# Excursion 14 Durness, Balnakeil Bay and Faraid Head

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*Purpose:* To examine the carbonate rocks of the Durness Group and the faulted exposures of the Moine Thrust Sheet.

*Aspects covered:* Carbonate sedimentology and sequence stratigraphy, Cambro-Ordovician stratigraphy, Moine and basement-derived mylonites, Caledonian thrusts, and post-Caledonian faults.

*Maps:* OS: 1:50,000 Landranger sheet 15 Cape Wrath; 1:25,000 Explorer sheet 446 Durness and Cape Wrath. BGS: Scotland sheet 114W Loch Eriboll.

*Terrain:* Coastal paths and wave-cut platform.

*Time:* The main part of the excursion (Localities 14.1–14.13), around Balnakeil Bay, including Durness Group and Moine lithologies and Caledonian structures, will take a full day. The additional localities (14.14–14.18) can be visited separately, depending on the interests of the party. An alternative day is to combine Localities 14.1–14.10 with 14.14, 14.15 and 14.17; in this way a complete review of the foreland carbonates of the Durness Group can be undertaken in the type area, in ascending stratigraphic order.

*Access:* This excursion largely comprises coastal outcrops and no access problems are known. The first part of the excursion is adjacent to Durness golf course, and care should obviously be taken in this area. All the outcrops in this excursion lie in Sites of Scientific Interest, and thus hammering should be avoided.

## Excursion 14A: Balnakeil Bay and Faraid Head

In the centre of Durness village, turn left at Mackay's Hotel, signposted to Balnakeil. After 2 km Balnakeil Church is reached, where there is a public car-park. To the west are exposures of carbonates of the Durness Group, which will be visited first; to the north is the Faraid Head outlier of the Moine Thrust Sheet, which constitutes the second part of the excursion (Figure 90).

From the carpark, walk along the continuation of the road to the golf club and then walk west across the golf course to the head of a small bay to the east of Eilean Dubh, adjacent to the deserted village of Solmar [NC 735 686]. The beach sand at the head of the bay is a mixture of quartz sand and a typical foramol carbonate assemblage, with abundant bryozoa, calcareous algae and some forams.

The carbonates of the Durness Group contain a particularly diverse range of sedimentary rocks generated and/or mediated by bacteria (Figure 91). These are collectively termed microbialites and include stromatolites (with a laminated fabric), thrombolites (with a clotted mesofabric) and leiolites (internally structureless). Although sediments of this type originated in the Palaeoproterozoic, the Early Ordovician represents the final major flourish of this distinctive type of biogenic sediment. From the mid-Ordovician onwards, microbialites are restricted to a range of niche environments rather than constituting the dominant components of continent-scale sedimentary systems.

## Locality 14.1 Type sequence of the Eilean Dubh Formation. [NC 3762 6878]

The coast eastwards from the small bay exposes the upper part of the Eilean Dubh Formation (minimum exposed thickness 120 m . Walk northwards along the eastern edge of the bay, climbing over small ledges to the base of a small cliff [NC 3762 6878]. The Eilean Dubh Formation here comprises typical peritidal facies, with well-developed ripple and parallel lamination and flaser bedding overlying structureless microbial domes, indicating a muddy tidal flat environment. Thin beds and laminae of millet seed quartz sand and brown siliciclastic silts, of probable aeolian origin, punctuate the laminated facies. At the foot of the main cliff, *c.*5 m below the top, is a horizon containing distinctive gutter casts, with axes slightly less than perpendicular to the cliff face, which have been accentuated by compaction and pressure solution.

The orientation of these is consistent with them being developed perpendicular to the shoreface. Forty centimetres above the gutters is a distinctive flake conglomerate containing reworked intraclasts of local carbonate material that is overlain by hackly weathering, crinkly laminated microbialite (Figure 92). The development of metre-scale shallowing upwards units (parasequences) is here characterised by an alternation of stromatolites with a variety of microbial and current-laminated dolostones.

## Locality 14.2 Stromatolites in the Eilean Dubh Formation. [NC 3765 6879]

Return to the head of the bay and walk back along the cliff top to a point directly above the last locality. Spectacular 1–2 m wide domed and columnar stromatolites rest on top of a flake conglomerate and possible thrombolites that mark the base of the parasequence. The stromatolites are draped by fine-grained peritidal dolostones that cap the parasequence and contain ripple lamination, contorted lamination, laminae of millet seed sand grains and acicular cavities left after the dissolution of evaporates (Figure 93); there are also occasional halite pseudomorphs. Laminites above this horizon are contorted and contain well-developed tepee structures and irregular quartz nodules, the latter probably representing pseudomorphed anhydrite.

