the production of high-temperature minerals such as sillimanite.

Deformed ‘veins’ of granite, pegmatite and quartz-tourmaline rock are very abundant within and just outside the migmatite belt. Most of the granite ‘veins’ are concordant sheets and lenses with sharp
margins against the gneiss, but cross-cutting veins are also common. The largest granite mass has a maximum thickness of 500 m and extends for 6.5 km along the strike. Many of the concordant sheets are boudinaged and most have a marked schistosity which is parallel to, and continuous with, the regional foliation. The cross-cutting veins have been folded by buckling.

The two most easterly members of the Whiteness Division, the Wadbister Ness Group and the Laxfirth Limestone, are best seen in the area east of the Nesting Fault. The former is also well exposed around the head of Laxo Voe in Delting, just west of the fault, and forms the peninsula of South Nesting as well as Wadbister Ness. It consists of alternating bands of flaggy micaceous psammite and semipelite, frequent ribs and striped bands of calc-silicate rock and impure marble, and some bands of hornblende-schist. The Laxfirth Limestone may be more than half a kilometre thick. It is lithologically similar to the other limestones, but finer-grained.

**Clift Hills Division**

The Clift Hills Division follows conformably to the east of the Laxfirth Limestone. Its predominant rock types are chlorite- and biotite-muscovite-phyllites, but there are several important bands of spilite and some thick beds of grit. Along the western side (base) of the division the Asta Spilitic Group is developed along the ridge east and north-east of Scalloway and close to the east shore of Lax Firth, and can be recognised further north on the islands of Gletness and on Hoo Stack. It consists of metasedimentary phyllite together with hornblende phyllites and coarse-grained hornblende rocks, which may have originated respectively as basic lavas and/or pyroclastic deposits and as basic intrusions.

The Clift Hills Phyllitic Group, though on the whole very uniform, contains rocks which range from pelites to impure quartzites. The phyllites are laminated on a millimetre scale, the darker, more micaceous layers representing metamorphosed mud, while the lighter are probably derived from sand and silt. It is occasionally possible to detect small-scale cross-bedding in these rocks. All the phyllites contain muscovite together with either reddish brown biotite and/or one of two varieties of chlorite. Some are graphitic. Within the group there are several thick units of coarse feldspathic grit, the most important being the Dales Voe Grit which can be traced from Dales Voe southwards to the latitude of Quarff.

The Clift Hills Phyllitic Group passes eastward through a transition bed into the Dunrossness Phyllitic Group. The latter can be followed from the latitude of Scalloway southwards along the eastern slopes of the Clift Hills to Scousburgh, where its outcrop turns sharply westward and then northward. The group also forms a large part of the Fitful Head peninsula. These phyllites are very uniform in texture and composition and they are characterised by abundant chlorite and muscovite and the almost invariable presence of chloritoid. Kyanite occurs in quartz segregations. In the metamorphic aureoles (see Granodiorite and porphyritic adamellite) they also contain staurolite. The Dunrossness Spilitic Group, which crops out at Cunningsburgh, Channerwick and on the western cliffs of Fitful Head, contains metamorphosed lavas and pyroclastic rocks in which the original textures are locally well preserved. Pillow structure has been noted but is not common. At Cunningsburgh there is a considerable mass of serpentinite extensively altered to talc-magnesite-schist and intimately associated with the lavas and pyroclastics. The spilites are intercalated with metasediments, mainly graphitic phyllites, gritty impure quartzites and recrystallised cherts. The spilites and cherts of this group are thought by Garson and Plant (1973) to be part of an ophiolite complex and to mark the position of a subduction zone.

**Other rock groups**

There are a number of areas in south Mainland, bounded either by tectonic dislocations or by the
sea, which consist of rocks that resemble certain members of the East Mainland Succession but have not been definitely correlated with them (Flinn 1967a)\[3\]. The Bigton Grits, for instance, are a series of well-bedded quartzitic grits with lenses of hornblende-feldspar rock. They crop out along the western coastal strip between Maywick and Scousburgh and resemble the Dales Voe Grit. It is likely that they are part of a fault-bounded slice of a grit in the Clift Hills Phyllitic Group. The Garths Ness Hornblendic Series forms the peninsula of Garths Ness, just east of Fitful Head. It consists of a shear-bounded mass of striped epidotic hornblende-schist with isolated beds of semipelite. It is at least 500 m thick, far thicker than any other hornblende-schist on Shetland Mainland.

