North Pabbay, Sound of Harris

[NF 875 885]–[NF 904 887]

D.J. Fettes

Introduction

This coastal site provides an excellent cross-section across an area of Laxfordian reworking of Scourian metasedimentary and meta-igneous gneisses and 'Younger Basic' Suite mafic intrusions in the Lewisian Gneiss Complex of North Pabbay. The Laxfordian reworking varies from very low to high and is manifest as progressive changes in the degree of strain and the style and intensity of folding, fabric development and recrystallization. In North Pabbay these structural and metamorphic effects can readily be related to the regional Laxfordian structures and strain patterns (Figure 2.11).

The North Pabbay GCR site also crosses the junction between the two major lithological groups present on Pabbay; the typical grey to white and cream, banded, Archaean-age, granodioritic to tonalitic felsic gneisses with subsidiary amphibolitic mafic sheets and pods of the north-eastern part of Pabbay; and the dominantly metasedimentary succession in the remainder of the island. The metasedimentary rocks are mainly flaggy biotite-rich quartzofeldspathic gneisses, but in parts contain pink homogeneous granitic gneisses and locally abundant quartz-feldspar and pegmatitic granite veins. Graham (1970) termed these rocks the 'pink and blue' gneisses, and found that they were useful for determining the degree of Laxfordian strain. Around Bàgh Alairip (Alarip Bay) impure quartzite and minor semipelite are present (Figure 2.12). The metasedimentary rocks show similarities to both the Langavat Belt of South Harris and the zone of metasedimentary rocks mapped in North Uist (Institute of Geological Sciences, 1981; Fettes *et al.,* 1992). A notably thick amphibolitic mafic sheet forms the main part of the ridge of Greanan. To the southeast of this body in the central part of Pabbay is a thick sheet-like ultramafic body. The lithologies of North Pabbay can be readily traced south-east along strike into Berneray (Graham, 1970).

The Sound of Harris Antiform and the Berneray Synform dominate the regional structure (Figure 2.11). The axial planes of these major Laxfordian ($D3_L$) folds trend approximately north-west, and their axes plunge at low to moderate angles to the north-west. The steeply dipping common limb of this fold pair runs through the islands of Bemeray and Pabbay and is marked by high degrees of Laxfordian reworking. Laxfordian strain falls off north-eastwards towards the axial zone of the Sound of Harris Antiform.

The area received little attention from the early surveyors (for example, Jehu and Craig, 1926). It was first mapped in detail and described comprehensively by Graham (1970) and the following account draws heavily from his work.

Description

The island of Pabbay lies at the western entrance to the Sound of Harris. The north coast is marked by a rocky cliff-line 5–30 m high, and the GCR site between Cisinis (Kishinish) and Rubha Bhreinis (Brenish Point) provides a near-continuous exposed coastal section and hinterland area some 3 km long. The clean rocky outcrops extend inland to the high point of Beinn a' Charnain at 196 m above OD.

The western end of the section around Cisinis [NF 875 888] is marked by fine-grained, typically planar-banded and foliated, grey biotitic felsic gneiss with locally abundant pink granitic and felsic veins. These are the typical 'pink and blue' gneisses of Graham (1970). The banding and foliation dip steeply north-east. Tight F2 folds are common with a well-developed planar biotite fabric parallel to the axial planes. The L2 lineations show variable orientations in the plane of the foliation with their plunge varying from steeply north-west to steeply south-east in this area. The 'Younger Basic' mafic intrusions are concordant with this gneissic fabric, and internal S1 fabrics are strongly crenulated by tight F2 minor folds. The degree of Laxfordian reworking is intense with structural features implying very high $D2_L$ strain and high $D3_L$

strain.