## Locality 14.3 [NC 3769 6880]

Walk east over rock ledges at a level a few metres beneath the base of the grass slope to the next locality. Locality 14.3 shows further details of microbialite–sediment relationships. A vuggy but otherwise structureless, microbialite mound is flanked by a breccia with angular clasts composed of peritidal laminites. Other mounds occur at the same horizon, some of which show faint stromatolitic lamination and irregular mottling. Beds composed of millet seed quartz grains drape the mound horizon and pass upward into peritidal dolostones with tepee structures. Farther eastwards, across a small fault that throws down to the north, is a spectacular flake conglomerate with large but relatively thin, red-weathering intraclasts. Mudstone intraclasts such as these result from desiccation and subsequent reworking during storm or flooding events on supratidal flats.

## Locality 14.4 Eilean Dubh–Sailmhor Formation boundary. [NC 3782 6878]

Walk up the grass bank and eastwards along the cliff top to the next promontory of pale grey Eilean Dubh Formation, immediately before a dark cliff farther to the east. Descend the steep grass bank with care and then walk across the wavecut platform to the foot of the black cliff. The upper Eilean Dubh Formation comprises pale grey weathering dolostones with ripple lamination; cherts preserve ooids, which must have been more common prior to diagenesis and dolomitisation of these sediments. The abrupt change from pale to dark dolostones at around 1 m above the base of the cliff marks the Eilean Dubh–Sailmhor formation boundary. Conodont collections (Huselbee, 1998) indicate that the Cambro-Ordovician boundary lies in the upper few metres of the Eilean Dubh Formation. The boundary marks a major facies change from peritidally dominated dolostones of the Eilean Dubh Formation to the dark, subtidal Sailmhor Formation. This coincides with a major eustatic shift that is seen globally at the base of the Ordovician, and in north-east Laurentia a similar transition is seen at the same level in North Greenland, East Greenland and Newfoundland.

## Locality 14.5 Face in Sailmhor Formation. [NC 3788 6881]

Return to the top of the cliff and walk around to a point directly above the last locality. Prominent pinnacles of dark Sailmhor Formation carbonates adorn the top of the cliff, and around 20 m farther east is a face with prominent white chert nodules. **BEWARE — there are deep shafts (blowholes) immediately in front of this face**.The cherts are laminated and pillow- or balloon-shaped (Figure 94), and lie in the depressions between large stromatolite domes. The dark host rock is distinctively mottled, and has often been informally termed 'leopard rock'. The origins of the mottling have been much debated and variously attributed to bioturbation, diagenetic artefact, or thrombolites. Although bioturbation with superficially similar patterns does occur in the Durness Group, it is not likely to be the cause here since burrow junctions are not seen on bedding surfaces. The mottling is here considered to be thrombolitic in origin, with each individual thrombolite body being rather biostromal or tabular in form, although a degree of diagenetic modification as a product of dolomitisation is recognised. Parasequences are well-developed, with biostromal thrombolites at the bases overlain by the large domal stromatolites. Increased sediment accommodation space at the base of the next parasequence, created by a rise in relative sea-level, is recorded by the small, chert-replaced columnar stromatolites that frequently occur on top of the domal forms.

Regain the coastal path and continue to walk eastwards to where a prominent deep geo lies on a fault plane. Inland, farther along the fault, a fenced-off blowhole is seen [NC 3813 6869]. The top of the blowhole reveals collapsed sections through the superficial deposits overlying the Sailmhor Formation; a thin till with clasts predominantly composed of Eriboll Formation quartz arenites and Lewisian Gneiss Complex lithologies is overlain by the base of the blown sand unit that dominates the landscape in Balnakeil Bay. Carry on eastwards along the coastal path across a bare landscape of winnowed tills with quartzite and gneiss clasts overlying fractured carbonates of the upper Sailmhor Formation. Continue until the cliff path ascends a marked change in slope, with a cairn to the left at the base of the slope. Leave the path and descend towards the sea, bearing right towards the foot of a cliff with a prominent notch at the base.