**Quarff Nappe and the Mélange**

Between Rova Head, 4 km N of Lerwick, and Cunningsburgh, the East Mainland Succession is bounded on the east by a poorly exposed zone of tectonic dislocation which is probably made up of many shear-bounded slices of rocks similar to those found in the relatively unstrained ground both to the east and west. There are slices of graphitic phyllite, quartzite, staurolite-schist, altered serpentinite, marble and grit. This zone is believed to be a ‘mélange’ or schuppen-zone which was formed when a major nappe, now represented by the Quarff Succession (P915596) overrode the rocks of the East Mainland Succession. The Quarff Succession is best exposed around Quarff and Fladdabister where four main rock groups can be recognised. Three of these can be fairly confidently correlated with rock types in the East Mainland Succession. Thus the most westerly belt of rocks in the Quarff area consists of gneisses which are similar to the gneiss in the Colla Firth Permeation Belt. To the east of these a thick series of flaggy psammites, semipelites and calc-silicate rocks is closely similar to the schists of the Wadbister Ness Group, and a limestone, which crops out south-west of Fladdabister, has been tentatively correlated by Flinn with the Laxfirth Limestone. East of this limestone there is a thick series of bedded grits called the Fladdabister Grits. These are different from any of the rocks in the East Mainland Succession, and they consist of quartz and acid plagioclase grains set in a matrix which ranges from calcareous to siliceous. Flinn has suggested that these grits may never have been part of the East Mainland Succession, and that they are part of a rock slice which might be equated with a slice of similar grit just east of the mélange at Rova Head.

**Structure**

Only one period of intense deformation, termed the Main Deformation (Flinn 1967a)\[3\], is recognised in the East Mainland Succession. This was responsible for the formation of the tectonic fabric in the rock which ranges from predominantly planar (s-tectonite) to linear (l-tectonite). During this phase small tight and isoclinal folds of the bedding were formed in many parts of the succession, but major folds have not been recognised with the possible exception of a big fold picked out by the outcrop of the Dunrossness Phyllite in the Channerwick-Scousburgh-Maywick area. The foliation of the rock is determined by the limbs of the isoclinal folds; a schistosity lying parallel to this foliation is present in the more micaceous beds. In the migmatite belts the foliation is less regular and is commonly distorted around resistant lenticular masses. Many hornblende-schist bands are boudinaged and most rocks display a prominent rodding or mineral lineation.

Structures associated with later phases of deformation include minute crinkles in some micaceous beds, attributed to weak tectonic movements, and small kink-bands and conjugate folds, locally with broken axial planes and shattered short limbs. These were formed by a late phase of folding which took place under brittle conditions. There is also a very small number of large open folds which may be attributed to the forceful emplacement of the Spiggie and Channerwick granites.

At a later date the East Mainland Succession was cut by a number of sub-parallel faults of which the
Walls Boundary Fault and the Nesting Fault, both probably with large dextral displacements (see Correlation), are the most important. The Quarff Nappe was emplaced before the deposition of the East Shetland Old Red Sandstone and probably before the main movement along the faults associated with the Nesting Fault.

**Metamorphic history**

The metamorphic and structural history of parts of the East Mainland Succession has been studied by Flinn and May. Flinn (1954)\[1\] suggests that in Delting (north Mainland) the earliest recognisable episode after the deposition of the sedimentary rocks was a period of regional metamorphism. This coincided with the main phase of deformation which imprinted the dominant planar and linear tectonite fabric on the rock. He believes that at that time the grade of metamorphism increased westwards and that most of the Scatsta Division lay within the kyanite zone, whereas the Whiteness Division, which contains much less garnet, was low in the garnet zone or even below. The next episode was the development of the Scatsta and Colla Firth permeation belts. This took place after the period of deformation and its associated regional metamorphism, but while thermal gradients generated within the rocks at that time were still in existence. The location of the belts of permeation was in no way controlled by the regional metamorphism, as they cut across the pre-existing isograds and follow the structural and lithological pattern of the rocks. The permeation was accompanied by thermal metamorphism in the immediate neighbourhood of the belts. Flinn concludes that in Delting the regional metamorphism and permeation were two largely independent processes.

Flinn (1967a)\[3\] recognises a very similar sequence of events in the southern part of Shetland Mainland, where he notes the following metamorphic episodes:

1. **Tectonising metamorphism** (i.e. metamorphism associated with the tectonic phase). This coincided in time with the principal period of deformation. During this period the platy and elongate minerals developed a preferred orientation which determined the foliation and lineation of the rocks. Minerals formed at this stage are biotite, chlorite, muscovite, quartz, feldspar and possibly garnet.

2. **Porphyroblast metamorphism.** During this phase a number of minerals, normally developed as a result of regional metamorphism, crystallised as porphyroblasts. The orientation of these minerals is random and quite unrelated to the tectonite fabric of the rocks, thus indicating that their growth was later than the ‘tectonising metamorphism’. The new minerals formed were biotite, chlorite, staurolite, kyanite, chloritoid and garnet.

