Uyea to North Roe Coast

[HU 310 930]–[HU 380 950]

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Introduction

The N-facing cliffs of North Roe in the north-west part of Mainland Shetland present a continuously exposed and mostly accessible section through the Caledonian Front (Figure 9.3). From west to east, the section consists of: Lewisian gneisses (the Western Gneisses), overthrust from the east by Moinian psammites containing tectonically emplaced Lewisianoid inliers, which are in turn overthrust from the east by metasedimentary rocks and greenschists of probable Dalradian affinity. These Shetland exposures extend the basic tectonic features and lithologies of the Caledonian Front seen in mainland Scotland some 230 km to the north, about halfway to Norway. The thrusts in Shetland dip more steeply and are associated with higher-grade metamorphism than in mainland Scotland, so that the area is of national and international importance in studies of the Caledonides.

The area was mapped by J Phemister for the Geological Survey between 1930 and 1932 (see Wilson, 1932 for brief description) and in more detail by Pringle (1964, 1970). Subsequent work has refined the understanding of the structure and wider stratigraphical correlation of the units (Flinn *et al.,* 1979; Robinson, 1983; Roddom, 1992). The coastal section is particularly relevant to the offshore extension of the Caledonian Front (Ritchie *et al.,* 1987; McBride and England, 1994). The nomenclature used here follows that on the Geological Survey 1:50 000 map, Sheet 129, Northmaven (British Geological Survey 2004e) and is essentially that of Pringle (1970).

Description

The Uyea to North Roe GCR site comprises near-continuous sea cliff and limited foreshore exposures. The section extends for roughly 10 km between the island of Uyea (pronounced 'oo-ye') and the peninsula of Fethaland (Figure 9.3). The western part of the site, between Uyea and Heoga Neap, is underlain by two groups of quartzofeldspathic orthogneisses, which are collectively called the 'Western Gneisses'. In the west, the deeply weathered Uyea Group is continuously exposed in cliffs that are mostly inaccessible. This unit is composed of banded felsic orthogneisses and coarse-grained granitic gneisses, containing plagioclase and K-feldspar, with locally occurring bands of pyroxene-hornblende mafic rock. A large body of coarse-grained brown hornblende-feldspar gneiss, a metagabbro, intrudes the granitic gneisses near Fugla Ness. The Uyea gneisses are not schistose, but they have been extensively sheared and cataclastically deformed, producing local zones of mylonitization, and have also been intruded by plagioclase-rich pegmatite veins. The whole of the Uyea Group appears to be a metamorphosed igneous complex. It is separated from the Wilgi Geos Group to the east by a broad E-dipping shear-zone, the Uyea Shear Zone, which cuts across the regional banding in the Uyea Group.

The Wilgi Geos Group is continuously exposed along the coast from its western contact with the Uyea Group to its contact with the overlying Sand Voe Group in the east. In the central part of the section it consists of leucocratic oligoclase-quartz granitoid gneisses, characterized by small (less than 5 mm) plagioclase augen and containing minor amounts of hornblende, muscovite and biotite. To the east, and more strongly to the west, an ESE-dipping late schistosity enclosing relict feldspar augen is developed as the neighbouring units are approached. The Wilgi Geos gneisses are cut by widely but sparsely distributed sheets and irregular masses of dark blue-green amphibolite, and a number of plagioclase-rich pegmatite veins.

In the cliffs to the north and south of the entrance to Sand Voe, the Wilgi Geos Group is overthrust by the Sand Voe Group, along the Wester Keolka Shear Zone (Figure 9.4). The shear zone is characterized by a consistent strong planar schistosity that dips eastward at about 60° parallel to the thrust contact (Figure 9.5). The rocks on either side of the contact, the psammites above, and granitoid gneisses below, have similar quartz-plagioclase-dominated compositions,

and hence their sheared and schistose counterparts are virtually indistinguishable within the shear zone. The line of contact is revealed only by the presence of tiny relict plagioclase augen in the underlying gneisses.

