Excursion 12 Durness and Faraid Head

Bob Holdsworth and Rob Strachan

Purpose:	To examine down-faulted segments of the Moine Thrust sheet and Moine Thrust Zone in the Caledonian foreland.
Aspects covered:	Moine andbasement-derived mylonites; Cambrian quartzites and limestones, Caledonian thrusts and other low-angle faults; late to post-Caledonian faults.
Maps:	OS: 1:25,000 sheet 446 Durness and Cape Wrath; BGS:1:50,000 sheet 114W Loch Eriboll.
Useful information:	Accommodation may be obtained in Durness, Rhiconich and Tongue.
Type of terrain:	Almost entirely coastal exposures. *Distance and time:* If staying in Durness, driving is minimal; the excursion involves *c.*6-7km walking and could easily be completed in one day. Low tide is advantageous for the Durness part of the excursion. Durness is *c.*30 minutes drive from Rhiconich and *c.*1 hour from Tongue.
Short itinerary:	The Durness part of the excursion is very accessible, could be covered in 2-3 hours and demonstrates the most important aspects of the geology.

This is a short excursion designed to examine unique occurrences on the Caledonian foreland of segments of the Moine Thrust sheet and Moine Thrust Zone that were down-faulted during the late Palaeozoic and/or the Mesozoic ((Figure 12.1); Peach *et al*., 1907; Hippler & Knipe, 1990; Holdsworth *et al*., 2006, 2007). These outcrops are of historical importance because Peach *et al*. (1907) were able to deduce from them a minimum displacement of *c.*15km along the Moine Thrust – one of the first times that this approach had been used to constrain large-scale horizontal movements in an orogenic belt.

If driving to Durness from Tongue, the route passes up the west side of Loch Eriboll, along the strike of the easterly-dipping Cambrian quartzites of the Caledonian foreland. There are numerous opportunities along this road section for a short stop to examine these rocks. Groups may also wish to stop *c.*4km ESE of Durness at Traigh Allt Chailgeag (parking at [NC 4435 6537]) to view steeply-dipping Lewisian basement gneisses that were strongly reworked in the Laxfordian event. Kinny & Friend (1997) reported a U-Pb zircon age of *c.*2680 Ma for the igneous protolith of a dioritic gneiss from this locality. The road climbs slightly to the west, and it is worth pausing briefly at one of the various passing spaces in order to look north-eastwards across Loch Eriboll to the spectacular cliffs of Whiten Head that expose the northernmost part of the Moine Thrust Zone. The white cliffs comprise imbricated Cambrian Pipe Rock, and the darker rocks at a structurally higher level are Lewisian gneisses of the Arnabol Nappe (Holdsworth *et al*., 2007; see Excursion 11).

Locality 12.1 Sango Sands, Durness ([NC 4100 6740] to [NC 404 685]

Sango Sands, Durness (Figure 12.2). Down-faulted basement and Moine Thrust sheet and Moine Thrust Zone mylonites overlying the Cambrian Durness Limestone.

Parking is available for coaches and cars at the Tourist Information Centre in Durness [NC 4070 6775] overlooking Sango Sands. From the car park, view the steep wall of Durness Limestone *c.*400m to the SE; this lies along the Sangobeg Fault, one of the main bounding normal faults of the Durness outlier (Figure 12.2). Walk *c.*300m east along the road to roadside exposures in the Durness Limestone at Locality 12.1A [NC 4100 6740] that lie in the immediate footwall of this fault. Here, a series of carbonate-cemented red sandstone-breccia infills and carbonate veins are preserved in

sub-vertical fractures trending NNE–SSW, approximately parallel to the trend of the adjacent normal fault. The sedimentary material is thought to have infilled tectonically active open fractures in the limestone that formed synchronously with normal faulting activity. This suggests that this phase of extension was associated with sedimentation, although most of the basin infills have subsequently been eroded. Similar red-bed infills are common in the region between Durness and Cape Wrath (e.g. see Locality 12.1F for further details). Clast types are mainly Durness Limestone, but isolated examples of mylonite and Cambrian quartzite are also preserved. Climb the grassy slope above the exposure, look northwestwards across Sango Bay and compare the annotated view presented in (Figure 12.3) with the geological map (Figure 12.2).

