North Uist Coast

[NF 738 767]–[NF 729 756], [NF 727 755]–[NF 717 731], [NF 714 729]–[NF 706 713]

J.R. Mendum

Introduction

The *c.* 6.5 km-long coast section in the northwest part of North Uist between Hogha Gearraidh (Hougharry) in the south and Caisteal Odair in the north provides a well-exposed oblique transect through folded Scomian felsic gneisses and 'Older Basic' and 'Younger Basic' mafic dykes, sheets and irregular bodies. Minor occurrences of metasedimentary rocks also occur. The rocks have been reworked during Laxfordian tectonometamorphic events. A complex pattern of folds and strain variation has resulted, dependent largely on the nature and geometry of the pre-existing elements of the Lewisian gneisses. The 'Younger Basic' bodies are now mainly amphibolites, but in rare instances the larger mafic bodies retain granulite-facies mineralogies. In these mafic bodies, shear zones are developed that have been the subject of analysis to determine amounts of strain and relative movement involved (Ramsay and Graham, 1970).

The area contains two main types of felsic gneiss: the typical white to grey, banded tonalitic to granodioritic orthogneiss, and a pink to pale-grey granitic orthogneiss. Graham (1970) referred to them as 'Rough' and 'Smooth' gneisses respectively, reflecting their coastal weathering characteristics. Their distribution and that of the mafic rocks is shown on (Figure 2.15). The abundant mafic rocks are mostly members of the Palaeoproterozoic 'Younger Basic' Suite, originally metadolerites and metagabbros. As Laxfordian strains are commonly high, most mafic bodies are parallel or sub-parallel to the gneissose banding. They range from a few centimetres up to 100 m wide, and now are generally amphibolites. However, the two thickest units, the Hoglan and Hosta amphibolites that occur north-west of Tigh a' Ghearraidh, are both finely striped, partly garnetiferous, planar subvertical bodies that are interpreted as part of the Archaean 'Older Basic' Suite. Between the two bodies are granitic gneisses and metasedimentary schists and gneisses, with interbanded mafic and ultramafic bodies and layers. The metasedimentary rocks include quartzites, semipelites and iron-rich cherts. Metasedimentary rocks also crop out at Bagh Scolpaig where anthophyllite-bearing quartzose gneiss is recorded.

The low cliffs and intervening sandy bays provide clean and accessible exposures of variable orientation, which facilitate detailed analysis of the structural pattern. The area lies on the complex western limb of a large NW-plunging Laxfordian F3 asymmetrical antiform that encompasses the whole of North Uist and whose hinge zone lies at the northern end of the coast section (Figure 2.11). The hinge of the complementary synform lies at the south-western end of the section. The fold axial planes trend north-west and dip subvertically.

Jehu and Craig (1926) briefly described the geological aspects of the area, noting the presence of pink 'acid' gneisses and the abundant hornblende 'gneiss' bodies. R.H. Graham carried out a detailed structural analysis of the coast section as a major part of his PhD studies (Graham, 1970), and subsequently the hinterland area was mapped by the Geological Survey as part of the regional coverage of the Outer Hebrides (Fettes *et al.,* 1992). The information in this account is taken mostly from these last two sources.

Description

The indented coast section consists of low cuffed headlands and rocky foreshores separated by small shell-sand beaches. The cliffs rise to some 25 m high north of Scolpaig. At Rubha Ghriminis (Griminish Point) natural arches and geos have developed as a result of enhanced marine erosion along broken fault-zones, and a large blowhole, Sloc Rubha, is present. The normally prevailing westerly wind and salt spray naturally clean the section and also etch the various lithologies to different degrees. Wide areas of clean glaciated bedrock are common in the immediate coastal hinterland, but are covered by windblown shell sands and limited machair in the southern part of the section.

Lithologies

The typical felsic gneiss is a white- to pale-grey and fawn-weathering, thin- to medium-banded, coarse-grained quartzofeldspathic rock composed of essential quartz, plagioclase feldspar and biotite, commonly with subsidiary hornblende. Subsidiary interbanded mafic amphibolite layers, pods and lenses are very common in the gneisses. Early-formed, mainly concordant, thin quartz-feldspar pegmatite veins and pods are also present. In places the pegmatite veins exhibit folds that pre-date the Laxfordian deformation. This typically banded felsic and mafic gneiss (the 'Rough' gneiss of Graham, 1970) is interspersed with zones of more-homogeneous, pink-weathering, foliated, medium-grained, but only weakly banded gneiss (the 'Smooth' gneiss of Graham, 1970). This pale-grey to pink granitic gneiss is composed of quartz, microcline, plagioclase feldspar and biotite and locally contains porphyroclasts of pink potash-feldspar up to 2 cm across. Early pegmatitic veins are absent. The distribution of felsic and granitic gneiss types is complex and its relationship to the mafic intrusive bodies and the detailed Laxfordian structures is shown on (Figure 2.15).