Eastwards, strain remains high around the thick mafic body and metasedimentary gneisses that form the ridge of Greanan. Quartzites and gneissose garnetiferous semipelite occur immediately adjacent to the mafic amphibolite body and also extend farther east, forming the western side of Bàgh Alairip [NF 885 890]. Inland to the south-east of Greanan is a thick ultramafic body, some 250–300 m thick that extends for at least 1.3 km. It is probably a peridotite or harzburgite, by analogy with a similar sheet-like body along strike on Berneray.

Across Bagh Alairip, the degree of Laxfordian strain decreases markedly. To the east F2 folds are typically open monoclines and S2 fabric development becomes weaker and eventually absent. The change in strain state that locally marks the front of Laxfordian reworking is broadly coincident with a lithological boundary between the dominantly metasedimentary rocks to the south-west and grey to white, banded, felsic and subsidiary mafic gneisses to the north-east.

East of Bàgh Alairip two large (up to 50 m thick) 'Younger Basic' mafic dykes crop out on the north coast at [NF 8885 8930] and [NF 8912 8928]. Relatively open F2 folds affect the dykes but they markedly cross-cut the gneissose foliation, which therefore must be dominantly Scourian (Figure 2.13). The fold axial planes and related S2 fabric trend north-west, here regionally parallel to the gneissose foliation. Traced inland to the south and east the two dykes become thinner and their angular discordance to the gneissose foliation decreases as the $D2_L$ strain increases. At around [NF 892 879] the mafic dykes are effectively concordant with the gneissose foliation. This zone of high $D2_L$ strain is the south-eastward extension of that seen between Cisinis and Bàgh Alairip in the western part of the section.

Immediately south of Rubha Scarasdail (Scarasdale Point) (at [NF 886 891]) evidence for the $D1_L$ deformation event is found (Graham, 1970, fig. 5, p. 70). Here, a 'Younger Basic' mafic dyke, a branch of the more westerly of the two large dykes mentioned above, contains an internal S1 fabric sub-parallel to its margins (Figure 2.14)b. Both S1 and the dyke are folded around an F2 fold. A secondary axial-planar fabric (S2) has developed in the dyke. East of Rubha Scarasdail F2 folds are absent and the 'Younger Basic' dykes are highly oblique to the gneiss foliation. However, the mafic dykes still retain an internal S1 fabric, although $D1_L$ structures are not demonstrable in the host gneisses whose foliation is essentially of Scourian age (Figure 2.14).

Around [NF 891 893] the 'Younger Basic' intrusions dip only gently, whereas the gneissose foliation has a steep attitude. Eastwards, these relationships change until at Rubha Bhreinis [NF 901 892] the dip of the 'Younger Basic' dykes is steep and that of the gneissose foliation is nearly horizontal. Graham (1970) ascribed this change to rotation of the two elements during Laxfordian F3 folding, the section effectively transecting part of a broad antiformal core (Figure 2.14)a. Traversing south-eastwards along the coast from Rubha Bhreinis the $D2_L$ strain is moderate to low until a zone lying north of Rubh' a' Bhaile Fo Thuath around [NF 908 881] is reached, where it increases rapidly. Here, 'Younger Basic' dykes and sheets show tight F2 folds, analogous to those seen on the east side of Bagh Alairip.

Farther south the transition into the $D2_L$–$D3_L$ high-strain zone, which can be traced across the island from the north coast, is poorly exposed. Graham (1970) carried out a detailed analysis of the deformed lineations on Pabbay and was able to show that the degree of $D3_L$ strain mimics that of $D2_L$, increasingly markedly south-westwards across the transition zone.

Interpretation

The grey felsic orthogneisses and the metasedimentary gneisses on Pabbay have not been dated, and hence the ages of their protoliths or their reworking are not known. However, Whitehouse and Bridgwater (2001) have obtained ion-microprobe U-Pb zircon ages from tonalitic felsic gneisses at Loch a Bhàigh in Berneray, which lie along strike from the felsic gneisses of north-east Pabbay. The ages were discordant, and ranged from 2860 Ma to 2740 Ma. The most concordant age, from a finely banded zircon phase, gave a Pb-Pb age of 2834 ± 9 Ma, interpreted as the age of the igneous protolith. Surprisingly, these gneisses show no sign of disturbance to the U-Pb system during Laxfordian times. It is unclear as to whether the metasedimentary rocks link to the Palaeoproterozoic rocks of the Leverburgh and Langavat belts of South Harris (see Na Buirgh GCR site report, this chapter), or whether they too are of Archaean age.