The Sand Voe Group is about 830 m thick and contains several intercalated lenses of orthogneiss. Two types of gneisses are found: (a) granitoid gneisses correlated with the Western Gneisses; and (b) banded hornblendic mafic and subsidiary felsic gneisses (the 'Sand Voe Banded Gneisses' or 'Eastern Gneisses' — Flinn, 1988) that resemble the Lewisianoid inliers in the Moine succession of mainland Scotland. The dominant psammites are composed mainly of quartz and plagioclase with minor amounts of micas and garnet. There is a strong schistosity parallel to compositional layering, except in the hinge regions of small isoclinal folds whose axial planes lie parallel to the schistosity.

Sedimentary structures are not seen generally in the psammites, but relics of slumped units [HU 364 918] and current bedding (HU 362 915 and [HU 363 918]) are recognizable locally. Conglomerates containing pebbles similar to the Wilgi Geos gneisses are preserved at [HU 369 926] and [HU 364 923]. Immediately above the Wester Keolka Shear Zone similar flattened pebbles occur locally in the psammite sequence.

Some 50 m above the base of the Sand Voe Group is a cross-cutting lens of Wilgi Geos gneisses, up to 100 m thick, which is overprinted by a secondary schistosity. Higher in the psammite succession lenses of the Eastern Gneisses, up to 50 m thick are dominant. The contacts between the gneisses and the psammites appear to be planar and conformable, but they are at least partly tectonic and difficult to pinpoint except where there is a marked lithological contrast.

The psammites of the Sand Voe Group become very platy and fissile at the junction with the overlying Eastern Gneisses. These mainly Lewisianoid gneisses are about 230 m thick, and similar lithologies occur in the Hascosay Slide Zone on Yell (see Cullivoe GCR site report, this chapter). They are of striking appearance, being mainly whitish and quartzofeldspathic, but with very sharply defined dark-grey to greenish-black mafic laminations, and thin bands. The dark layers represent concentrations of hornblende with garnet, biotite and epidote. They are typically continuous, parallel and generally rectilinear, with locally up to 25 laminations per centimetre. Within these banded gneisses, and wrapped by the laminations, are mainly unfoliated lenses of other rock-types varying in size from tens of centimetres to tens of metres. They include garnet amphibolite, hornblende-plagioclase gneiss (with augite and garnet), serpentinite, steatite, zoned balls of talc-actinolite-biotite rock (metasomatized serpentinite), and garnet-hornblende-clinopyroxene-quartz granofels. The hornblende in the laminated rocks is blue-green, but locally the unfoliated lenses contain relict brown hornblende and pyroxene.

Certain distinctive layers can be traced within the Eastern Gneisses. At the base of the unit is a persistent layer of schistose garnet-rich psammite some 3 m thick. Some 60 m above the base is the Benigarth Garnet-Mica Schist, a pelitic unit several metres thick that can be traced for many kilometres. Sixty metres higher is the Setter Quartzite, a feldspathic quartzite up to 10 m thick that contains distinctive small pink microcline augen. Again, although only a thin unit, the quartzite can be followed for many kilometres. Neither the quartzite nor the schistose pelite bands are of undoubted sedimentary origin. Lenses of garnet amphibolite and hornblende-plagioclase mafic gneiss occur mainly above the Setter Quartzite in the upper part of the Eastern Gneisses, and are also found in the schistose pelite above.

The schistose garnetiferous pelites and semipelites lying to the east of the banded gneisses constitute the upper part of the Sand Voe Group. They are medium-grained garnetiferous, quartz + muscovite-rich schistose pelites with minor amounts of biotite. In places they contain sharply defined bands of muscovite-rich schist with centimetre-sized chloritoid porphyroblasts enclosing kyanite and garnet [HU 375 943].

These lithologies can be followed intermittently for some 25 km to the south, as far as Hillswick Ness on the north shore of St Magnus Bay.