## Locality 14.6 Sailmhor–Sangomore Formation boundary. [NC 3836 6885]

The notch at the base of the cliff marks the Sailmhor–Sangomore Formation boundary (Figure 95). The uppermost part of the Sailmhor Formation contains coarsely crystalline dolostones, which in places contain preserved ooids (one well-preserved horizon lies 1.5 m below the top of the formation).

Abundant coast-parallel fractures that cross the upper Sailmhor Formation are deeply eroded by karstic weathering and commonly contain a partial fill of cemented beachrock. The fissures continue westwards across the bare ground and were mistaken as an intra-Ordovician unconformity by Palmer *et al*. (1980). The existence of the unconformity has been questioned on the basis of Sr isotope geochemistry (Nicholas 1994) and there is no evidence for a significant gap in the conodont record (RJR/MPS unpublished collections).

The formation boundary is marked by a distinctive dolostone bed that when hammered reveals only dolomite cleavage planes. However, close inspection of weathered surfaces reveals that the bed is a coarse- to very coarse-grained sandstone composed almost entirely of reworked clasts of dolomite. The base of the Sangomore Formation contains thrombolites and is paler weathering than the Sailmhor Formation; there are also thick chert beds in the lower few metres. It is not clear what criteria were used by Peach e*t* al*.* (1907) for differentiating the two units, though it was probably a combination of colour and the grain size of the dolomite. However, the colour contrast of the dolostones is not always reliable, and the colour of the cherts in the two units is a more distinctive character, with white cherts in the Sailmhor Formation abruptly giving way to orange-brown cherts in the Sangomore Formation.

Return to the cliff path via the cairn and follow the path to a gate. After passing through the gate, cut down to the left towards the cliff top.

## Locality 14.7 Sangomore Formation. [NC 3860 6886]

The locality illustrates typical lithologies in the Sangomore Formation. Peritidal laminites with possible quartz-pseudomorphed chicken-wire anhydrite nodules occur in an area of small faults. The parasequences comprise a thin, subtidal unit of peloidal grainstone and/or thrombolite overlain by a thicker peritidal succession of stromatolites, microbial laminites and ripple lamination.

## Locality 14.8 [NC 3864 6885]

Continue east along the cliff to the next small headland. Walk down a bedding plane ramp to the foot of the small cliff with pale/dark bedding alternations, which constitute well-developed parasequences. The bases of the parasequences are developed in dark burrow-mottled facies with very dark grey limestones containing silicified burrows. The parasequence tops comprise pale laminated dolostones, some of which have well-developed tepee structures. The bedding plane used for descent contains oncoids.

The uppermost bed, a dark parasequence base, forms a limestone pavement at the north-western tip of the distinctive horseshoe-shaped bay. The bed contains silicified burrows and a moderately abundant fauna of gastropods together with rare cephalopods.

## Locality 14.9 Sangomore–Balnakeil formation boundary. [NC 3887 6876]

Walk around the horseshoe bay to the final green of the golf course. Keep to the left of the green and descend the steep grassy slope to the wave-cut platform, then walk eastwards at the foot of the low cliff. This is still within the Sangomore Formation and at [NC 3883 6876] there are well-developed thrombolite heads with cherts lying between each head (Figure 96). Farther on, large structureless microbial bioherms are developed. Proceed to where a fence stops at the top of the low cliff, with wire stays attached to the dolostones. Just before the fence, the extensive microbialite facies are overlain by *c*.5 m of peritidal laminites, which are in turn overlain by a distinctive oncoidal pebble bed that marks the Sangomore–Balnakeil Formation boundary. The pebble bed is best seen close to the base of the stays that anchor the final fence post and can be traced from there onto the foreshore. The basal metre of the Balnakeil Formation also contains a series of erosional surfaces, dolostone breccias and chert breccias, and marks a major shallowing event that may correlate with the pebble bed horizon within the upper Boat Harbour Formation in western Newfoundland.

## Locality 14.10 [NC 3903 6872] Balnakeil Formation.

Proceed eastwards across darker microbialitic limestones of the Balnakeil Formation to a small bay and continue beyond the bay to a point around 30 m before the beach armour below the road begins, at the point where the road bends seawards and the beach becomes sandier.