Both types of felsic gneiss contain abundant discrete mafic dykes, lenses and pods, which were assigned by Graham (1970) to the 'Younger Basic' Suite. These dark-green to black, medium-to coarse-grained intrusive bodies are now mainly amphibolites, but show no gneissose banding and only sparse later veining by pegmatitic veins and minor agmatization. They range in thickness from a few centimetres to several tens of metres and are commonly folded and boudinaged. Most are concordant with the Scourian gneissose banding, but excellent examples of discordant, weakly foliated, dyke-like bodies and larger pods are seen. They are mainly amphibolites, composed of hornblende-plagioclase-quartz, but at Caisteal Odair a larger gabbro pod retains meta-igneous textures in places and locally contains clinopyroxene and small garnets. These 'Younger Basic' mafic bodies can normally be distinguished from the more-banded, veined and gneissose amphibolitic members of the Archaean 'Older Basic' Suite except where Laxfordian deformation and recrystallization are very strongly developed. (Figure 2.15) shows the distribution of the main mafic units on the coastal section.

Near the south end of the coast section in Bàgh Hogha Glan (Hoglan Bay) [NF 7070 7234] and on Rubha Mhànais [NF 7115 7311] two *c.* 140 m-wide amphibolitic metabasic bodies, the Hoglan and Hosta amphibolites, crop out (Graham, 1970). They are both subvertical, exhibit strong planar and linear fabrics, and include quartzofeldspathic and granitic gneiss layers and some metasedimentary lithologies. In parts they show a fine-scale but marked compositional banding, which is defined locally by garnetiferous layers. Pyrite- and chalcopyrite-rich bands are common in the amphibolites. They lie within a zone of high Laxfordian strain and both the mafic bodies and their internal banding and fabrics are parallel to banding and foliation in the adjacent felsic gneisses. The two bodies can be traced along strike to the SSE for some 6 km, and here too mineralogical banding is seen. They are similar to the banded 'Older Basic' bodies of South Uist (see Cnoca Breac and Gearraidh Siar and Baile a' Mhanaich GCR site reports, this chapter).

The metasedimentary lithologies can be distinguished from the orthogneisses by their flaggy nature, generally finer grain-size and brown iron-oxide staining. Biotite is common and typically shows a distinct purple-brown tinge. In the zone between the Hoglan and Hosta amphibolites, quartzites, semipelites and pyrite-rich lithologies are recorded. Anthophyllite is present locally, and farther north-east at Bagh Scolpaig anthophyllite-rich psammitic and semipelitic gneisses occur (Coward *et al.,* 1969; Graham, 1970).

Structure and metamorphism

The structure of the North Uist coast section, taken from Graham (1970), is shown in (Figure 2.15). The section encompasses the overall steep western limb of the Laxfordian F3 North Uist Antiform (see (Figure 2.11)). The overall strike of the gneissose banding is NNE, and dips are steep and locally vertical. A series of subsidiary hundred-metre- to kilometre-scale F3 antiforms and synforms make up the overall profile. Their axes mainly plunge moderately to gently northwest. Their axial planes dip generally steeply (commonly at > 75°), with the dip direction variable from ENE and north-east through the vertical to WSW and south-west. Graham (1970) named the major structures, from south to north, the 'Hougharry Synform and Antiform', the lloglan Synform', the 'Tigharry 'Isocline'', the 'Balelone Synform', the 'Cliffs Antiform', the 'Scolpaig Synform', and the 'Griminish Antiform and Synform'. Generally, the nature, geometry and thickness of the mafic bodies define the F3 fold profiles. The medium- and large-scale F3 folds are commonly spectacularly displayed in the coastal cliff-sections, for example in the vertical cliffs immediately west of Loch Sgileabhat at [NF 7225 7481]. At the southern end of the section by Hogha Gearraidh (Hougharry) the regional strike turns from

NNE to ENE and overall dips are moderate to the north and northwest as they are over much of North Uist.