Return to the car park and walk down onto the beach via the wooden steps. East of the base of the steps is a prominent headland (1B) that comprises outcrops of banded quartzo-feldspathic and amphibolitic Lewisianoid basement gneisses (Figure 12.2). These are thought to lie close to the base of the Moine Thrust sheet; the underlying Moine Thrust is not exposed in the bay, but is seen on Faraid Head (see Locality 12.2). Creamy-pink acidic gneisses and dark green metabasic sheets are cut by pegmatitic and quartz veins. The gneisses contain greenschist-facies mineral assemblages (chlorite, actinolite, epidote) indicative of retrogression; the dominant banding dips east and carries an ESE-plunging mineral and extension lineation.

The gneisses are probably bounded to the west by a normal fault that separates them from upstanding outcrops (1C) in the central part of the bay of a green chlorite phyllonite (Figure 12.2). These phyllonites are identical to the 'Oystershell Rock' identified within the mylonite belt of the Moine Thrust Zone at Loch Eriboll (see transect 4, Excursion 11). They contain numerous lunate quartz segregations and pervasive shear bands that indicate a top-to-the-west sense of displacement parallel to an E-W-trending lineation that is particularly well developed in the quartz-bearing layers.

Walk towards 1D, the rocky headland at the NW limit of the beach (Figure 12.2). Look up towards the cliffs to the left to see further outcrops of the Oystershell Rock. These contain thin mylonitized pegmatitic veinlets; a set of intrafolial isoclinal folds can be identified as well as later folds that deform the mylonite fabric. The structurally lowest rock unit on the headland is rather fractured, pink-purple weathering Durness Limestone. This is separated by a gently-inclined detachment fault from a 2-3m-thick slice of quartz mylonite, that is itself overlain by another low-angle fault, above which is the Oystershell Rock. Walk up onto the headland to examine these detachments in detail, and then follow them around to the west into the next bay. Note that the low-angle faulted contacts are very much disrupted by the effects of later carbonate veining, located mainly in the footwall of the lowermost detachment, and also due to offsets along numerous, steeply-dipping normal faults (Hippler & Knipe, 1990). Care should be taken on this path if conditions are wet. An alternative route into this bay is to retrace the route back to and up the wooden steps, and walk westwards along the main cliff-top, parallel to the boundary fence of the campsite. The interpretation favoured here is that the lowermost detachment corresponds to the Lochan Riabhach Thrust that is thought by Holdsworth *et al*. (2006) to underlie the mylonite belt at Loch Eriboll (see transect 4, Excursion 11) and interpreted by them as a separate structure from the Moine Thrust exposed at a higher structural level at Faraid Head (see below). The alternative view is that the lowermost thrust does in fact correspond to the Moine Thrust (R. W. H. Butler, *pers. comm*.).

Locality 12.1E (Figure 12.2) is bounded to the SE by a steep face of Durness Limestone that is thought to lie very close to another NNE-trending normal fault. Slickenlines on the fault pitch steeply. Carbonate fault breccias are extensively developed in places and there is abundant evidence for carbonate veining and cementation. Low tides expose further outcrops of Oystershell Rock (Figure 12.2). A small headland at the back of the beach exposes brecciated and fractured Durness Limestone that is overlain by the Lochan Riabhach Thrust (Figure 12.4). However, at this locality the rocks that immediately overlie the thrust appear to be a slice of Lewisian-derived mylonite. These are in turn overlain by quartz mylonites and Oystershell Rock. Walk further west to see a steep face of Durness Limestone cut by NE-dipping brittle faults. White-weathering quartz mylonites (presumably underlain by the Lochan Riabhach Thrust) are visible in the upper parts of the cliff, but are inaccessible.

