Sgeir Ruadh (Portskerra)

[NC 876 667]–[NC 883 657]

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Introduction

Adjacent to Portskerra in north-east Sutherland, a near-continuous coastal section is exposed on rock platforms and in cliffs at the Sgeir Ruadh GCR site. This section lies within the Swordly Nappe and illustrates the relationships between migmatitic Moine psammites of the Portskerra Psammite Formation, amphibolite sheets of the Bettyhill Suite, and the Strath Halladale Granite Complex. Middle Devonian sandstones and breccio-conglomerates unconformably overlie these Neoproterozoic and Early Palaeozoic rocks (Figure 6.31).

Good exposures of the northernmost part of the Silurian-age Strath Halladale Granite Complex occur on the rock platform south of Sgeir Ruadh and the contact relationships of this sheeted granitic complex with the Portskerra Psammite Formation can be studied at Sgeir Ruadh itself. Coastal exposures west of Rubha Bhrà reveal the typical gneissose and migmatitic character of the Portskerra Psammite Formation. There are also numerous examples of the amphibolite sheets and dykes that represent metamorphosed Neoproterozoic intrusive mafic sheets and dykes.

The prominent basal unconformity of the Old Red Sandstone (ORS) Supergroup sedimentary rocks with the underlying Moine psammites and Strath Halladale granitic rocks is exposed at Sgeir Ruadh and at Port Skerra (Figure 6.31). These unmetamorphosed, Middle Devonian breccio-conglomerates and sandstones were deposited at the fringe of the Orcadian Basin. They underlie the gently undulating countryside around Portskerra village (Figure 6.32). A number of small faults are exposed, and their markedly different fault manifestations in the various lithologies can be studied in the coastal section.

Edward Greenly first mapped the area for the Geological Survey between 1890 and 1892, and Crampton and Carruthers (1914) gave a brief account of the geology. The migmatitic character of the Moine rocks of Portskerra was recognized by Read (1931) as being part of the Strath Halladale Granite Complex. More-recent work has divided the migmatitic Moine rocks into a series of smaller units, in part separated by significant ductile shears or thrusts (e.g. Moorhouse and Moorhouse, 1983; Fletcher and Key, 1991; Holdsworth *et al.,* 1994; British Geological Survey, 1996).

The Moine metasedimentary rocks contain numerous amphibolite sheets that form part of an extensive mafic sill-complex, part of the Bettyhill Suite (see Moorhouse and Moorhouse, 1979). These mafic intrusive rocks, originally dolerite and basalt sheets and dykes, appear to pre-date the earliest deformation and metamorphism and have been folded, boudinaged and partly migmatized during the extended deformation and metamorphic history. Only rarely do they still show discordant relationships.

The Strath Halladale Granite Complex forms a series of essentially concordant lenticular sheets within the Portskerra psammites. The intrusion was first recognized during the primary Geological Survey mapping (Crampton and Carruthers, 1914). Read (1931) recognized that metasedimentary (Moine) xenoliths occur throughout the main intrusion and noted the intimate relationship of the intrusion and its country rock. McCourt (1980) recognized several generations of granitic intrusions in the Strath Halladale Granite Complex. Kocks *et al.* (2006) have recently published a U-Pb TIMS titanite age of 426 ± 2 Ma for the main Strath Halladale Granite, which is interpreted as dating the granite emplacement. There is no associated thermal aureole around the Strath Halladale granite sheets and they suggest that the granites were emplaced into hot country rock, roughly coeval with the regional Scandian tectono-thermal event associated with the generation of the Moine Thrust Belt (see below).

The major ductile shears/thrusts in the Moine succession of Sutherland trend generally northwards with variable easterly dips and separate the succession into folds or nappes (Figure 6.3), (Figure 6.4). The gneissose psammites at Portskerra lie in the Swordly Nappe, the most easterly and one of the structurally higher nappes. Friend *et al.* (2000) have dated a high-grade metamorphic event that produced the migmatites in the underlying Naver Nappe at 467 ± 10 Ma (U-Pb SHRIMP zircon overgrowth age). In contrast, Ar-Ar and Rb-Sr isotopic studies on muscovite and hornblende from the lower A' Mhoine Nappe suggest that the pervasive W-directed thrusting and related deformation took place during the Scandian Event between about 440 Ma and 410 Ma (Dallmeyer *et al.,* 2001).

