Faraid Head

[NC 378 715]–[NC 406 687]

R.E. Holdsworth

Introduction

Faraid Head, to the north of the village of Durness, preserves an important klippe of Moine and Lewisianoid rocks belonging to the Moine Thrust Sheet, together with mylonites in the upper part of the Moine Thrust Belt. These rocks form part of the larger fault-bounded Durness outlier that stretches from Leirinmore [NC 425 670] in the east, to Balnakeil Bay and the Kyle of Durness in the west (Figure 5.12). The Sangobeg Fault, the major south-eastern bounding fault to the inlier, drops down the Durness carbonate rocks against the Lewisian gneisses. The Durness outlier is important in that it provides the most complete section through the Cambro-Ordovician sequence of the foreland (see the Durness and Balnakeil GCR site report in the *British Cambrian to Ordovician Stratigraphy* GCR Volume; Rushton *et al.,* 2000). Faraid Head forms the north western fault-bounded part of this structural outlier.

The western shores of Faraid Head expose some of the best and most accessible sections through the Moine Thrust Zone mylonites (Lapworth, 1885) (see also Sango Bay GCR site report, this chapter). The site also forms an important onshore reference point constraining offshore geological interpretations of the E-W-trending MOIST deep seismic reflection profile (Brewer and Smythe, 1984).

The site is of historical importance as it provided some of the first evidence for kilometre-scale translation on the Moine Thrust. It also featured prominently in the so-called 'Highlands Controversy' during the latter part of the 19th century (Oldroyd, 1990). Murchison (1859) had suggested that the metamorphic rocks of Faraid Head conformably overlay the nearby unmetamorphosed carbonate rocks of the Durness Group. This hypothesis was refuted by the subsequent work of numerous authors (e.g. Nicol, 1861; Callaway, 1881; Lapworth, 1883; Peach and Horne, 1884; Peach *et al.,* 1907) who suggested that the units of Faraid Head are down-faulted remnants of the thrust sheets that were emplaced by WNW-directed Caledonian movements over most of the foreland region in north-west Scotland. The preservation of the Faraid Head klippe allowed Peach *et al.* (1907, p. 469) to demonstrate directly that the Moine Thrust Sheet had been displaced at least 15 km westwards (arrow in (Figure 5.12)). Together with early work in the Alps (e.g. Heim, 1878, 1919), this was one of the first examples of documented large-scale horizontal movements to be demonstrated in an orogenic belt. The detailed structure of the Faraid Head peninsula was described recently by Holdsworth *et al.* (2007).

Description

Faraid Head forms a narrow 3 km-long peninsula that rises to 100 m above OD at its north-west edge, but whose low-lying, central and southern parts are mainly covered by sand dunes (Figure 5.12), (Figure 5.13). Most of the coastline comprises cliffs and rocky shore, except in the west where beaches (Balnakeil Bay) separate isolated outcrops of rock. Much of the coastal outcrop is accessible at low tide, apart from the 20–80 m-high steep cliffs in the northern part of the peninsula. The site exposes three distinct lithotectonic units that dip mainly gently to the ESE (Figure 5.13). An upper unit of Moine psammites overlies a unit of variably mylonitized Lewisianoid orthogneisses with subordinate units of meta-carbonate rock and schistose metasedimentary rocks. The Lewisianoid rocks in turn overlie a white mica-chlorite-rich phyllonite unit — the 'Oystershell Rock' of Peach *et al.* (1907). The presumed faulted contact of the metamorphic rocks with the Durness Group carbonate rocks to the south — the 'Boundary Fault' (Figure 5.13) — is largely obscured by blown sand in the southern part of the peninsula.

The Moine rocks comprise at least 500 m of lithologically monotonous, fine- to medium- grained, grey-brown bedded psammites that crop out mainly on the craggy eastern shores of the peninsula between Gob nan Leac and Geodha Brat (Figure 5.13). Subordinate layers of sparsely garnetiferous semipelite and pelite, generally less that 10 mm thick, are preserved locally (e.g. at [NC 390 698]), as are narrow seams and diffuse pods of fine-grained, pale-green epidotic

material that may represent poorly developed calc-silicate lithologies. The Lewisianoid units are lithologically more varied, comprising units of variably mylonitized, pink felsic to dark grey-green mafic gneisses, inter-banded on both millimetre- and metre-scales. Minor lenticular intercalations of grey-brown carbonate rock, dark-brown biotite schist and concordant bright-green actinolitic amphibolites, up to 1 m thick, are also present locally. The concordant contact between Moine and Lewisianoid rocks is exposed only in the steep cliffs 300 m SSW of Gob nan Leac at [NC 391 715].