The garnetiferous schistose pelites of the Sand Voe Group have been overthrust from the east by the Queyfirth Group along the Virdibreck Shear Zone. Much of the Queyfirth Group in North Roe consists of a thick unit of calcareous, hornblendic and chloritic 'green beds', originally mafic volcanic and volcaniclastic rocks, locally interbanded with thin metalimestone and quartzite beds. Coarse-grained metagabbros also occur in places. The 'green beds' pass up into

banded quartzites and psammites with serpentinite bands, interbedded with graphitic phyllite and schistose conglomerate units. Rocks of similar type in south-east Shetland (Flinn, 1967) are considered to belong to the upper parts of the Dalradian Supergroup; hence, the Queyfirth unit is considered to be of similar affinity.

The Virdibreck Shear Zone lies in a zone of strongly developed, fissile schistosity, which is apparently continuous with that found in the garnetiferous pelites of the Sand Voe Group to the west. Unlike the Wester Keolka Shear Zone, the Virdibreck Shear Zone is disturbed by crenulation cleavages, microfolding and larger-scale distortions. These are also common within the Queyfirth Group, together with much late, tight to isoclinal folding accompanied by coarsely lenticular shearing, cataclasis, open folding and faulting. They have been imposed on the early, bedding-parallel penetrative schistosity, which is present in both the Queyfirth and Sand Voe groups.

Interpretation

From their appearance and situation the Western Gneisses have long been considered to be equivalent to the Lewisian Gneiss Complex. This has since been confirmed by K-Ar dating of hornblendes from an early hornblendite intrusion in the Uyea Group, which yielded a spread of ages ranging from 2873 Ma to 2661 Ma (Flinn *et* al., 1979). Provided there is no excess argon present, this spread is considered to be due to varying amounts of argon loss during a subsequent heating event, and the oldest date is taken to be nearest to the true age of emplacement. Robinson (1983) also obtained an ^{40}Ar-^{39}Ar total fusion age of 2440 Ma for a brown hornblende from the Uyea Group.

An ^{40}Ar-^{39}Ar step-heating age of 439 ± 3 Ma was obtained for blue-green hornblende from a recrystallized relict gneiss lens in the Eastern Gneisses (Robinson, 1983), and Roddom (1992) obtained an ^{40}Ar-^{39}Ar step-heating age of 466 ± 6 Ma from muscovite separated from schistose Wilgi Geos Group rocks immediately beneath the Wester Keolka Shear Zone. He interpreted this as a cooling age for the schistosity, indicating that the Wester Keolka Shear Zone was active at or before this date. He also obtained a date 20 million years younger than this for the Moine Thrust in the Eriboll area of Scotland, throwing some doubt on the direct correlation of the Wester Keolka Shear Zone and the Moine Thrust.

The Sand Voe Group has been broadly correlated with the Moine succession because of its psammitic nature and its structural position in contact with and to the east of the Archaean-age Western Gneisses. The dominantly psammitic lithologies are similar to those of the lower part of the Morar Group in that they contain conglomeratic and pebbly beds and current bedding, and the garnet-studded hornblende schists and talc-silicate bands characteristic of higher levels in the Moine are absent. However, Robinson (1983) pointed out that in detail the psammites of the Sand Voe Group are less feldspathic than those of the Morar Group, exhibit less current bedding and fewer elastic grains, and that heavy-mineral bands are absent. It is possible that the facies is laterally variable, and also that the stronger deformation of the Shetland rocks may have effectively destroyed some of the sedimentary features.

The schistosity superimposed on the Wilgi Geos Group gneisses and dated by Roddom (1992) lies parallel to the Wester Keolka Shear Zone and continues eastwards into the psammites and interbanded pelitic units of the Sand Voe Group and into the Eastern Gneisses with a consistent dip, parallel to the bedding and gneissic layering. It appears to be contiguous with a strongly developed schistosity adjacent and parallel to the Virdibreck Shear Zone, and with the main bedding-parallel schistosity and cleavage in the rocks of the Queyfirth Group. Adjacent to the Wester Keolka Shear Zone, at the base of the Eastern Gneisses, and in the Virdibreck Shear Zone, the schistosity is more strongly developed, such that the rocks are typically fissile, possibly as a result of later deformation.