Lithologically, they lack the more-exotic metalimestones, talc-silicate rocks and graphitic pelites of the Leverburgh Belt, and resemble the metasedimentary rocks of the Uists and Benbecula. The reworking is attributed to the Laxfordian event, as the structures form part of a regional pattern that can be traced on North and South Uist (Graham and Coward, 1973).

The structural variations across the site, as described above, clearly demonstrate that the north-east area of Pabbay is an area of low Laxfordian strain (Figure 2.14). South-westwards there is a rapid transition over some 500 m through a zone of moderate strain into one of high strain that encompasses the remainder of the island. Graham (1970) argued that throughout the island the Laxfordian $D1_L$ strain was low, being largely confined to the development of an internal foliation in the 'Younger Basic' mafic dykes and other bodies. The main agent of reworking was $D2_L$, and it is this episode that effectively superimposed the current strain pattern. $D3_L$ strain, as evidenced by the gentle F3 structures on the north coast, generally mimics the $D2_L$ pattern, increasing markedly to the south-west into the $D2_L$ high-strain zone. Indeed Graham (1970) argued that the distribution of $D3_L$ strain was determined by the $D2_L$ pattern. This is reflected in the regional-scale F3 folds, namely the Sound of Harris Antiform and Berneray Synform (as depicted in (Figure 2.11)). The former has a wide hinge zone marked by a low degree of Laxfordian reworking; the latter is a tight structure characterized by high degrees of reworking, particularly on its limbs (Graham, 1970; Fettes *et al.,* 1992). The common limb of the fold pair corresponds to the zone of very high strain on Pabbay. Graham has documented a complex pattern of folded L2 lineations in this steep zone, and attributed the geometry to the effects of the $D3_L$ deformation. The more-competent low $D2_L$ strain area of north-east Pabbay controlled the open nature of the F3 antiformal closure and the very high $D2_L$ strain zone formed the locus for high $D3_L$ strain, resulting in the development of the tight synformal closure.

Graham (1970) noted that the change from very high- to very low-strain is near-coincident with the change from the flaggy metasedimentary succession to the felsic orthogneisses. He suggested that it was this competence variation between the two lithologies that controlled the pattern of Laxfordian $D2_L$ strain and ultimately the pattern of $D3_L$ reworking in the region.