The concordant contact between the Lewisianoid-derived mylonitic rocks and the underlying 'Oystershell Rock' is exposed halfway up the steep cliffs west of Poll a' Gheodha Bhain [NC 382 713] and on the shore 0.5 km NNW of A' Chleit [NC 382 708], where it is offset by a late fault (Figure 5.13). The 'Oystershell Rock' comprises a mottled dark grey-green fine-grained, white mica-chlorite-rich phyllonite (see Clèit an t-Seabhaig GCR site report, this chapter).

Layers of grey quartzofeldspathic rock up to several metres thick, and narrow seams of fine-grained grey-brown metacarbonate rock up to 1 cm thick are locally interlayered with the phyllonites, notably near to the contact with the overlying Lewisianoid rocks (Peach *et al.,* 1907; see also Clèit an t-Seabhaig GCR site report, this chapter). The base of the phyllonites is not exposed on the peninsula, but may lie close to its western shore, as Dueness Group carbonates crop out on small skerries a few hundred metres south-west of An Fharaid (Figure 5.13). This contact is exposed at the Sango Bay GCR site.

On a large scale, the Moine rocks at Faraid Head are disposed in a northward-closing, tight fold with a gently ESE-dipping axial-planar fabric of local D2 age (Figure 5.13). Remnants of cross-lamination indicative of way-up are preserved only in low-strain psammites adjacent to F2 fold hinges. These features suggest that the western limb of the major fold is right-way-up and thus the fold faces SSW. Minor F2 folds deform an earlier bedding-parallel foliation (S1) and, in semipelitic/pelitic units, fold an S1-parallel quartz segregation fabric. Minor F2 folds are only well developed in the hinge region of the major fold, exposed on the coasts west of Clach Bheag na Faraid and Meall a' Bhuic. F2 fold axes and intersections plunge ESE sub-parallel to a ubiquitous down-dip mineral-stretching lineation. Poorly developed shear bands are developed in semipelitic and pelitic lithologies and suggest top-to-the-WNW displacements. The S2 fabrics are mylonitic but are mostly annealed, with the quartz-microstructure dominated by secondary recrystallization textures. As in the Clèit an t-Seabhaig GCR site, the D2 fabrics pass downwards into the mylonitic Lewisianoid gneisses and into the finer-grained, sub-parallel, mylonitic L-S fabrics affecting the underlying 'Oystershell Rock' unit.

The rocks of the Faraid Head peninsula are cut by a dominant set of subvertical, NW-trending faults including the inferred Boundary Fault that separates the metamorphic rocks from the Dueness Group (Figure 5.13). Where similarly orientated minor fault planes are exposed, they preserve predominantly dip-slip slickenslides and offset geological boundaries, implying that the downthrow is mainly to the north-east. Other brittle faults are also steeply dipping and display various trends between NNW and west. E- to SE-plunging, open, brittle-style folds of the ductile foliation on a metre- scale are preserved adjacent to some NW–SE-trending faults (e.g. at [NC 382 707]). Where exposed in cliff sections, most faults contain narrow (less than 50 mm wide) belts of red breccia and gouge. NW-trending faults exposed in the crags of carbonate rock immediately south-west of the Boundary Fault at Geodha Brat [NC 404 685] are locally infilled with carbonate-cemented red sandstones and breccias of presumed sedimentary origin. Clasts in these rocks include carbonate rock, mylonite and Moine psammite. A subvertical basic dyke, up to 2.0 m wide, intruded along linked WNW- and NW-trending faults in the coastal section 400 m north of Geodh' a' Lochaidh [NC 392 706] is interpreted to belong to the Carboniferous–Permian-age camptonite-monchiquite suite.