The subvertical zone around Tigh a' Ghearraidh (Tighgarry), defined by the lineated, foliated and highly strained Hoglan and Hosta amphibolites, is unusual in that it does not fit easily into the overall structural profile. The zone can be traced south-eastwards to Balranald and Ceann a' Bhaigh (Bayhead), but does not appear to extend much farther as no disruption to the moderate NNW dip is seen on Baleshare (Figure 2.11). Graham (1970) interpreted this zone as an isoclinal antiform within an overall complex synformal hinge zone, and termed it the 'Tigharry 'Isocline''. However, this interpretation was assessed and rejected by Fettes *et al.* (1992) (see 'Interpretation' below).

In addition to the open to tight F3 folds, the section shows many examples of pervasive $D2_L$ folding and boudinage, and the dominant penetrative foliation in the section is S2. Here too, the mafic rocks show the folding best with tight, small- to medium-scale examples abundant. F2 fold axes plunge moderately to gently to the north-west, generally close to, and even coincident with, the later F3 axes. Axial planes are typically sub-parallel to the gneissose banding. Graham (1970) noted that there are concentrations of F2 medium- and minor-scale folds in three areas on the north-west coast sectio of North Uist. These occur at Aird an Rùnair, south-west of the GCR site, in the cliffed area west of Loch Sgileabhat (Bharlais to Port na Copa), and on Rubha Ghriminis. The larger-scale $D2_L$ pattern is one of mainly kilometre-scale, complex S-profile tight folds separated by zones of pervasive S2 foliation in which minor F2 folds are only present in parts.

Good examples of F2 folds defined by mafic sheets and dykes were recorded by Graham (1970) from the 10–15 m-high cliffs around Geodha nan Colman [NF 7213 7458]. These F2 folds occur in the simple open hinge zone of the F3 Cliffs Antiform. Farther north around [NF 7235 7506] F2 folds are locally refolded by small- to medium-scale F3 open to close folds giving rise to complex interference patterns. On the west side of the Raicinis peninsula at [NF 7173 7330] an F2–F3 interference pattern defined by amphibolitic 'Younger Basic' sheets can be mapped out over some 60 m on the foreshore. These structures lie on the south-western limb of the F3 Balelone Synform close to the fold hinge. Metabasic sheets define tight F2 folds with axial planes orientated sub-parallel to the gneissose banding. These are refolded by moderately N-plunging, open F3 folds with sub-vertical N-trending axial planes. In parts of this area minor F2 structures fold a pre-existing foliation/schistosity in the amphibolitic meta-basic sheets. Graham (1970) assigned this fabric to a Laxfordian $D1_L$ event.

Tight F2 folds and F2–F3 interference patterns are also well seen on Rubha Ghriminis. Here a very well-exposed, broad, open 'box-like' F3 antiform is present, but the detailed structures and related fabrics are all basically of $D2_L$ origin. An F3 monocline refolds tight F2 folds and the prominent S2 fabric, which here is commonly discordant to the gneissose banding. In parts the original gneissose banding is recrystallized to such an extent that it is transposed into a new penetrative S2 foliation. Many of the 'Younger Basic' mafic dykes and sheets are boudinaged on Rubha Ghriminis with the majority of boudinage structures patently of $D2_L$ age (Figure 2.16)a. In some of these mafic boudins, examples of folded earlier S1 schistosity/foliation have been recorded by Graham (1970) and in parts boudins are folded by F2 structures. F1–F2 and F1–F2–F3 fold interference patterns are also recorded, attesting to the presence of significant D1 strains and small-scale tight folding in the banded acid gneisses of this area.

The 'Younger Basic' body on Caisteal Odair [NF 732 768] is a 40–50 m-wide lenticular pod, which is dominantly amphibolitic metagabbro and metadolerite, but which retains granulite-facies textures locally and contains abundant small garnets and limited clinopyroxenes. It lies in the hinge zone of the F3 Griminish Antiform and is a region of low $D2_L$ strain. Its margins are moderate to strongly foliated and amphibolitic and it is traversed by a series of small shear-zones (Ramsay and Graham, 1970) (Figure 2.16)b. Other examples of relict granulite-facies mineralogies are found within the larger 'Younger Basic' body that underlies the hills of Beinn Riabhach [NF 740 744] and Carra-crom [NF 734 735] (Fettes *et al.,* 1992).