Limestones typical of the Balnakeil Formation are present here, with large thrombolite domes draped by 'ribbon rock' lithofacies (centimetre-scale alternations of ripple laminated dolostone and darker siltstone). Good silicified burrows are present in places, but most commonly the burrow fills are dolomitised. The 'ribbon rock' lithofacies is characterised by the reworking of penecontemporaneously dolomitised burrow fills into parallel and ripple lamination. The lithofacies is considered indicative of a shallow subtidal depositional environment above storm wave base.

The overlying beds a few metres farther eastwards include large stromatolites with smaller conical 'egg-carton' forms on the top surface and a shallow channel filled with edgewise intraclast conglomerates.

Walk northwards across the beach, aiming for outcrops close to the track marked on the OS map.

## Locality 14.11 Moine psammites in the Faraid Head outlier. [NC 3925 6965]

At this locality there are exposures of Moine psammites that carry a strong mylonitic fabric, which dips shallowly to the ESE and is associated with a down-dip mineral and extension lineation. The mylonitic fabric is axial-planar to rare 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 10 cm. thick carry a quartz segregation fabric that is folded around the hinges of minor folds; garnets up to 7–8 m in diameter are strongly wrapped by the mylonitic fabric that is axial planar to these folds.

These outcrops are part of the Faraid Head outlier (Holdsworth *et al.*, 2007), a segment of the Moine Thrust Sheet that was down-faulted during the late Palaeozoic and/or the Mesozoic. These outcrops are of historical importance because Peach *et al.* (1907) were able to deduce from them a minimum displacement of *c*.15 km 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.

## Locality 14.12 Gneissic mylonites in the Faraid Head outlier. [NC 3855 7070]

Walk northwards to beach outcrops at [NC 3855 7070]. If the tide is high, good outcrops are also present nearby above the high-water mark. spectacular exposures here are of Lewisianoid 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 (Figure 97) 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, centimetre-scale, close to tight minor folds are present, plunging at low to moderate angles to the mineral lineation. Numerous quartz-chlorite veins are preserved; early types are concordant and mylonitic, later types cross-cutting, often in boudin necks, and little deformed. In more feldspathic units, mylonite is associated with pale yellow-green 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 (White *et al*., 1982). In places just above the high-water mark to the west, strain is less intense and the mylonites resemble more closely the Lewisianoid rocks that lie at the same structural level at Sango Sands (Locality 14.17). These basement mylonites are thus considered to have a Lewisianoid protolith; that is, they formed part of the basement to the Moine psammites.

Traverse inland to [NC 3825 7084], a series of crags composed of the Oystershell Rock just below the unexposed trace of the Moine Thrust. The Oystershell Rock is a mottled, dark grey-green, fine-grained phyllonite which is rich in chlorite and white mica; it is considered to be derived from a (foreland) Lewisian gneiss protolith (Holdsworth *et al*., 2001, 2007). The Moine Thrust has therefore been mapped at the boundary between the Lewisianoid basement mylonites and the Oystershell Rock. Gently-dipping Oystershell Rock includes numerous deformed quartz veins; a strong lineation plunges to the ESE. Pervasive shear bands and 10 cm. scale shear zones again indicate a top-to-the-WNW sense of displacement (Figure 98). The Oystershell Rock is notable here for the presence of 10–15 cm. thick bands of brown-weathering marble that are continuous for several metres in some cases. $F_3$S-folds of the mylonite fabric verge north-west to north, and hinges are markedly curvilinear, plunging between the north-east and east; eye-structures consistent with sheath fold development are locally present. A 10 cm. thick east–west-trending, steeply-dipping basic dyke of possible Permo-Carboniferous age cross-cuts the upper part of these crags at [NC 3828 7093].

### Locality 14.13 [NC 3785 7135] Moine Thrust viewpoint.

Walk 700 m north-west across the raised beach, in which isolated crags of Oystershell Rock are exposed, until the far end of the headland is reached at [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 hangingwall from more uniform dark-green-grey Oyster-shell Rock in the footwall (Figure 99).

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

## Excursion 14B: additional localities

### Locality 14.14 The Croisaphuill Formation at Loch Borralie. [NC 384 670]

The upper part of the Durness Group is not visible in Balnakeil Bay, and the Croisaphuill Formation, which overlies the Balnakeil Formation, is best examined on the east side of Loch Borralie. Park at the Cape Wrath Hotel [NC 380 662] and cross the field to the north, towards Loch Borralie. Proceed along the eastern side of the lake, crossing the end of one wall that descends to the loch, until a second wall in poorer repair is met where the strait between island and shore is at its narrowest [NC 3844 6709]. This point is very close to the base of the Croisaphuill Formation, which extends down-dip for over half a kilometre to the east.