Interpretation

Lithologically and structurally, the three metamorphic units at Faraid Head are directly comparable with units recognized in the uppermost parts of the Moine Thrust Belt to the east of Loch Eriboll (Figure 5.12) (Holdsworth *et al.,* 2007). The origins of the 'Oystershell Rock' are discussed in the Clèit an t-Seabhaig GCR site report (this chapter). Recent work has concluded that this phyllonite unit generally represents highly deformed and altered greenschist-facies metamorphosed rocks of Lewisian or Lewisianoid affinities (Holdsworth *et al.,* 2001). This suggests that the phyllonites are best assigned to the Moine Thrust Belt and hence places the Moine Thrust at the contact between the Lewisianoid rocks and the 'Oystershell Rock' (Figure 5.13). The contact between the Lewisianoid and overlying, apparently right-way-up Moine

rocks at Faraid Head is therefore again interpreted as a highly sheared unconformity (cf. Holdsworth, 1989a; Holdsworth *et ed.,* 2001).

The observed continuity between D2 fabrics in the Moine and the mylonitic fabrics in the underlying units is consistent with these structures being broadly the same age. Shear-sense criteria (e.g. shear bands, asymmetrical porphyroclasts) are abundant throughout, and consistently imply top-to-the-WNW thrust displacement. The movements are presumed to be of Caledonian age based on their similarity with other parts of the Moine Thrust Belt. The grade of metamorphism in the lower part of the Moine Thrust Sheet is difficult to assess due to the dominantly psammitic lithologies. Minor F2 folds (at [NC 390 698]) deform an early, Sl-parallel quartz-segregation fabric in fine- to medium-grained petite, and garnet porphyroblasts, up to 5 mm across and strongly wrapped by S2, carry relict S1 inclusion trails. At the same locality, garnet is slightly altered to greenish biotite, which together with white mica and quartz, define the S2 fabric. This suggests that the metamorphism in the Moine prior to D2 deformation was at least garnet grade, but that syn-D2 metamorphism may have been a retrograde mid- to low-greenschist-facies event (Wilson, 1953; Barr *et al.,* 1986; Holdsworth, 1987, 1989a). Greenschist-facies retrogression is ubiquitous in the underlying originally gneissose Lewisianoid rocks; hornblendes are replaced extensively by tremolite–actinolite, biotite and chlorite, and calcic plagioclase by albite seeded with numerous fine-grained crystals of clinozoisite. Fibrous overgrowths around relict porphyroclasts (feldspar, amphibole and epidote), and along top-to-the-NW shear bands, typically consist of quartz, biotite, chlorite and white mica, consistent with the low grade of metamorphism. As the intensity of mylonitization increases, the effects of retrogression are more widespread, suggesting that these processes are inter-related.