To interpret this fabric as a single schistosity resulting from a single deformation would be naive in view of the different ages and very different lithologies involved. It is probable that the Eastern Gneisses, with features analogous to those in the Hascosay Slide Zone, formed by extreme heterogeneous deformation of older hornblendic gneisses. This unit is now inter-layered with schistose pelitic units of lower competence, which would have preferentially taken up the deformation provided that the two lithologies were deformed at the same time. It seems likely that the schistosities formed at different times in the different lithologies, but have been reactivated during their later assembly.

The late folding, cataclasis, secondary cleavage and faulting distributed throughout the Queyfirth Group were probably related to movements on the Walls Boundary Fault (Flinn, 1977), which lies little more than 1 km to the east of the

Virdibreck Shear Zone. Distortions caused by movement on the Walls Boundary Fault would have focused on the shear zone, which acted as a pre-existing surface of weakness, resulting in the fissile enhancement of the schistosity in the adjacent rocks.

The link between the Moine Thrust and the Wester Keolka Shear Zone is still uncertain, and McBride and England (1995) observed that it is not possible to justify the interpretation of the Moine Thrust as a single continuous structure between Scotland and Shetland on geophysical grounds. However, even if the Wester Keolka Shear Zone is not physically connected to the Moine Thrust, it plays a sufficiently similar role to be taken as the Caledonian Front in Shetland. The Western Gneisses link to the west with a belt of gravity and magnetic anomalies that extends south-west from Uyea towards north-west Scotland, defining the Caledonian Foreland (Flinn, 1969; Ritchie *et al.,* 1987).

The course of the Caledonian Front to the north of Shetland has been the subject of recent debate. Ritchie *et al.* (1987) suggested that the Moine Thrust (i.e. the Wester Keolka Shear Zone) trends approximately northwards, across the continuation of the gravity and magnetic anomaly that appears to characterize the foreland. This trend is based on their conclusion that the Caledonian Front must run to the west of a series of boreholes that were drilled in the area of significant gravity and magnetic anomalies, and which yielded granitoid rocks with Caledonian K-Ar biotite ages (430–360 Ma). However, the Ronas Hill Granite, with a K-Ar age of 358 Ma (Miller and Flinn, 1966), intrudes the Western Gneisses to the west of the Caledonian Front in North Roe, indicating that the borehole evidence alone does not necessarily pin down the position of the Caledonian Front.

Flinn (1992, 1993) suggested that the Caledonian Front intersects, and is offset by, the Walls Boundary Fault north of Shetland and then continues to the north-east along the south side of the belt of gravity and magnetic anomalies, and passing to the south of the boreholes described by Ritchie *et al.* (1987). Ritchie and Hitchen (1993) challenged this conclusion, noting that Flinn's (1992) model failed to take into account the accepted location of the Caledonian Front in east Greenland. Work using more up-to-date palaeogeographical reconstructions (e.g. Higgins *et al.,* 2001), has shown that there is little doubt about the presence of the *c.* 430 Ma Caledonian Front in east Greenland. However, the exact position of the Moine Thrust has not been identified, but it is difficult to see that it would cross the gravity and magnetic anomalies that are believed to mark the Caledonian Front.

McBride and England (1994) could not recognize the Moine Thrust in a seismic line to the north of Shetland, but they did identify a reflective wedge, which they considered might represent a thrust zone below the Moine Thrust itself. They suggested that the Moine Thrust had been truncated by strike-slip movements along the Walls Boundary Fault.