Description

The GCR site encompasses the coastal section from Melvich Bay west to the rocky promontories of Rubha Bhrà and Rubha Ghoiridh and the steep gully of Allt na Clèite. The section lies just north and east of the village of Portskerra and consists of mainly intertidal, clean-washed rock exposures and platforms, with backing cliffs of till and bedrock up to 60 m high (Figure 6.31), (Figure 6.32).

Gneissose, magnetite-bearing psammites form the headlands of Rubha Bhrà and Rubha Ghoiridh. Aligned biotite flakes define a penetrative foliation parallel to the compositional layering. The beds dip steeply north-east and are closely jointed. The gneissic layering is defined by dark-grey, biotite-rich seams and enhanced by coarse-grained, locally pegmatitic, quartzofeldspathic segregations up to 5 cm thick. Individual segregations are lenticular and typically up to 1 m long. Thin biotite-rich pelitic laminations are preserved within mica-poor psammite beds. The laminations are mostly parallel to layering but locally define possible relic cross-bedding structures (e.g. at [NC 8770 6663]).

Dark grey-green to black amphibolite bodies are common in the psammites and also occur as xenoliths in the thick Strath Halladale Granite Complex (see below). They vary from thin sheets up to several metres in length to mappable lenses up to about 40 m thick that show some slight discordance to the compositional layering in the host psammites. They form part of the Bettyhill Suite of Moorhouse and Moorhouse (1979) (see Ard Mor GCR site report, this chapter) and have a penetrative foliation that may well be composite; their intrusion appears to pre-date all the deformation phases. The largest amphibolite bodies in the Strath Halladale Granite Complex are exposed north of Portskerra pier (Figure 6.31). Granite with amphibolite rafts is also exposed in the cliffs of Geodh' Geal to the north-west of Portskerra, where it is strongly jointed and faulted.

Several generations of minor granitic intrusions cut the psammites and amphibolites. The earliest of these are white granodiorites that occur as concordant and discordant sheets, locally with diffuse margins. They have been termed the 'Badanloch Granite Sheets' farther south in central Sutherland where they are more extensively developed. The granodiorites comprise quartz, sodic plagioclase (oligoclase), biotite and ilmenite/magnetite with large K-feldspars. The K-feldspar phenocrysts generally overgrow a pervasive 'ghost' foliation in the granodiorites that is defined by aligned biotite flakes and locally by ribbon quartz. However, at Sgeir Ruadh a fine-grained, foliated granodiorite contains potash-feldspar phenocrysts wrapped by the foliation. The larger granodiorite bodies have biotite schlieren and generally disoriented small xenoliths of calc-silicate pods and amphibolite – the more refractory lithologies of the host gneisses. More rarely there are indurated psammite inclusions up to several metres long, for example at Sgeir Ruadh. Numerous micro-granite veins cut this granodiorite and its various inclusions. It has been suggested that the diffuse patches of granodiorite reflect localized saturation by sodic fluids and the discordant sheets represent local mobilization of partial-melt material (Read, 1931; Brown, 1971). Small asymmetrical folds that verge towards the northwest post-date the early granodioritic veins. Fold axes plunge moderately towards the SSE and related axial planes dip some 35°–40° to the south-east. An axial-planar biotite foliation is only pervasive in the semipelitic layers. Larger-scale examples of these folds are present at Rubha Ghoiridh [NC 8730 6648].

A network of pink- or red-weathering granodiorite to leucogranite veins of the Strath Halladale Granite Complex cross-cuts the white granodiorites. The pink granite veins increase in abundance towards the main Strath Halladale granite sheet, which is exposed near Portskerra pier. The veins comprise up to 50% of the rock volume, but individual veins rarely exceed 1 m in thickness. Shears and disharmonic open folds of more than one generation affect these granitic veins. For example, at [NC 8823 6540] a late granite vein has been injected along a shear that offsets older veins. The late granite has an internal penetrative fabric, parallel to the host shear-zone. Highly discordant aplitic granite veins and rare quartzofeldspathic pegmatites cross-cut the pink granite vein network. Several generations of these late intrusions can occur in a single exposure; again they may be locally injected along shears that offset earlier veins.