The lower part of the Croisaphuill Formation comprises burrow-mottled limestones with abundant brown cherts. The burrow fills were penecontemporaneously dolomitised (Morrow, 1978), and in places evidence of this can be seen where dolomite burrow-fills are reworked into parallel and ripple lamination (as in the ribbon-rock lithofacies of the Balnakeil Formation). Following the wall up to the cairned summit of the small hill provides a discontinuous but representative section through the lower 90 m of the formation. Cherts become less abundant, but otherwise this part of the Croisaphuill Formation is remarkably uniform. This is the most macrofossil rich part of the Durness Group, and close searching will reveal a variety of dolomitised and silicified gastropods, several species of the silicified snail operculum Ceratope*a* and a moderately diverse cephalopod fauna, including both coiled and orthoconic forms. Conodonts indicate that the unit is of basal Arenig age, and the base of the formation marks a major shift away from the microbially dominated Middle Cambrian–Tremadocian part of the group. This change in depositional architecture was caused by a eustatic rise in sea-level that flooded most of Laurentia and which constitutes one of the highest sea-level stands in the Phanerozoic.

There are excellent views from the summit cairn of the down-faulted outlier of Durness Group that constitutes the east side of the Kyle of Durness, surrounded by Precambrian and Lower Cambrian rock units.

## Locality 14.15 Smoo Cave. [NC 418 671]

Smoo Cave, a short distance east of the main village of Durness, is well signposted and has a small car-park. Walk eastwards from the car-park through the picnic area and down the slope to a series of swallow holes. At the top of the opposite slope, turn left at the T-junction and turn northwards along the cliff top on the east side of Smoo inlet. The path doubles back and descends into the inlet, affording an excellent view of the large entrance (approximately 40 m wide and 15 m high) – the cave results from the interaction of coastal processes with a karst drainage system. At the rear of the entrance chamber is a large fan of vegetated flowstone (undated) and there is some flowstone on the walls. A covered walkway leads to a second chamber where Allt Smoo descends a shaft into a large pool. Boat trips into a third chamber are sporadically available.

The accessible part of Smoo Cave is developed entirely within the Sangomore Formation, but the inlet shows good sections across the Sailmhor–Sangomore formation boundary (Figure 100). Two prominent chert bands run down the length of the inlet, offset half-way down by a small fault, and the formation boundary lies 3 metres above the base of the lower chert. The upper part of the Sailmhor Formation comprises a series of parasequences that consist of dark, burrow-mottled subtidal carbonates overlain by thin, pale, laminated peritidal carbonates. The shallowing-upward parasequences form part of a classical, lower order, shallowing upward succession in which the subtidal portions of the parasequences progressively thin upwards, and there is a concomitant decrease in the subtidal-peritidal balance of each parasequence. This aspect is clearly illustrated from a distance by the proportion of dark subtidal to pale peritidal carbonate. A closer view of these parasequences can be safely gained by following the cliff top path to the end of the inlet on the northern side.

## Locality 14.16 [NC 4100 6740] Sangobeg Fault.

Park at the Tourist Information Centre in Durness [NC 4070 6775] overlooking Sango Sands. From the car-park, view the steep wall of Durness Group dolostone *c*.400 m to the SE; this lies along the Sangobeg Fault, one of the main bounding normal faults of the Durness outlier of the Moine Thrust Sheet (Holdsworth *et al*., 2006). Walk *c*.300 m east along the road to roadside exposures in the Durness Group at [NC 4100 6740], which lie in the immediate footwall of the Sangobeg 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 (Figure 101). The sedimentary material – which is most likely to be of Permo-Triassic age – 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. Clast types are mainly Durness Group, but isolated examples of mylonite and Cambrian quartz arenite are also preserved (see Wilson *et al.*, 2010 for details).

## Locality 14.17 Sango Bay. [NC 4080 6770] to [NC 4070 6800]

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, which comprises outcrops of banded quartzo-feldspathic and amphibolitic Lewisianoid basement gneisses. These are thought to lie close to the base of the Moine Thrust Sheet (Holdsworth *et al.*, 2006). 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 in the central part of the bay of a green chlorite phyllonite. These phyllonites are correlated with the 'Oyster-shell Rock' identified within the mylonite belt of the Moine Thrust Zone at Loch Eriboll (see Localities 14.12–14.13, and Excursion 15). 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 lenticular quartz-bearing layers.