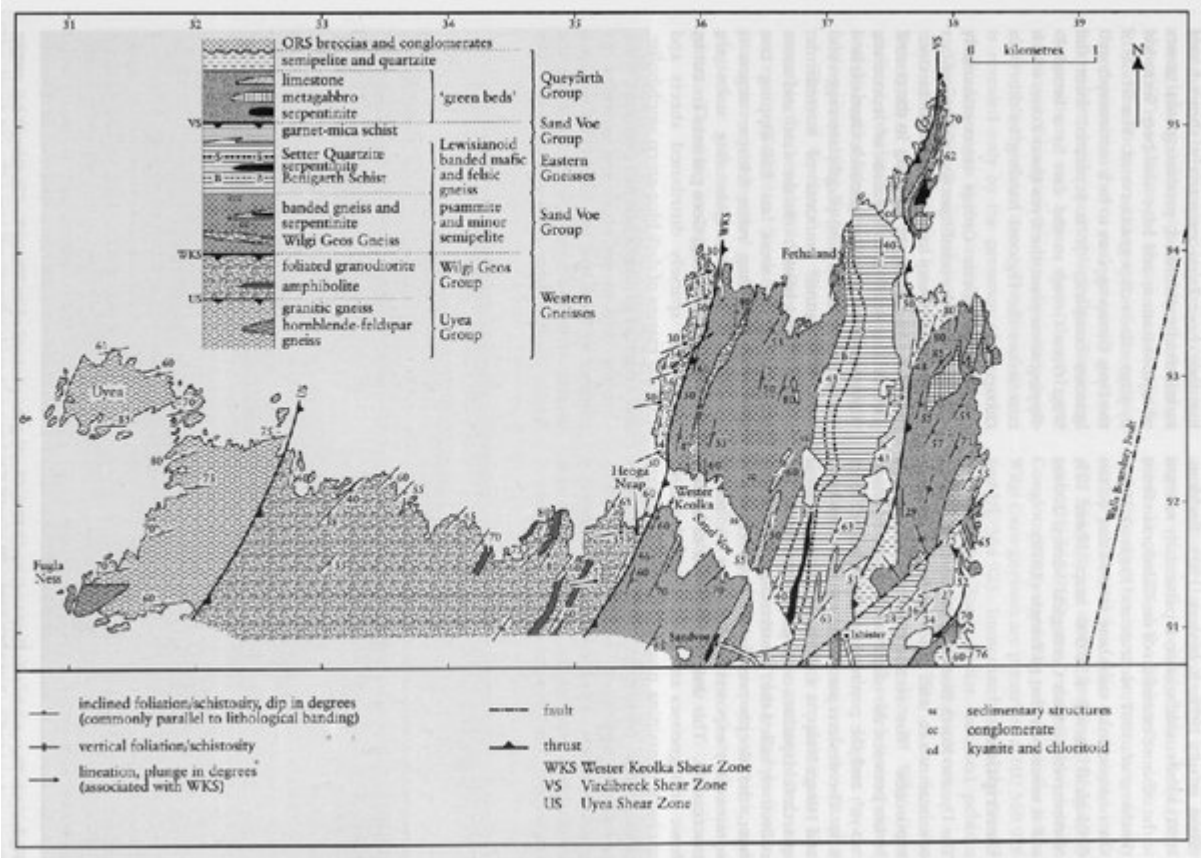
Conclusions

The Uyea to North Roe Coast GCR site is an excellently exposed, roughly 10 km-long coastal section that is representative of the pre-Caledonian and Caledonian metamorphic rocks to the west of the Walls Boundary Fault. It includes rocks of probable Lewisian, Moine and Dah¯adian affinities, and lies at the most northeasterly extent of these units. The section is undoubtedly of international importance for correlation purposes along the Caledonides orogenic belt.