Interpretation

The main protolith of the grey and white, banded felsic gneisses was a complex sequence of granodiorite and tonalite sheets intruded at moderate to deep crustal levels. Although now strongly reworked by the Laxfordian deformational and metamorphic episodes, isotopic data suggest that the igneous protoliths to the felsic gneisses are Archaean in age

(Moorbath *et al.,* 1975; Whitehouse, 1990b; Friend and Kinny, 2001; Mason *et ed.,* 2004a; Kelly *et ed.,* 2008). Within these gneisses are several early mafic bodies, termed the 'Older Basics' by Fettes *et al.* (1992). Some of the larger bodies were originally mineralogically and compositionally banded (cumulate banding), with the geochemical variations, notably in Fe and Al, later reflected in the relative abundance of metamorphic plagioclase, garnet, hornblende and more rarely pyroxene. Although now strongly deformed and pervasively metamorphosed under amphibolite-facies conditions during Laxfordian reworking, the Hoglan and Hosta amphibolites still show well-developed fine-scale mineralogical banding and are attributed to the 'Older Basic' Suite. Early mafic rocks also occur as thinner amphibolite pods or bands within the acid gneisses. They represent Archaean basic sheets, dykes and irregular pods, which were either intruded into the tonalite and granodiorite protolith or, by analogy with rocks in west Greenland, were incorporated as xenoliths or screens (see Fettes *et al.,* 1992). Although some of the mafic bodies were probably intruded into the felsic intrusions, the bulk of the 'Older Basic' bodies are interpreted as included screens and hence as pre-existing older mafic material.

Metasedimentary lithologies are spatially associated with the larger 'Older Basic' bodies, and Fettes *et al.* (1992) have discussed the nature and wider significance of this relationship. Metasedimentary rocks are not abundant in the North Uist coast section and here they may represent xenolithic or hornfelsed material, preserved adjacent to the 'Older Basic' intrusions as suggested by Coward *et al.* (1969). They are problematic in that they were undoubtedly originally deposited at the Earth's surface, yet are interleaved with meta-igneous rocks that appear to have been emplaced at deep crustal levels (> 15 km). They are assigned to the Archaean, in contrast to the wider, more-coherent belts of metasedimentary rocks in the Outer Hebrides, for example the Leverburgh and Langavat belts of South Harris, which have been shown to have a younger Palaeoproterozoic age. These thicker Palaeoproterozoic belts have been juxtaposed against the older Archaean gneisses by later Proterozoic orogenic events (Friend and Kinny, 2001).

The granitic or 'Smooth' gneisses of Graham (1970) represent late-Scourian granite bodies that intruded the earlier gneissose complex, probably at around 2600 Ma (Fettes *et al.,* 1992). They contain few included mafic lenses or pegmatitic veins and pods, in contrast to the earlier banded felsic 'Rough' gneisses, which are coarser grained, lithologically well banded, contain abundant thin mafic bands and lenses, and are cross-cut by numerous pegmatitic veins and lenses. The granitic 'Smooth' gneisses are foliated medium-grained sheets that range from *c.* 1 m up to several tens of metres wide. Porphyritic examples are not common in this coastal section, but are found within a 2–4km-wide zone that roughly 'tracks' the north and west coasts and hinterland of North Uist (Institute of Geological Sciences, 1981). Within this zone and farther south around Balranald and Ceann a' Bhligh (Bayhead), foliated, coarser-grained, porphyritic granites form larger ovoid intrusive bodies, typically 600 m to 1 km long, but exceptionally up to 3.5 km long and 500 m wide (Fettes *et al.,* 1992).

The bulk of the mafic rocks in the GCR site belong to the 'Younger Basic' Suite, a series of irregular sheets and dykes that post-date the late Archaean granites and related pegmatites. They are thought to be equivalent to the Scourie dykes of the mainland, which were mostly emplaced around 2420 Ma and 2000 Ma (Heaman and Tarney, 1989). They were intruded into the gneisses at crustal depths of some 20 km and equilibrated to the ambient metamorphic conditions. Hence they contain mineral assemblages typical of middle- to upper-amphibolite- and, locally, even granulite-facies conditions. Laxfordian reworking has largely retrograded these assemblages to lower- and middle-amphibolite facies but at Caisteal Odair relict granulite-facies assemblages still remain.