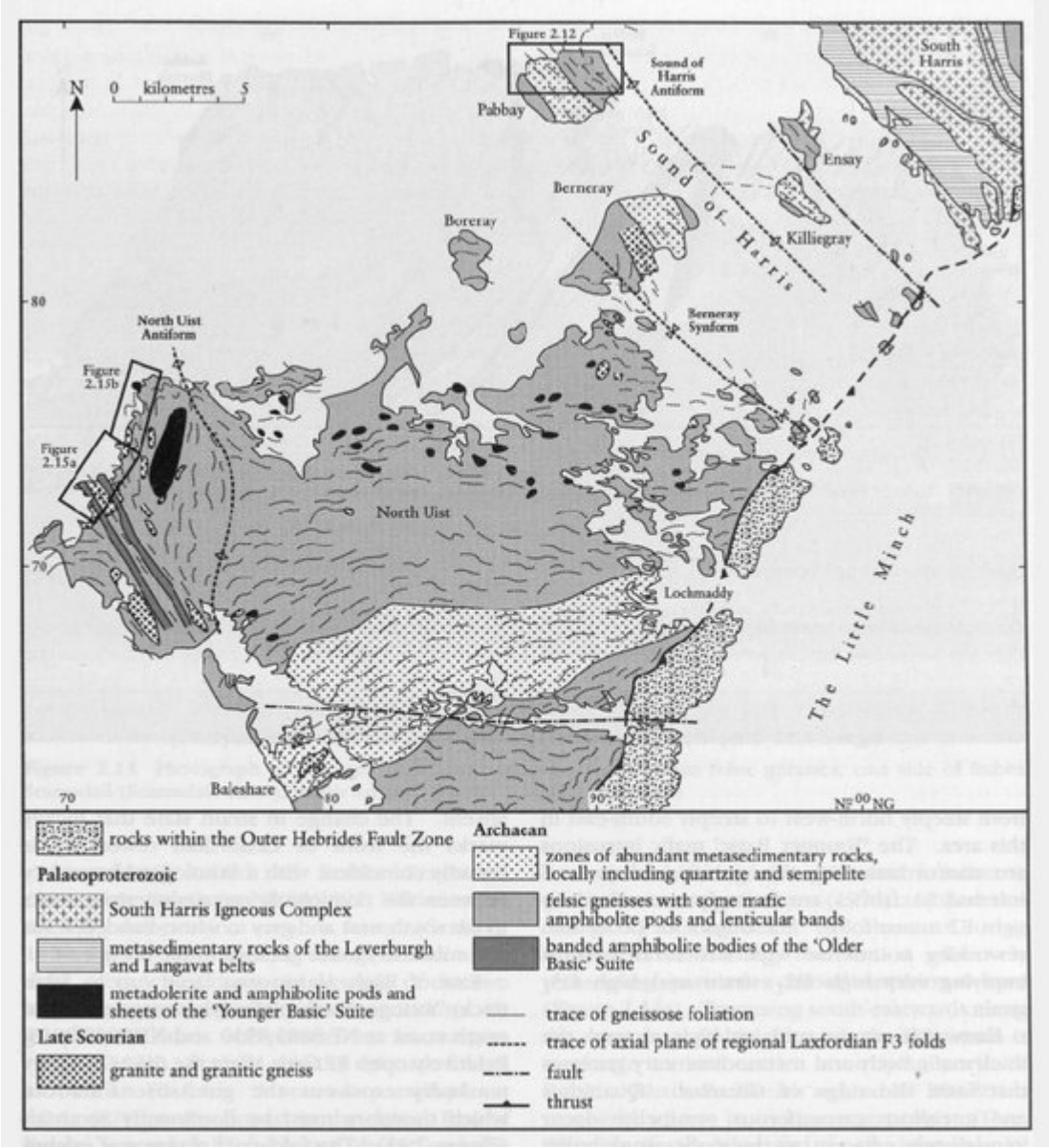
Conclusions

The North Pabbay GCR site provides a spectacular demonstration of the nature of Laxfordian reworking in the Outer Hebrides. The reworking affects Scourian orthogneisses, metasedimentary rocks and mafic intrusive rocks of the Palaeoproterozoic 'Younger Basic' Suite.