A major sheet of the Strath Halladale Granite Complex is well exposed on both sides of Portskerra pier and also north-west of Portskerra [NC 871 663] (Figure 6.31). It is composed of pink, locally foliated biotite granite with prominent potash-feldspar megacrysts up to 3 cm long. The penetrative foliation is confined to narrow zones and wraps around the feldspar augen; it is itself locally tightly folded at [NC 8819 6547]. There are angular gneiss xenoliths and amphibolite rafts as well as late aplitic granite veins in the granite.

On the foreshore at Sgeir Ruadh, Strath Halladale granite is overlain unconformably by a veneer of Middle Devonian basal breccio-conglomerate, overlain in turn by buff coarse-grained sandstone. The strata mostly dip gently northwards and form cliffs up to about 30 m high. An uneven unconformity between the gneissose psammites and Devonian sandstone and breccio-conglomerate is well exposed at Port Skerra [NC 878 664]. The breccio-conglomerate is matrix-supported with abundant granite and psammite clasts and subsidiary fine-grained sandstone clasts, in a coarse matrix resembling disaggregated granite. Farther west at [NC 8731 6631] fawn to buff sandstone beds are draped over a small crag of psammite. The sandstones form laterally discontinuous beds up to 1 m thick, and basal breccio-conglomerate occurs in lenses up to 3 m thick. Sedimentary structures in the sandstones include ripple *marks* (indicating currents from the west), low-angle planar cross-bedding, pebble beds and dewatering structures.

Faults and parallel jointing control coastal geomorphological features including natural arches, great gashes in steep cliffs and inlets such as Geodh' Glas [NC 8755 6645]. A series of NE-trending faults can be seen cutting granites in the cliffs to the north-west of Portskerra. Where faulted, the granite is friable, altered and commonly highly fractured. A small fault trending approximately east is exposed at [NC 8770 6663], where an apparent downthrow of 10 cm to the south can be measured. This fault produces a 1 m-thick shatter zone where it cuts Devonian strata and also defines a gully in the underlying gneissose psammites. The psammites of Rubha Bhrà are strongly jointed with a dominant NE-trending set that dips moderately towards the north-west. Interplay between layering and joint planes breaks up the gneisses into rectangular blocks about 1 m^2 in cross-section. Individual joints are open, and locally they control the detailed shape of the coastline.

Interpretation

Early metamorphic event(s) produced the gneissic fabric in the Moine rocks, defined by the sub-parallel quartzofeldspathic segregations and the early biotite foliation. Isotopic studies on the Moine rocks of Sutherland suggest that several early high-grade metamorphic events affected the succession. These may date back as far as 870 Ma (Friend *et* al., 1997), but more probably occurred in the Neoproterozoic between 830 Ma and 790 Ma (Strachan *et al.,* 2002b) and around 470–460 Ma (Friend *et al.,* 2000). The white Badanloch granodiorite sheets were emplaced after these metamorphic events and were followed by the injection of the pink to red granitic veins and sheets of the Strath Halladale Granite Complex, dated at *c.* 426 Ma (Kocks *et al*., 2006). This latter magmatism accompanied the generation of the Scandian fold–thrust sequence and associated amphibolite-facies regional metamorphic overprint. Various small aplitic and pegmatitic granite veins were intruded after the folding, in part associated with minor shear-zone development. Dallmeyer *et al.* (2001) obtained a hornblende ^{40}Ar-^{39}Ar age of 404 Ma for amphibolite at Rubha Bhrà, which they interpreted as dating uplift and cooling. This was consistent with muscovite and hornblende ^{40}Ar-^{39}Ar cooling ages of 423–410 Ma from farther west in the Naver and Swordly nappes.