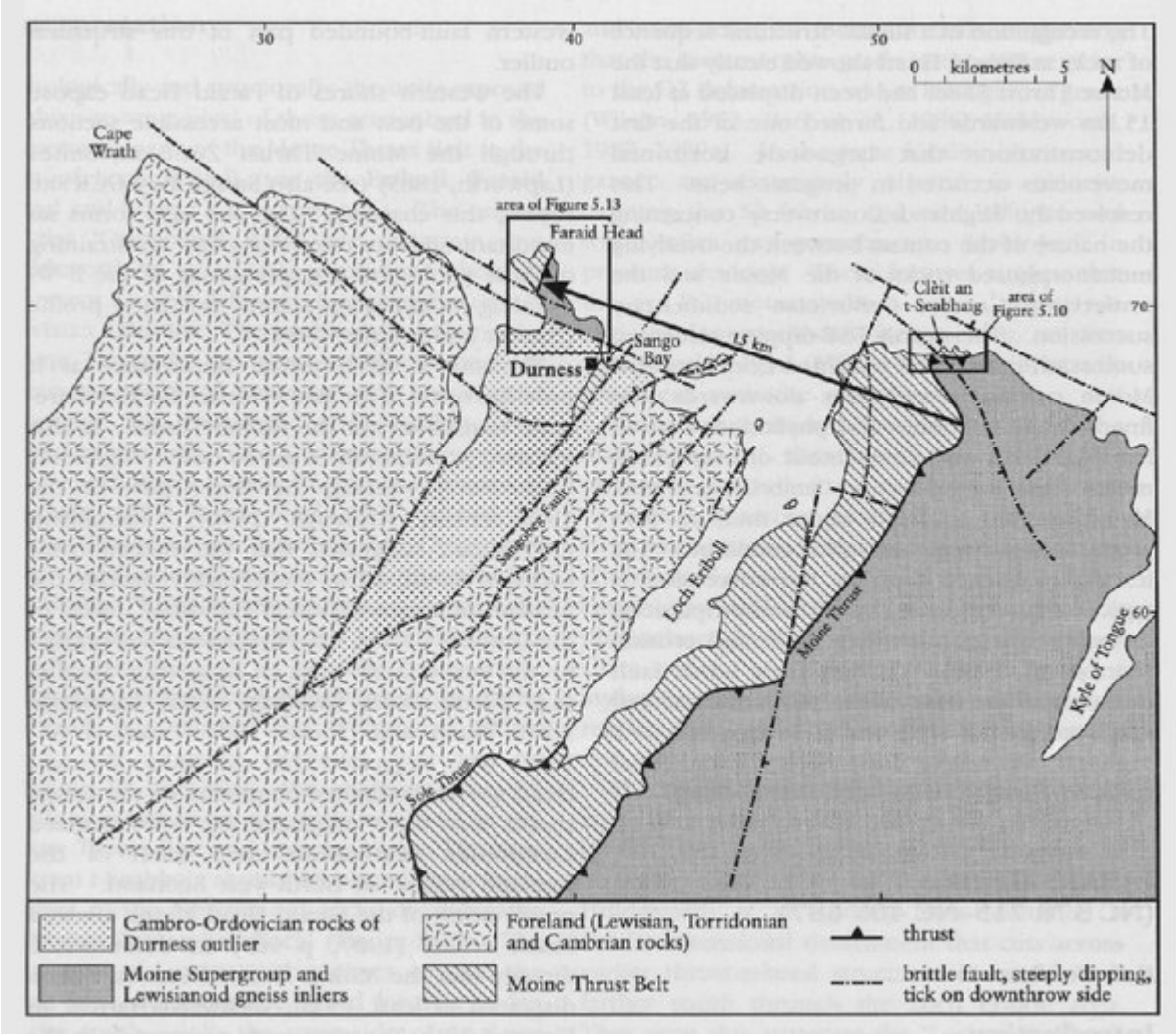
The late faults in the Faraid Head area are part of a regional system of NW- and NE-trending faults along the north coast of Scotland (Laubach and Marshak, 1987). They are also probably related to systems of normal faults associated with the southern margin of the Devonian and Mesozoic West Orkney Basin lying offshore to the north, which have been recognized from seismic reflection data (e.g. Brewer and Smythe, 1984; Coward and Enfield, 1987). The kilometre-scale anticlockwise swing observed in the foliation of the Moine psammites as they are traced from Geodh' a' Lochaidh southwards to the Boundary Fault (Figure 5.13) is interpreted as a late warping associated with variations in displacement along the NW-trending fault-zones. These faults probably formed close to the land surface, as the upper parts of structures adjacent to the Boundary Fault preserve a sedimentary infill. The NW-trending faults were probably initiated during the late Silurian or Devonian, prior to final exhumation of the Moine Thrust Sheet and the later intrusion of a Permo–Carboniferous camptonite-monchiquite dyke along pre-existing faults. Subsequent reactivation of some faults may have occurred.