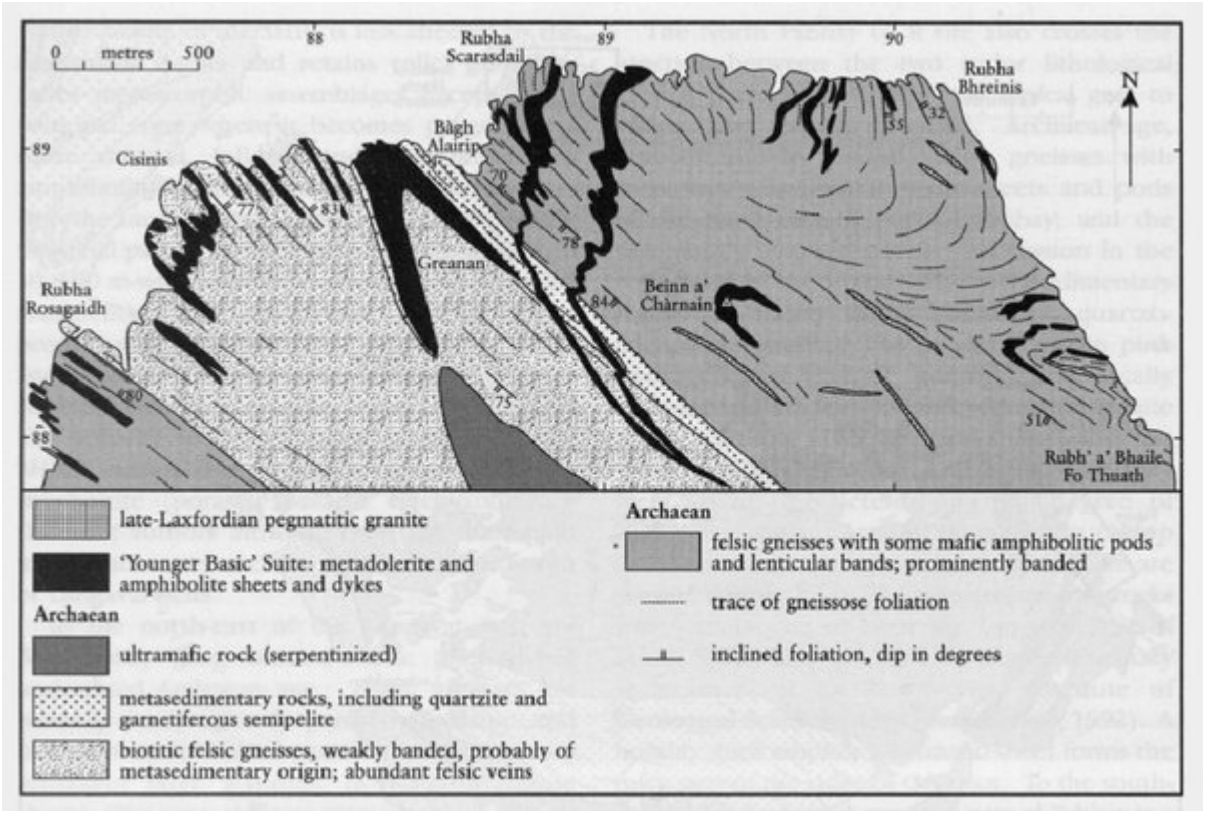
In the western part of the GCR site the Laxfordian reworking effects and strain are high and the 'Younger Basic' sheets and gneissose foliation are typically sub-parallel. In contrast in the north-eastern corner of Pabbay the Laxfordian effects are weak and 'Younger Basic' dykes markedly cross-cut the Scourian gneissose foliation. Individual 'Younger Basic' dykes can be traced along the section for over 1 km from areas where they are markedly discordant to where they are more strongly foliated, strained and only slightly discordant to the gneissose banding. This transition takes place over a *c.* 500 m-wide zone, coincident with the lithological change from banded Archaean felsic and mafic orthogneisses in the north-east to dominantly metasedimentary rocks in the south-west. The metasedimentary succession has acted in a less-competent manner compared to the orthogneisses and forms a locus for both the $D2_L$ and the subsequent $D3_L$ Laxfordian deformation episodes and related metamorphic effects. This illustrates the way in which an inherent weakness and lithological boundary within a gneissose basement terrain can become a focus for subsequent tectonothermal reworking.

The site is one of national importance and provides a coherent section where Laxfordian processes and structures can be demonstrated and further studied.