The unconformably overlying Mid-Devonian sediments were laid down in a fluvial to lacustrine desert environment with coarse sediments flushed out over highly irregular basement topography. The main rock-type is mature quartz sandstone, with local cross-bedding, which contains lenses of breccio-conglomerate in the basal 3 m. The basal breccio-conglomerate spreads have variable thickness, particularly where they infill hollows in the existing landscape. They are dominated by locally derived clasts, for example at Sgeir Ruadh, and have been interpreted as basal lags to channel fills (Fletcher and Key, 1991).

The post-Devonian faulting and strong and regular jointing seen at Sgeir Ruadh is possibly associated with major faulting that controlled the extensional development of the major offshore Mesozoic sedimentary basins. A major fault, the Strath Halladale Fault, lies a few kilometres east of the site. Its trace strikes approximately north along Strath Halladale and into Melvich Bay, but some 6 km offshore the trace curves to strike north-east. Here, it forms the bounding fault to

Perrno--Triassic sedimentary sequences, downthrowing units to the east or south-east. By analogy with the Strathy and Bridge of Forss faults, it probably has both a Devonian and Permo–Triassic movement history, linked to basin deposition.

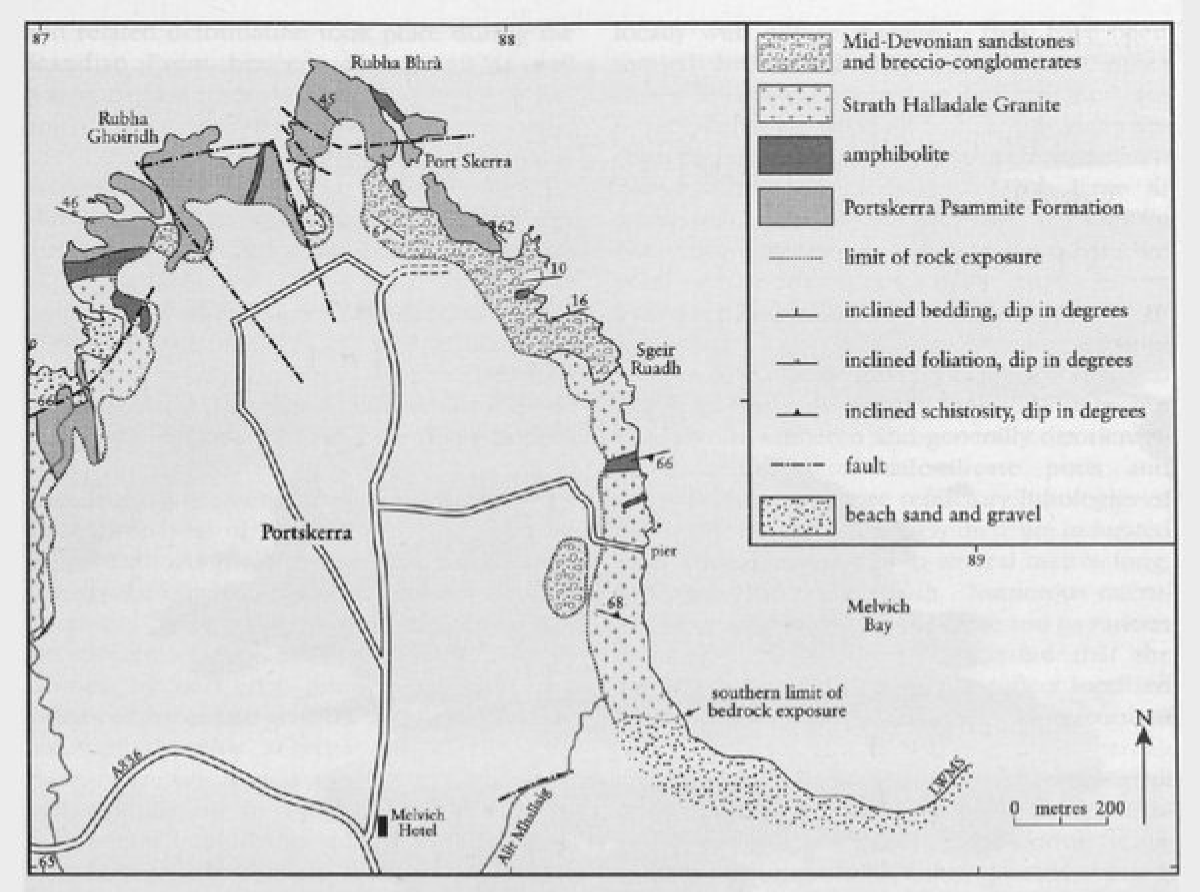
Conclusions

The Sgeir Ruadh site is of importance because it demonstrates the regional migmatitic character of the Moine rocks of northern Sutherland, the nature of the early-formed Bettyhill Suite mafic intrusions, and their relationships to the Strath Halladale Granite Complex, a series of granitic sheets and veins of Late Silurian age. An early migmatitic event affected the Moine psammitic rocks and is characterized by quartzofeldspathic segregations mostly parallel to the gneissic