Return to the top of the cliff and, following the fence, walk approximately 500m NW along the cliffs of Durness Limestone towards Locality 12.1F which lies south of Geodha Brat ((Figure 12.2); [NC 404 685]). The steep cliffs here define the trend of the WNW–ENE-trending Faraid Head Fault that down-faults the main Faraid Head outlier of Moine rocks and the Moine Thrust Zone mylonites that outcrop to the north. Most of the cliff comprises variably brecciated Durness

Limestone, but at its western end where the upper parts of the cliff can be accessed from the sand dunes, carbonate-cemented red sandstone-breccia infills are preserved in a series of sub-vertical fractures trending parallel to the main fault. These are virtually identical to those exposed at Locality 12.1A, and are also thought to represent sedimentary material that has infilled tectonically open fractures in the limestone formed synchronously with normal faulting activity. The dominant clast types are limestone, but clasts of Moine psammite, mylonitized Lewisian gneiss and quartzite mylonite are also present. At least two units of infill are recognized based on differences in grain-size and sorting.

The ages of the sedimentary infills at Localities 12.1A and 12.1F – and hence the age of extension – are unknown, but a Devonian (Old Red Sandstone) or Permo-Triassic age seems likely, given the timing of sedimentary basin formation in the West Orkney Basin that lies immediately offshore and to the north (Coward & Enfield, 1987; Enfield & Coward, 1987; Stoker *et al*., 1993). Detailed studies of the normal faulting along the north coast in the Durness-Cape Wrath area (Beacom, 1999; Wilson *et al.*, 2010) suggests that the NNE- and WNW-trending normal faults are likely to be contemporaneous, forming a complex transfer zone that defines the southern margin of the West Orkney Basin. Return to the vehicles, retracing your steps along the cliff-top.

Locality 12.2 Faraid Head [NC 3925 6965] to [NC 3785 7135]

Faraid Head (Figure 12.5). Down-faulted Moine, Lewisianoid basement and 'Oystershell Rock'.

Drive a few hundred metres west and at the sharp bend in Durness village take the minor road signposted to Balnakeil. Parking is available for coaches and cars on the south side of Balnakeil Bay at [NC 3915 6870]. Walk northwards across the beach to exposures of Moine psammites at 2A [NC 3925 6965]. These carry a strong mylonitic fabric that dips shallowly to the ESE and is associated with a down-dip mineral and extension lineation. The mylonitic fabric is axial-planar to rare F_2 isoclinal folds that plunge ESE sub-parallel to the mineral lineation. Thin layers of garnetiferous semi-pelite contain shear bands that indicate a top-to-the-WNW sense of displacement parallel to the lineation. Rare lenticular bands of garnetiferous pelite up to 10cm thick carry a quartz segregation fabric that is folded around the hinges of F_2 minor folds; garnets up to 7-8mm in diameter are strongly wrapped by the S_2 fabric that is axial planar to these folds.

Walk northwards to beach outcrops at 2B [NC 3855 7070]. If tide is high, good outcrops are also present above the high water mark. The spectacular exposures here are of basement-derived mylonites that exhibit a wide variety of features typical of mid-crustal shear zones. The mylonites vary from creamy-pink types derived from acid gneiss to strips and pods of chlorite-actinolite schist that may represent boudinaged and highly retrogressed amphibolites. Relict gneissic layering is represented by colour banding in the acid types. The mylonite fabric dips to the ESE and a strong lineation plunges down-dip. Classic examples of shear criteria such as shear bands, asymmetrically-wrapped porphyroclasts and boudins all indicate a top-to-the-WNW sense of displacement parallel to the lineation. Locally, cm-scale, close to tight minor folds are present plunging at low to moderate angles to the mineral lineation. Numerous quartz-chlorite-epidote veins are preserved; early types are concordant and mylonitic, later types crosscutting, often in boudin necks, and little deformed. In more feldspathic units, mylonite is associated with pale yellow-green, epidote-rich cataclasite seams, many of which are concordant with the foliation. These are examples of semi-brittle behaviour typical of greenschist facies fault rocks in which feldspar-rich layers deform in a brittle fashion whilst adjacent quartz and phyllosilicate-rich layers undergo dynamic recrystallization. In places just above the high water mark to the west, strain is less intense and the mylonites resemble more closely the Lewisianoid rocks at the same structural level at Sango Sands (Locality 12.1B).