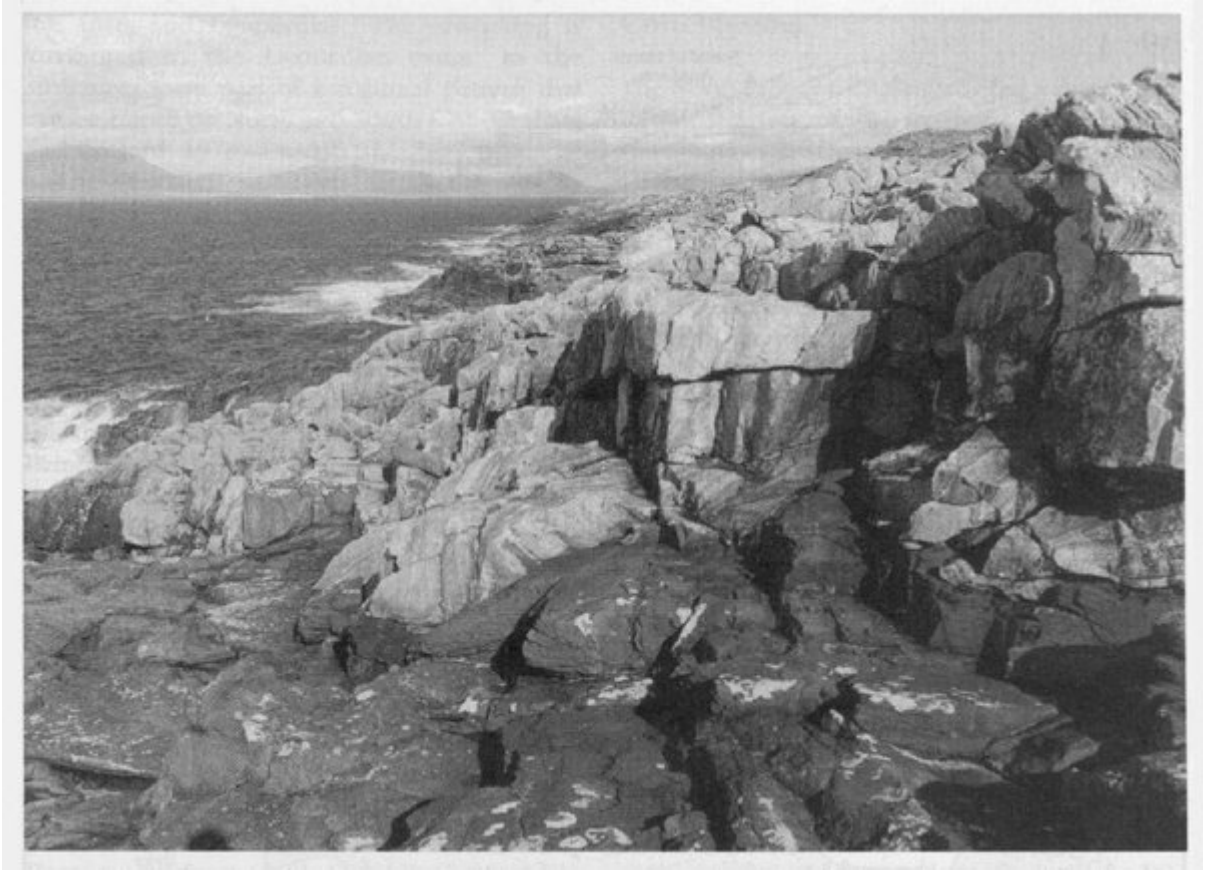
References



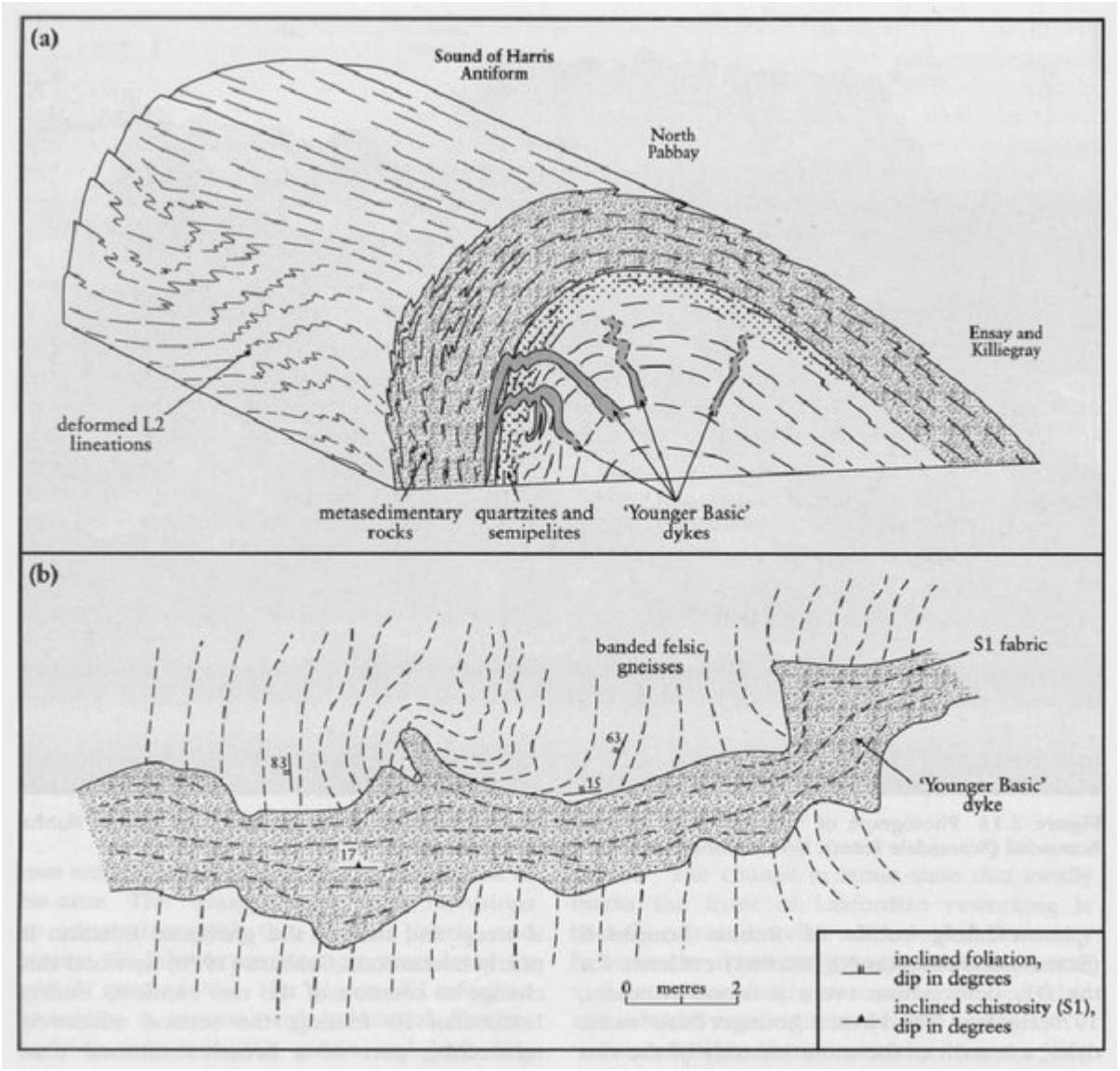
(Figure 2.11) Map showing the regional lithologies and structure of North Uist and the Sound of Harris. The positions of the North Pabbay Figure 2.12 and North Uist Coast Figure 2.15 GCR sites are indicated. After Fettes et al. (1992).



(Figure 2.12) Simplified geological map of North Pabbay. After Graham (1970).



(Figure 2.13) Photograph of 'Younger Basic' dyke cross-cutting Scourian felsic gneisses, east side of Rubha Scarasdail (Scarasdale Point), North Pabbay. (Photo: K.M. Goodenough.)



(Figure 2.14) (a) Sketch diagram of the Sound of Harris Antiform and the nature of Laxfordian strain (after Graham, 1970). (b) Detailed diagram of weakly deformed 'Younger Basic' dyke.