Laxfordian deformation is generally pervasive in this part of the Outer Hebrides, although the section does show excellent examples of local strain variation and different structural styles. The coast section is situated on the highly folded short limb of a major F3 asymmetrical fold, the North Uist Antiform. F3 axial planes mainly trend north-west and dip steeply, and the fold axes and attendant lineations plunge consistently to the north-west at moderate to low angles. Graham (1970) produced a structural synthesis of the fold geometry along the coastal section and distinguished elements of three major fold/deformation phases. He also noted the way in which competence differences in the gneisses were reflected in the style and tightness of the Laxfordian structures. During deformation the metabasic rocks acted as more-competent sheets or dykes, and as a result were folded and boudinaged. Coward *et al.* (1970) showed how the large-scale Laxfordian structures relate to the variable regional strain pattern and that most F3 folds have broad open antiformal zones but restricted and tight 'pinched-in' synforms.

Graham (1970) showed that F1 fold structures are rare and confined to minor tight folds of felsic veins and thin metabasic units in the hinge zones of F2 folds such as the Griminish and Cliffs antiforms. However, F2 folds locally refold a penetrative planar S1 fabric in amphibolitic 'Younger Basic' sheets and pre-$D2_L$ boudinage is also seen. $D2_L$ structures and fabrics are more abundant and pervasive, and S2 is the main gneissose fabric in most parts of the section. Graham (1970) deduced that prior to the F3 folding the F2 structures consisted of a few large-scale asymmetrical S-profile folds with near-planar long limbs and tightly folded short limbs. They are coaxial with the later F3 folds, but their axial planes originally trended north-east and dipped moderately to the north-west.

The F3 fold geometry is represented on (Figure 2.15). On a large scale it is controlled by the gross Archaean structural and lithological variations in the Lewisian gneisses of North Uist and by the pre-existing F1 and particularly F2 fold pattern. On a smaller scale (metres to kilometres) Graham (1970) documented numerous examples mainly showing how the abundance and thickness of amphibolites (mainly 'Younger Basics') control the amplitude and tightness of the F3 fold pattern. In parts the $D2_L$ + $D3_L$ strain is very high and the Archaean elements are highly attenuated. Graham (1970) obtained minimum $D3_L$ strain values from the measurements on deformed thin quartz-feldspar pegmatite veins that cut amphibolite from the Tigharry 'Isocline'. The veins cross-cut the earlier Laxfordian S2 fabric. Strain ellipse X: Y: Z values of 18: 6: 1 were obtained in the more-deformed parts, implying Laxfordian shortening of the succession here to *c.* 21% of its pre-deformation thickness.

In the hinge zones of the Hougharry and Hoglan synforms Graham (1970) recorded outcrop-scale examples of quartzofeldspathic gneiss lamellae that breach the amphibolitic mafic sheets which define the folds, resulting in geological 'hernias', which he termed 'shoot-through' structures. In effect the mafic sheet or dyke is boudinaged and gneissose material has flowed into the neck. In some examples quartz-feldspar pegmatite pods are also present. Graham interpreted the Hoglan and Hosta amphibolites as the two limbs of a much larger-scale isoclinal 'shoot-through' structure (F2 + F3). However, later mapping showed that the two amphibolites extend for at least 7 km to the south-east, no F2 or F3 hinge zone could be recognized, and the purported change in F3 minor fold vergence across the structure could not be substantiated (Fettes *et al.,* 1992). More probably, this zone represents an attenuated, highly sheared part of the large-scale F3 fold limb, possibly focused along an earlier Archaean and Laxfordian $D2_L$ lineament.

The shear zones in the large metabasic body at Caisteal Odair illustrate the inhomogeneous nature of the Laxfordian strain in this more-anhydrous lithology. D3 strain is very low in this fold hinge zone and the more-penetrative D2 strain has focused along certain zones giving rise to a three-dimensional pattern of anastomosing shear-zones. In the shear zones a new, lower amphibolite-facies, hornblende-plagioclase-quartz foliation is developed. Measurement of the variable angle between the internal fabric and the shear-zone margin can be used to assess the amount of simple shear (non-coaxial plane strain) across the shear zone, to give an estimate of the total amount of translation. Ramsay and Graham (1970) used this locality in their studies of strain variations in shear belts and it is cited as a 'classic' example in structural textbooks (e.g. Ramsay and Huber, 1983).