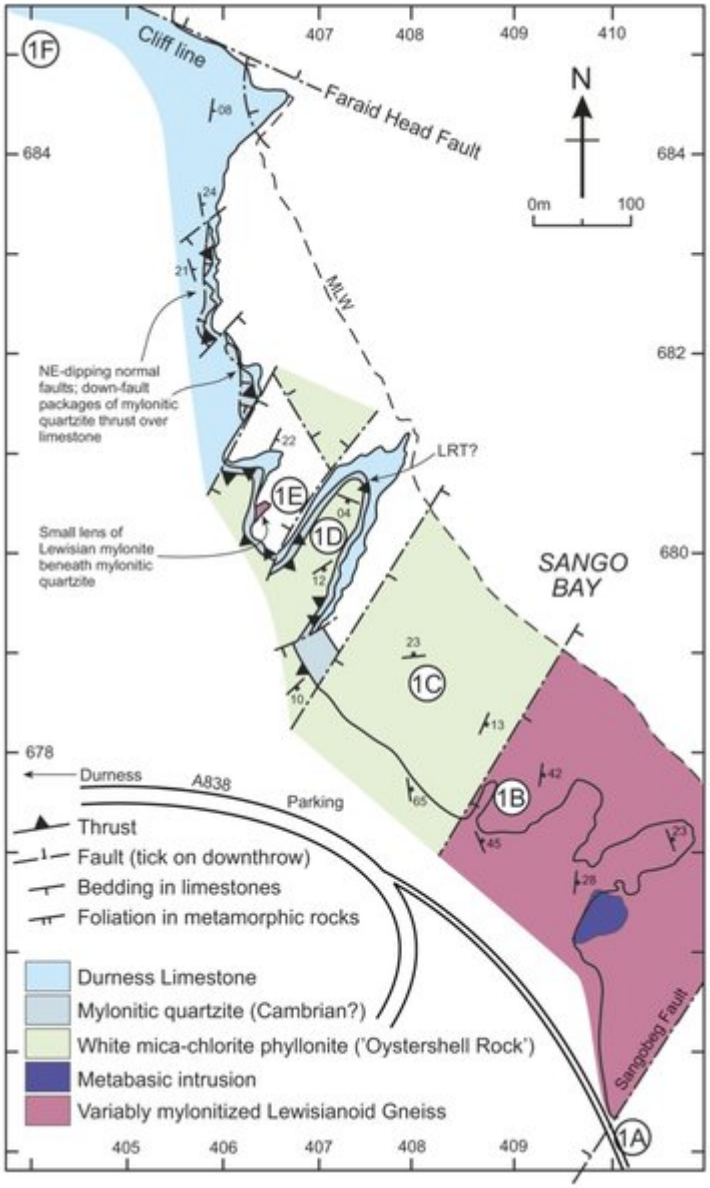
Traverse inland to 2C [NC 3825 7084], a series of crags composed of the Oystershell Rock just below the unexposed trace of the Moine Thrust. Gently-dipping Oystershell Rock includes numerous deformed quartz veins; a strong lineation plunges to the ESE. Pervasive shear bands and 10cm-scale shear zones again indicate a top-to-the-WNW sense of displacement. The Oystershell Rock is notable here for the presence of 10-15cm-thick bands of brown-weathering marble that are continuous for several metres in some cases. F_3 S-folds of the mylonite fabric verge northwest to north-hinges are markedly curvilinear, plunging between the northeast and east. A 10cm-thick E–W-trending, steeply-dipping basic dyke of possible Permo-Carboniferous age cross-cuts the upper part of these crags at [NC 3828

7093].

Walk 700m NW across the raised beach in which isolated crags of Oystershell Rock are exposed until the far end of the headland is reached at Locality 12.2D [NC 3785 7135]. Look ENE towards the Ministry of Defence buildings and the steep cliffs on the northern coast of Faraid Head to view the ductile Moine Thrust. This is the flat-lying boundary exposed in the western cliffs of Poll a Geodha Bhain that separates stripy, multicoloured Lewisianoid mylonites in the hanging-wall from more uniform dark-green-grey Oystershell Rock in the footwall. If time permits, trace this boundary south to the coast at [NC 3725 7080] where this boundary is exposed. Note, however, that it is difficult to distinguish precisely the location of this contact as it separates mylonites that are both derived from Lewisianoid protoliths.