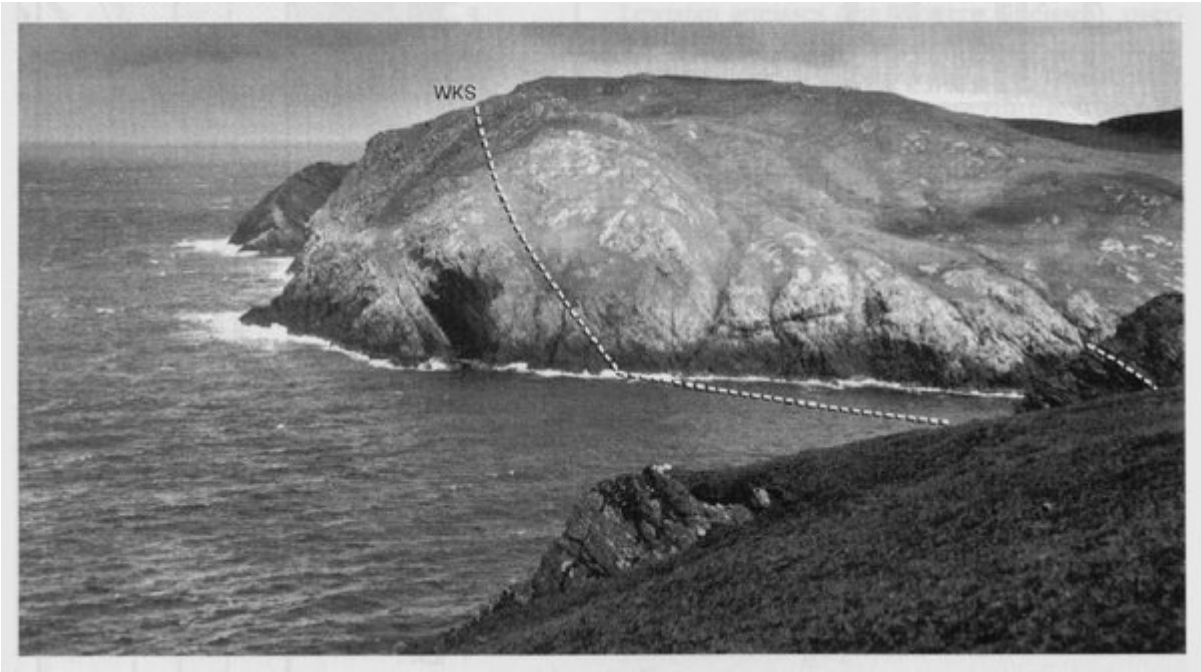
In the west of the GCR site, between Uyea and Heoga Neap, are exposures of Archaean granitic gneisses and subsidiary mafic rocks (the Western Gneisses) correlated with the Lewisian Gneiss Complex. These have been overthrust from the east, along the Wester Keolka Shear Zone, by psammites and schistose semipelites and pelites, which are interlayered with banded Lewisianoid felsic and mafic gneisses. The overthrust metasedimentary rocks, the Sand Voe Group, have been correlated with rocks of the Moine Supergroup on the Scottish mainland. The Wester Keolka Shear Zone therefore fulfils a similar role to the Moine Thrust on the Scottish mainland, and it has been suggested that it may be a northern continuation of that structure, marking the position of the Caledonian Front in Shetland. The eastern margin of the Sand Voe Group is marked by the Virdibreck Shear Zone, along which the rocks of the Queyfirth Group have been thrust westwards. The Queyfirth Group is composed of volcanic 'green beds' with quartzite, psammite and semipelite and meta-limestone units. The lithologies have been correlated with the higher parts of the Dalradian Supergroup found in south-east Shetland and on the Scottish mainland.

Some 2 km to the south of the coastal section, the Devonian Ronas Hill Granite truncates and hornfelses the successions described above, and this structural sequence is not seen elsewhere. Thus, the Uyea to North Roe GCR site is unique in that it provides the only well-exposed and coherent section across the Caledonian Front in Shetland.

References



(Figure 9.3) Map of the Uyea to North Roe Coast GCR site, North Maven, Mainland, Shetland.



(Figure 9.4) The entrance to Sand Voe, North Roe, showing the position of the Wester Keolka Shear Zone (WKS). View northwards from [HU 3560 9191]. (Photo: D. Flinn.)

(Figure 9.5) Rocks of the Wester Keolka Shear Zone at [HU 3560 9191] on the south side of the entrance to Sand Voe, North Roe. The coin lies over the shear plane and is 2.5 cm in diameter. (Photo: D. Flinn.)