Conclusions

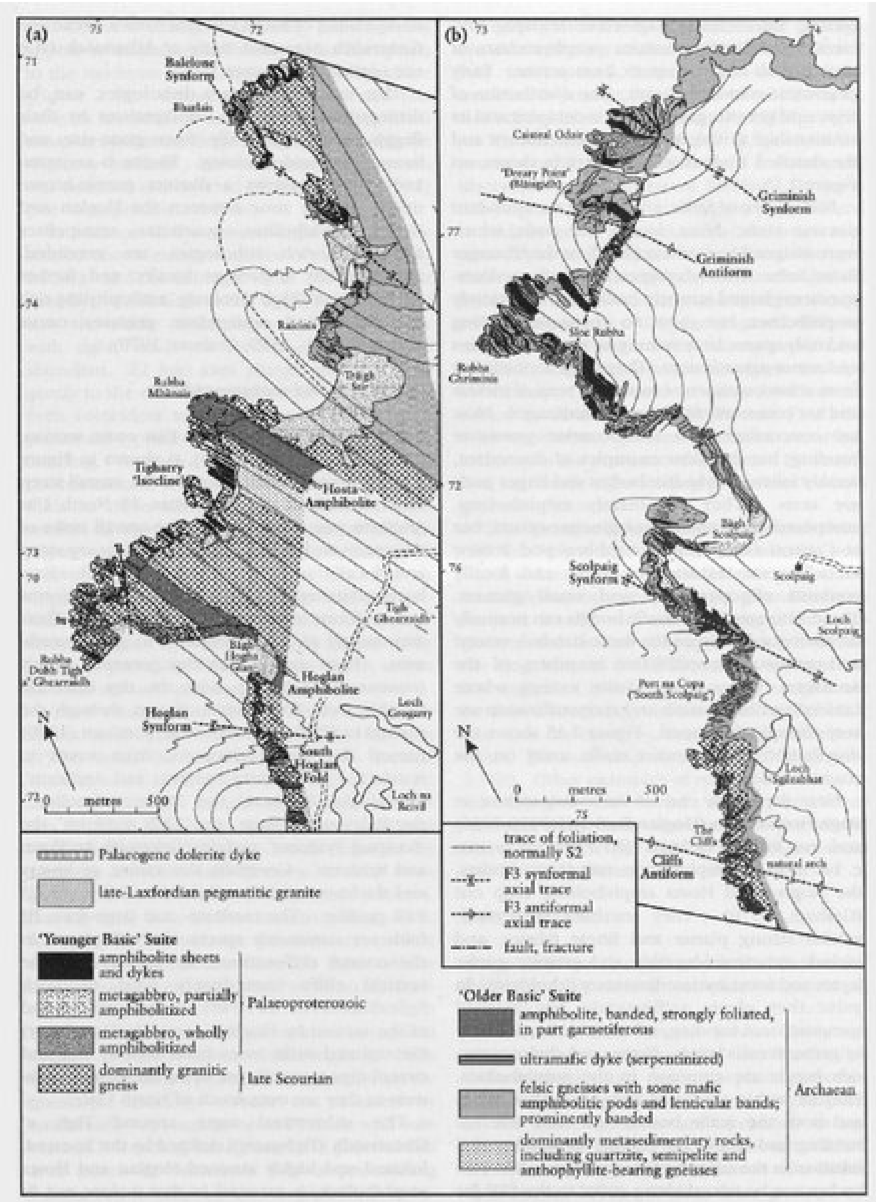
The North Uist Coast GCR site is one of national importance and provides a readily accessible, clean, etched and coherent section through large- and small-scale Laxfordian folds. The strain variations are already portrayed in various structural textbooks and the area remains an excellent site for teaching and for further detailed structural and metamorphic studies.

The site exposes a two- and locally three-dimensional oblique section through dominantly felsic and mafic orthogneisses formed from igneous intrusions during the Scourian event (*c.* 2850–2650 Ma). The gneisses here include the older metasedimentary units, and 'Older Basic' banded mafic bodies, which were intruded by late-Scourian granites (*c.* 2550 Ma), and abundant 'Younger Basic' mafic sheets, dykes and pods (*c.* 2420 Ma). All these elements that make up the Lewisian Gneiss Complex in North Uist were strongly folded and metamorphosed during the later multi-phase Laxfordian event (*c.* 1850–1600 Ma). The heterogeneity has resulted in the different Laxfordian fold patterns and strain variations seen in the section.