layering. The migmatization may be linked to a Neoproterozoic-age Knoydartian event, as seen farther west in the A'. Mhoine Nappe, or alternatively, the metamorphism and migmatization may reflect the Early Ordovician Grampian Event. White foliated granodiorite veins and irregular bodies, part of the more-widespread Badanloch Granite Sheets, are taken to be Ordovician in age. They are cut by pink to red granite sheets and veins that total several hundred metres in thickness, and form part of the Silurian-age Strath Halladale Granite Complex. The granite sheets are again foliated and were intruded during the later phases of the Scandian Event.

An angular unconformity between the various metamorphic and igneous rocks and overlying strata of the Middle Devonian Old Red Sandstone is well exposed at the site. The younger sedimentary rocks can be seen to drape over crags of gneissose psammite. A basal breccio-conglomerate is made up of eroded material from the immediately underlying bedrock, either completely broken down to a coarse-grained gravel, or into angular fragments up to boulder size that are supported in the gravel matrix. The overlying sandstones are typical of Old Red Sandstone material laid down by rivers that flowed across the strongly eroded Moine 'basement' in the desert landscape. The beds were deposited marginal to the main Orcadian lake basin succession that developed farther north-east.

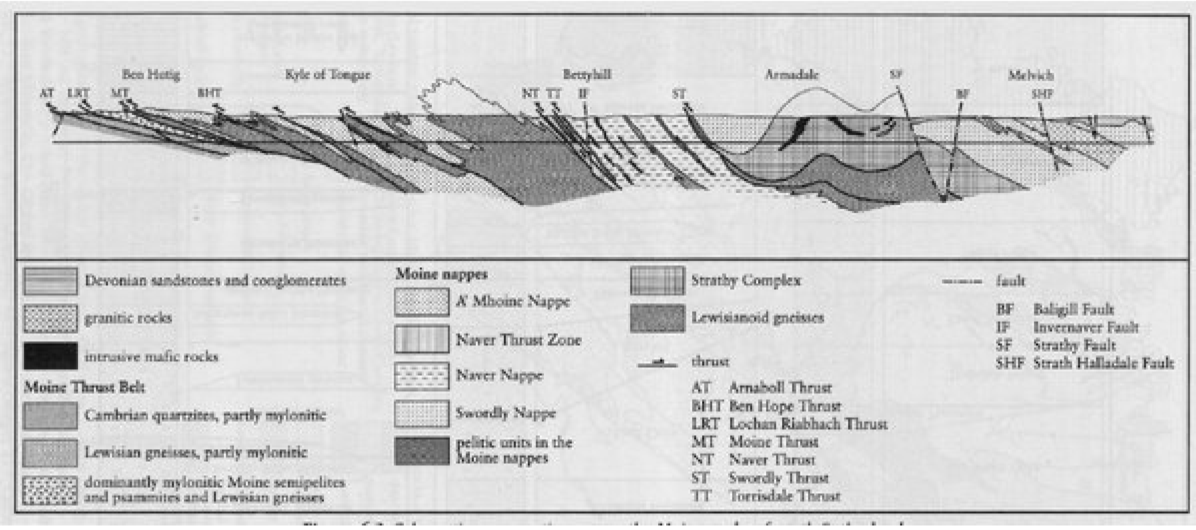
A number of small faults that may be related to the development of the sedimentary basins developed offshore can be examined at the site. The faults have different expressions in the different lithologies. Fault breccias occur in the Devonian sandstones and conglomerates; the granites are intensely weathered along fault lines; and gullies have formed in the harder, but more-brittle Moine psammites.