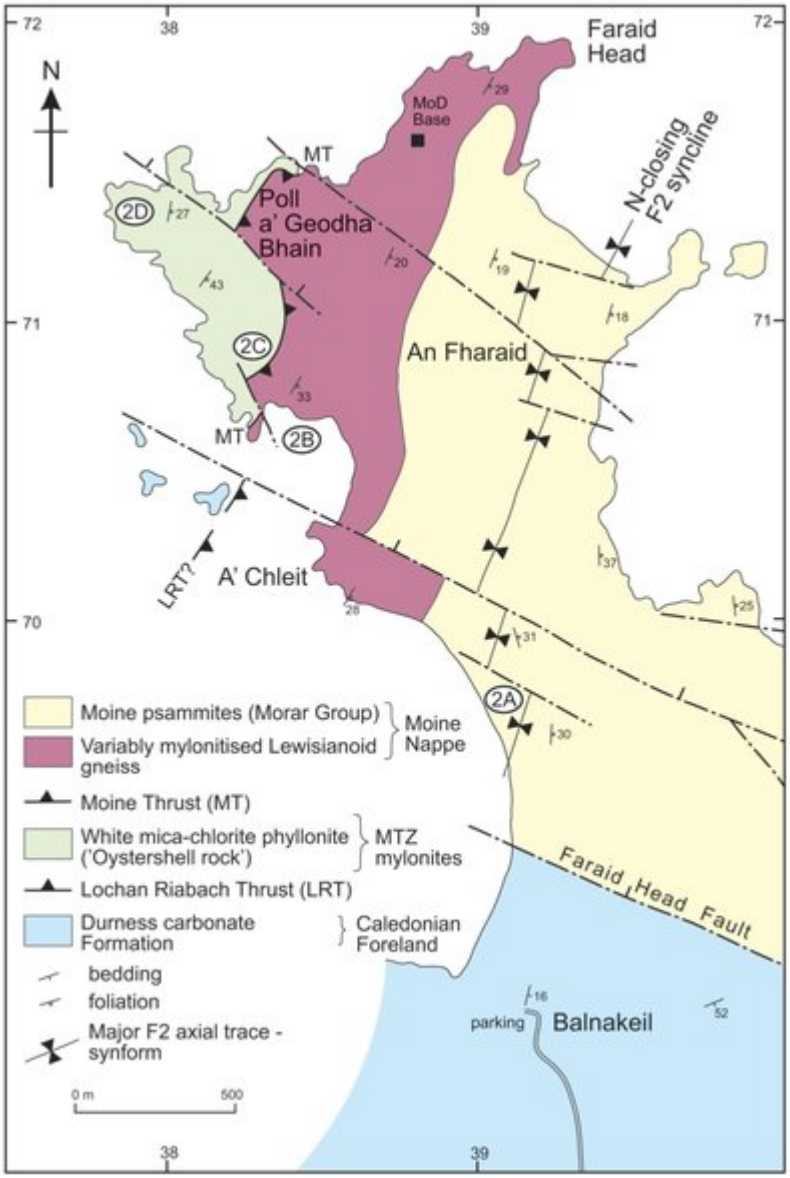
Return to the vehicles, noting the excellent views to the west of Cape Wrath, and to the south of the east-dipping Durness Limestone succession on the south side of Balnakeil Bay.

References



View from above Locality 12.1A, looking NW across the Durness outlier and towards the Faraid Head peninsula in the distance. Locations of Lewisianoid rocks of the Moine Nappe, Oystershell Rock (OSR), Lochan Riabhach Thrust (LRT) and the Faraid Head Fault (FHF) are also shown.

View of cliff at Locality 12.1E at NW end of Sango Bay, showing Moine Thrust Zone rocks Oystershell Rock (OSR), Cambrian quartzite (Cq), Lewisian (Lm) and Lochan Riabhach Thrust (LRT) directly overlying totally unmylonitized, autochthonous Durness Limestone (DL) in the uppermost part of the Caledonian foreland sequence.



Simplified geological map of north Sutherland together with the localities for the excursion. LL = Loch Loyal; LH = Loch Hope; MT = Moine Thrust; NT = Naver Thrust; ST = Swordly Thrust; TT = Torrisdale Thrust.