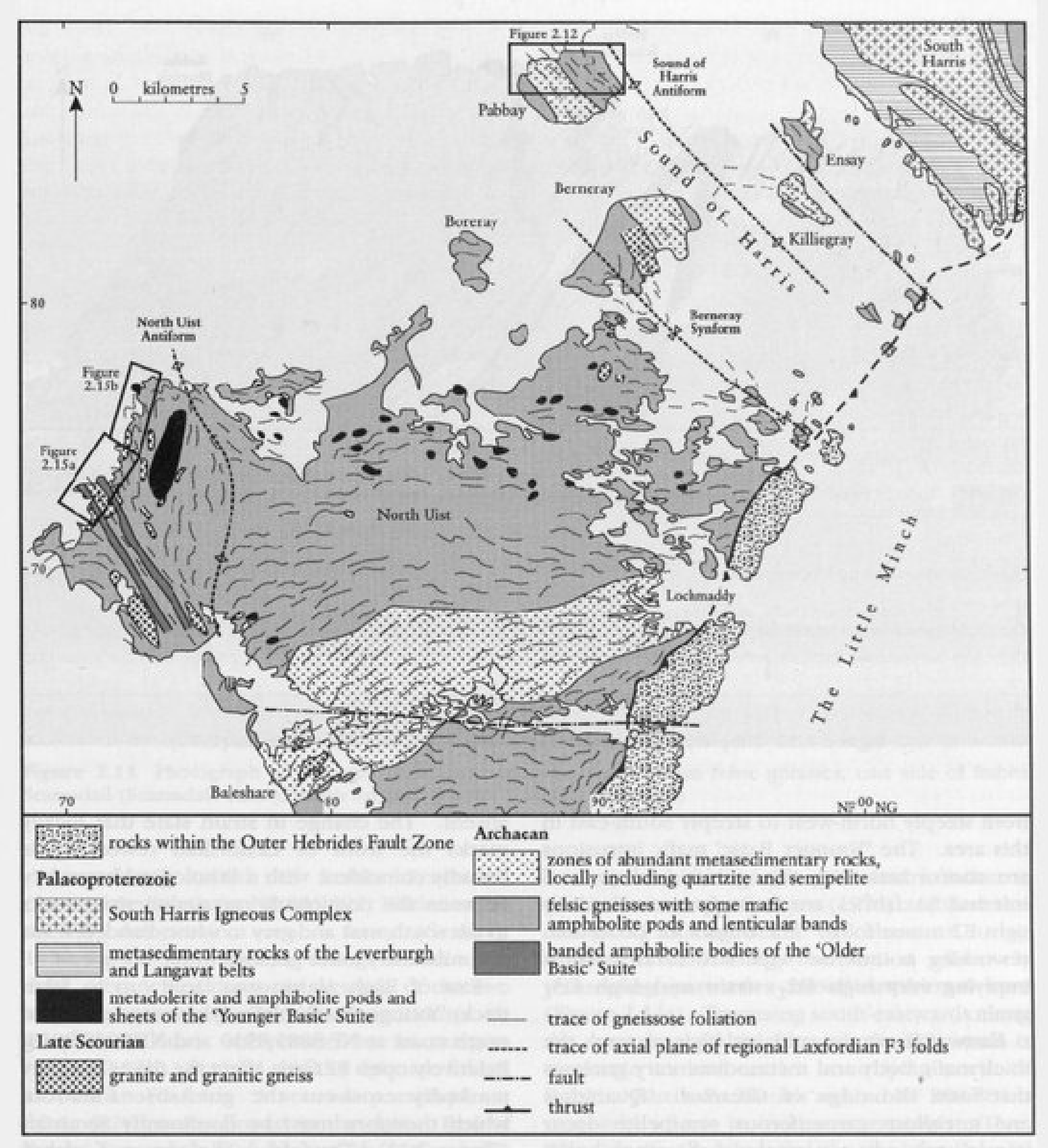
The 'Younger Basic' intrusive bodies, now dominantly amphibolites, generally lie sub-parallel to the gneissose banding. They have acted as more-competent units than the surrounding dominantly felsic gneisses under the amphibolite-facies metamorphic conditions prevailing at the time of Laxfordian deformation. It is the size and abundance of these mafic bodies that mainly control the resultant fold geometry and strain variations now seen along the section.

The coastal profile lies on the western short limb of a large Laxfordian third phase ($D3_1$), Sproule fold structure, the North Uist Antiform, and extends south-west to the complementary synformal hinge zone. The axes of these major F3 folds, and the related smaller kilometre- and metre-scale structures, all plunge moderately to gently to the north-west. Their axial planes trend north-west or NNW and dip steeply. The effects of earlier penetrative second phase ($D2_1$) deformation are apparent in a regionally developed fabric, minor folds and boudinage. Earlier D1 effects are limited to a locally developed planar fabric in some amphibolitic bodies, some tight minor folding, and boudinage.