3. **Permeation metamorphism.** This is the episode when the Colla Firth Permeation Belt was formed and the associated granite and pegmatite veins were emplaced. It took place while the thermal gradients of the regional metamorphism (phases 1 and 2) were still in existence. The permeation is believed to have taken place under static conditions, the alignment of many minerals parallel to the regional fabric being ascribed to mimetic crystallisation. As in Delting, the permeation produced a phase of localised thermal metamorphism, during which diopside and microcline were developed in the calc-silicate bands. The mineral associations in these thermally altered zones indicate conditions characteristic of the boundary between the pyroxene hornfels and hornblende hornfels facies.

4. **Thermal metamorphism.** The emplacement of the Spiggie, Channerwick and Cunningsburgh granites produced extensive thermal aureoles within which such minerals as
Staurolite, chloritoid, andalusite, kyanite, sillimanite, garnet and muscovite were developed in the pelitic rocks of the Dunrossness Phyllitic Group.

A somewhat different sequence of metamorphic episodes was deduced by May in his study of the area around Scalloway. Here the textural evidence suggests that prograde metamorphism took place in three stages. During the first stage kyanite and staurolite were formed in pelites, but most traces of this stage have been obliterated by later events. Most minerals now present in the rocks were formed during the second metamorphism which coincided in time with the main phase of deformation. This was also the period when the Colla Firth migmatite belt was formed and the numerous associated cross-cutting and discordant granite and pegmatite sheets and veins were emplaced. The crucial evidence for the belief that the migmatite emplacement took place while deformation was still in progress comes from the granites and pegmatites. In these rocks it can be shown that the constituent minerals have been granulated and recrystallised to produce a tectonite fabric which is continuous with the fabric of the country rock. The only evidence for a period of post-tectonic metamorphism is provided by the presence of diopside in calc-silicate rocks, some of which crystallised under apparently static conditions.

Lunnasting, Whalsay and Out Skerries

The metamorphic rocks forming the peninsulas of Lunna Ness and Lunnasting and the island of Whalsay consist of highly metamorphosed homogeneous pelitic and semipelitic gneisses with much quartzite and some impure limestones. Their inclination ranges from vertical in the west to horizontal in Whalsay in the east and their trend is generally north—north-easterly. Nearly all these rocks have been intensely migmatised and are now coarsely crystalline. In Lunna Ness some are almost completely granitised, showing only vague relicts of their original structure, and a continuous band of very coarse microcline augen-gneiss extends along the centre of this peninsula. In the Lunning district the gneiss has many prominent crystals of staurolite and kyanite, now mostly altered to shimmer aggregate. The most common minerals forming the gneiss are feldspar, biotite, muscovite, quartz and garnet. A thick band of limestone with calc-silicate ribs crosses Lunnasting from Dury Voe to the head of Vidlin Voe and there are a number of lenses of hornblendic gneiss, particularly in Lunna Ness. Whalsay is formed of pelitic gneiss with abundant garnet and kyanite, and some quartzites, cut by numerous small granite intrusions. A belt of very intense migmatisation extending along the south-east coast of the island has produced granite-like rocks.

The Out Skerries consist of a variety of rock types which have a trend that swings from north-east in the extreme west to east-north-east in the centre and east of the island group. The rocks also have a strong linear fabric due to intense folding, on all observable scales, on axes that are nearly horizontal. A thick crystalline limestone passes through the centre of the island group. This is bounded on either side by semipelitic granulites, calc-silicates and some pelites which are usually partially migmatised and commonly contain sillimanite. The migmatisation is most extensive along the southern shores of the island group. All the rocks have been invaded by pegmatite and granite veins and ribs, some of which are several hundred metres long. The edge of a somewhat larger granite intrusion occurs in the extreme north of the group.

No published modern work on the structure, metamorphic history and possible stratigraphic correlation of the Out Skerries is available. Robertson (in Summ. Prog. 1934, p.71) thought that these rocks bear a strong resemblance to those forming the eastern margin of the main permeation belt in South Nesting. If this correlation is accepted, the Out Skerries rocks form the north-eastward continuation of part of the Whiteness Division. Flinn believes that the rocks on both sides of the thick limestone are similar to the Wadbister Ness Group, but states that the migmatisation, which is of an unusual type, is less strongly developed than in the Colla Firth Permeation Belt. The Skerries
limestone may thus be the Laxfirth Limestone which here occupies the core of a tight fold and is flanked by rocks of the Wadbister Ness Group.

The islands south of the main group of Out Skerries contain rocks closely resembling the Asta Spilites of Shetland Mainland, associated with gritty quartzites with flute casts and with phyllites which contain some staurolite. All these rock types are closely similar to the rocks of the Clift Hills Division.

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