Conclusions

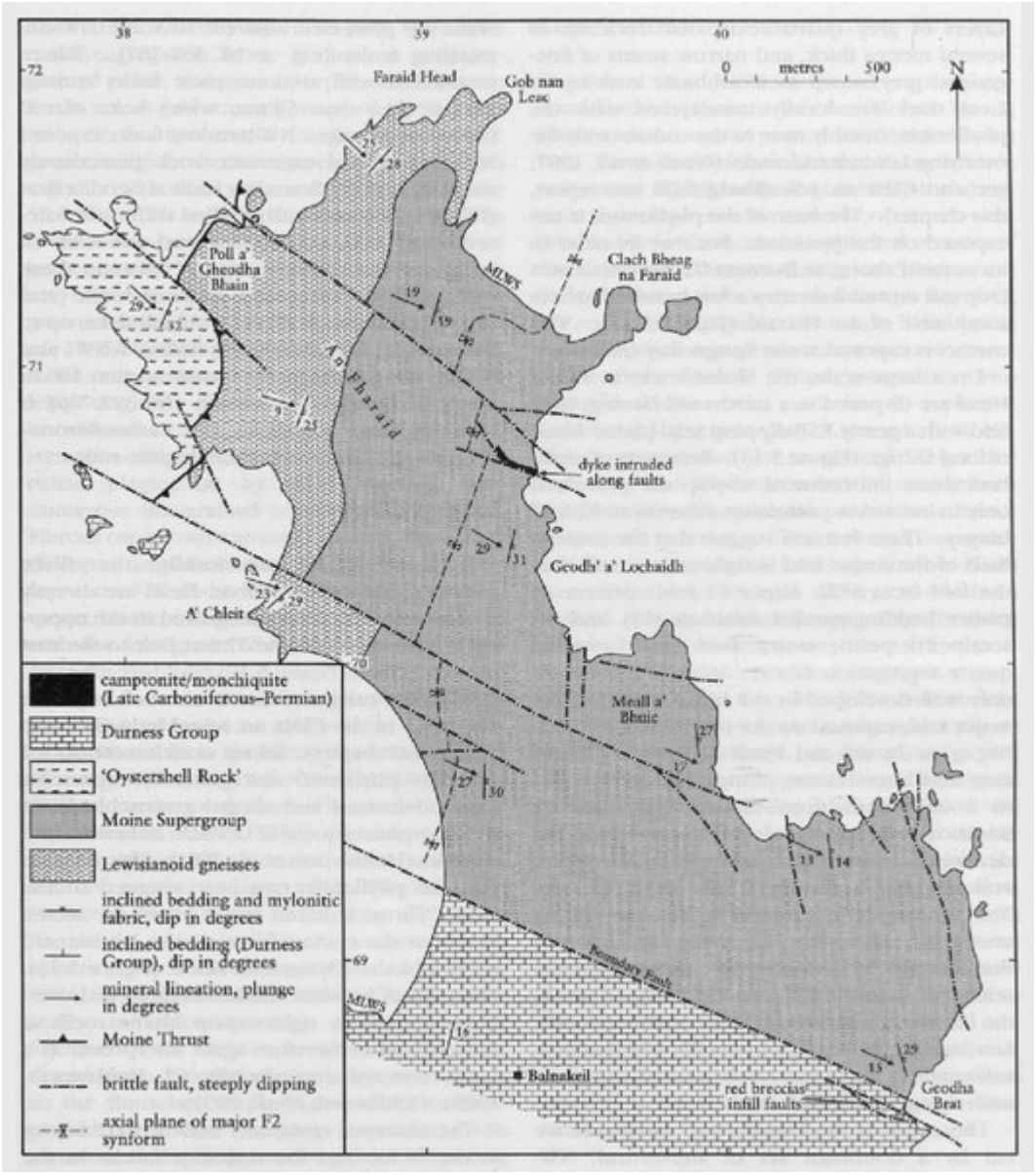
The Faraid Head GCR site preserves a unique down-faulted remnant of the Moine Thrust Sheet and the upper part of the Moine Thrust Belt. It can be demonstrated that these tectonic units were significantly displaced by thrusting, and that they overlay much of north-west Scotland prior to the main uplift and erosion of the Caledonian Orogen during late Silurian and Early Devonian times (see also Sango Bay GCR site report, this chapter). The mainly ESE-dipping metamorphic rocks preserve a transition downwards from folded Moine psammites into mylonitic Moine rocks, underlain by mylonitic Lewisianoid gneisses and 'Oystershell Rock'. This lowest exposed unit consists of fine-grained mylonites and phyllonites derived mostly from Lewisianoid orthogneisses and minor metasedimentary rocks. This textural sequence and the accompanying lower greenschist-facies metamorphic assemblages are typical of fabrics formed during foreland-propagating thrusting accompanied by exhumation.

The site is of international importance as it was one of the first localities where the kilometre-scale displacement of a major thrust sheet was demonstrated. It also played a part in resolving the long-standing 'Highlands Controversy' concerning the nature of the contact between the metamorphosed Moine rocks and the underlying Cambro–Ordovician succession of the foreland. Faraid Head is excellent for teaching structural geology, with the easily accessible and well-exposed mylonites exposed on the western side of the peninsula being particularly instructive. The site lies within the larger fault-bounded Dumess structural outlier and also offers an opportunity to study late faulting spatially associated with the southern margin of the Devonian and Mesozoic West Orkney Basin that lies offshore to the north.

References



(Figure 5.12) Map showing the relationship between the Moine Thrust Sheet and the Durness Klippe. Arrow drawn parallel to regional thrust transport direction (290°) shows minimum displacement of 15 km required along Moine Thrust due to preservation of Faraid Head klippe. Areas of Figures 5.10 and 5.13 are indicated.



(Figure 5.13) Map of the area around Faraid Head. After Holdsworth et al. (2007). See Figure 5.12 for location.