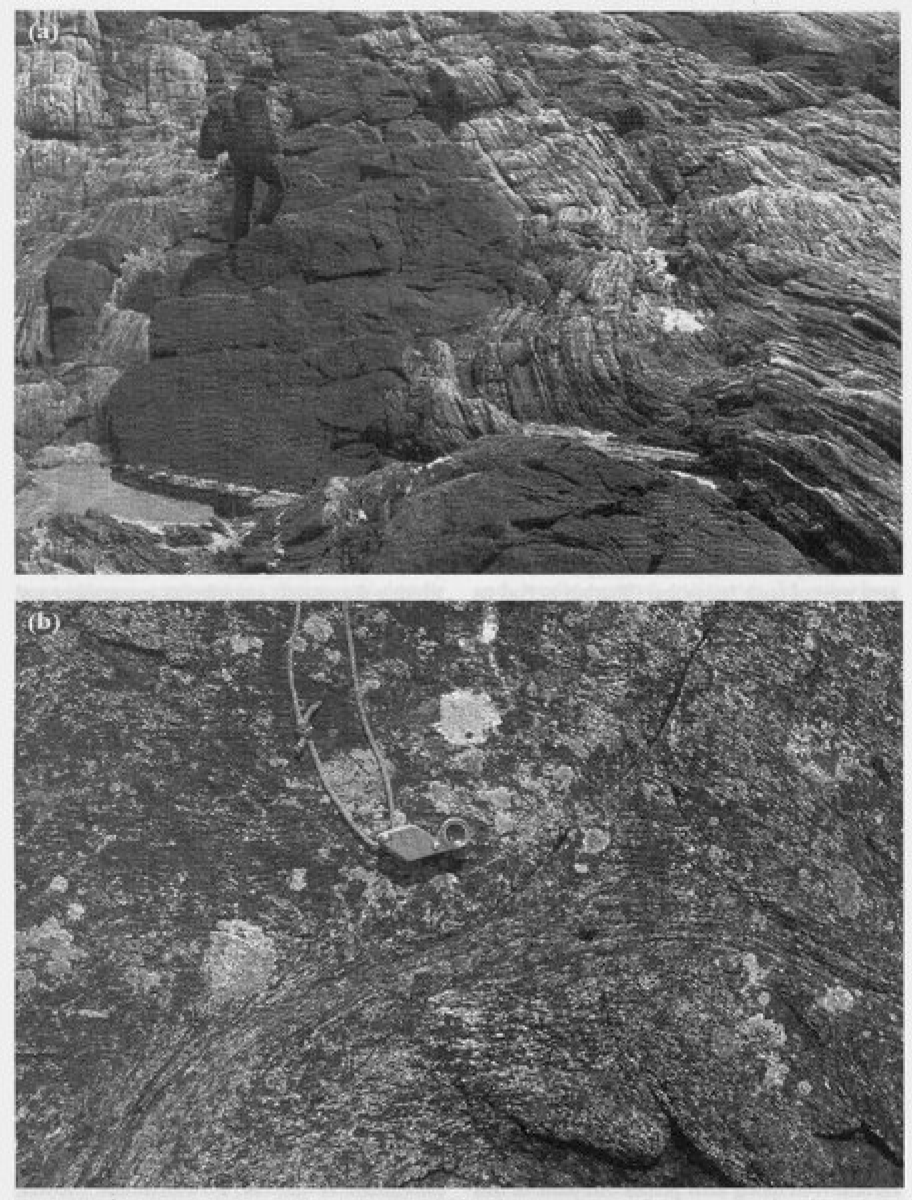
[References](#)



(Figure 2.15) Geological map of the North Uist Coast GCR site showing the detailed lithology and structure. After Graham (1970).



(Figure 2.11) Map showing the regional lithologies and structure of North Uist and the Sound of Harris. The positions of the North Pabbay Figure 2.12 and North Uist Coast Figure 2.15 GCR sites are indicated. After Fettes et al. (1992).



(Figure 2.16) (a) 'Younger Basic' dykes and pods at Rubha Ghriminis (Griminish Point). Note that although the dykes are boudinaged, foliated and now amphibolites, they cross-cut the prominently banded Archaean felsic and mafic gneisses. (b) Small shear-zone in granulite-facies 'Younger Basic' body at Caisteal Odair. Relative dextral movement across the shear zone can be inferred from the foliation traces. The hand lens is 6 cm long. (Photos: J.R. Mendum.)