References

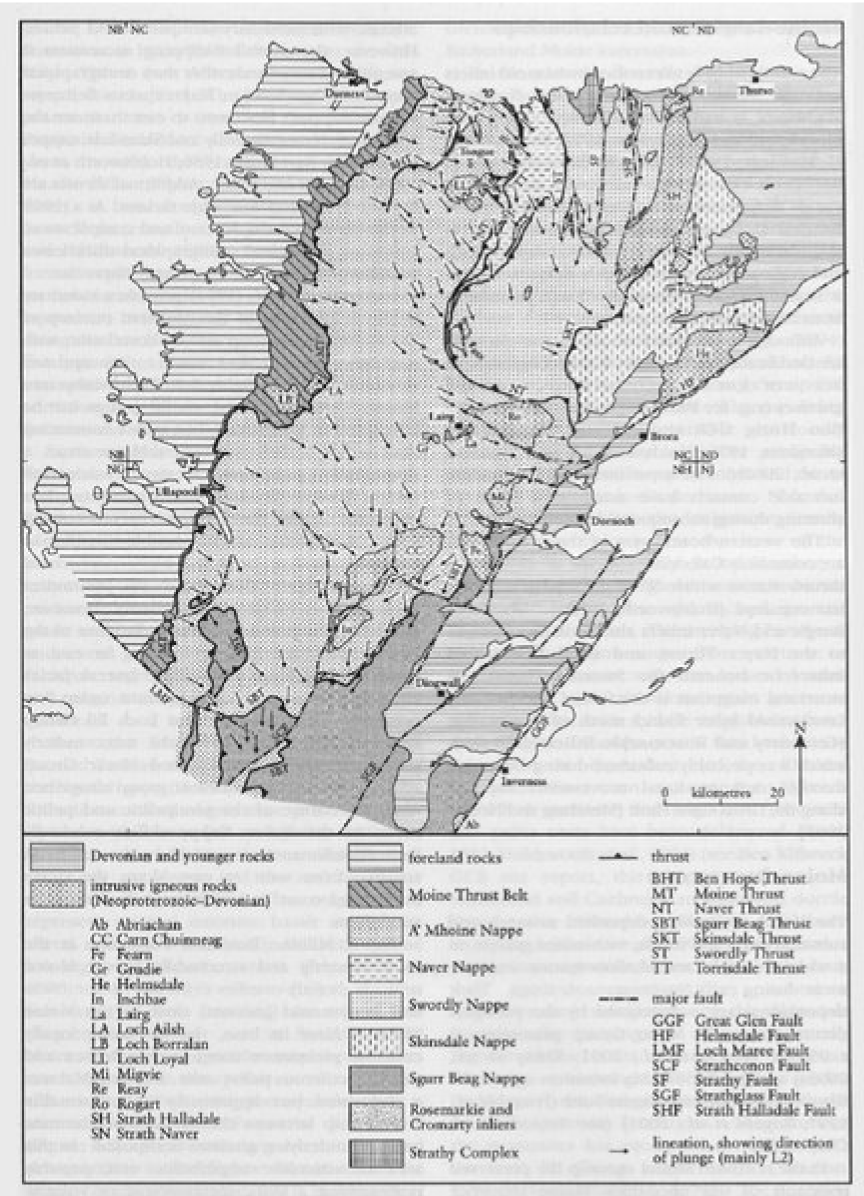


(Figure 6.31) Simplified geological map of the Sgeir Ruadh site.

(Figure 6.32) Oblique aerial photo of Rubha Bhrà and Portskerra. Mid-Devonian rocks, lying unconformably on the Moine succession, form the upper parts of the cliffs and underlie the higher parts of the peninsula. (Photo: BGS No. 21/6 (Fletcher and Key, 1991); reproduced with the permission of the Director, British Geological Survey, © NERC.)



(Figure 6.3) Schematic cross-section across the Moine rocks of north Sutherland.



(Figure 6.4) Tectonostratigraphy of the Moine (North) area.