Walk towards the rocky headland at the north-western limit of the beach. 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 recrystallised dolostone of the Durine Formation, the youngest unit of the Durness Group. This is separated by a gently-inclined thrust from a 2–3 m thick slice of quartz mylonite, which is itself overlain by another thrust above which is a more coherently laminated group of mylonites (derived from both the Oystershell Rock and, locally, Lewisian gneiss). Walk up onto the headland to examine these thrust contacts in detail, and then follow them around to the west into the next bay. Note that the continuity of the thrust contacts is very much disrupted by the effects of later carbonate veining, located mainly in the footwall of the lowermost thrust, and also due to offsets along numerous, steeply-dipping normal faults (Hippler and Knipe 1990; Holdsworth *et al.*, 2006). 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.

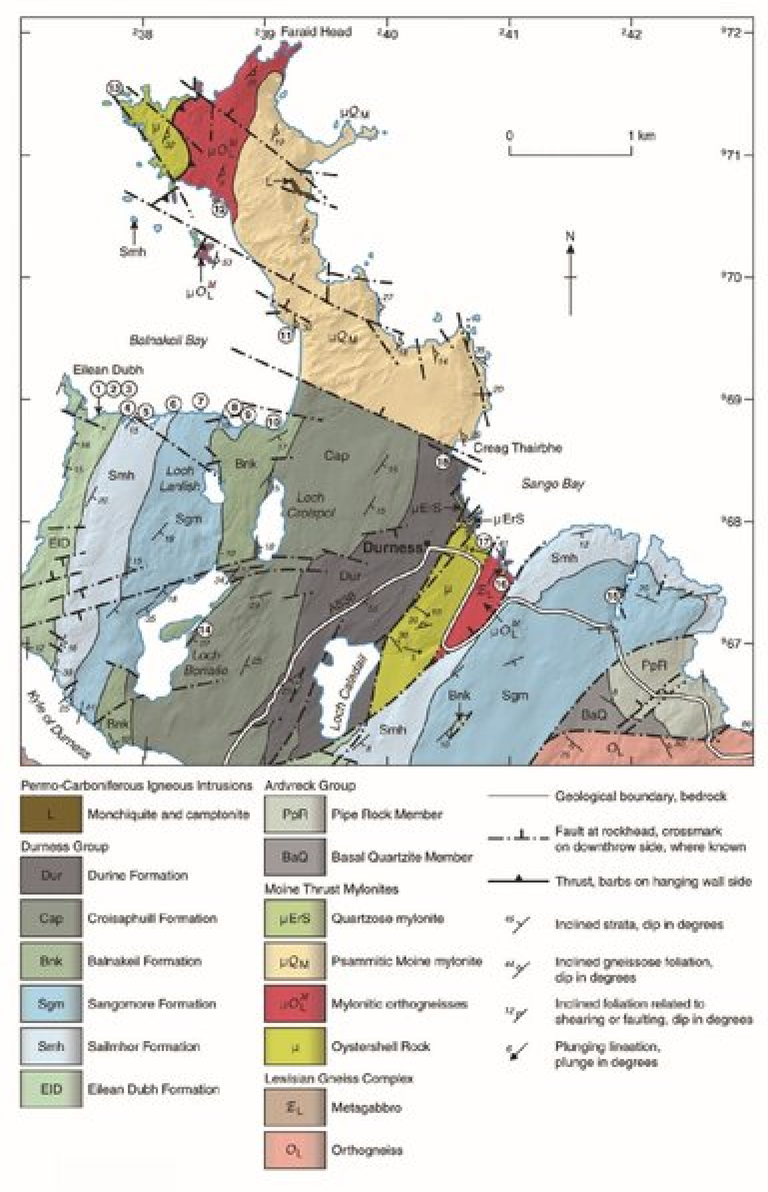
One interpretation of these outcrops is that the lowermost thrust corresponds to the Lochan Riabhach Thrust, which was thought by Holdsworth *et al.* (2006) to underlie the mylonite belt at Loch Eriboll (see Excursion 15) and interpreted by them as a separate structure from the Moine Thrust, which is exposed at a higher structural level at Faraid Head (see above). The alternative view is that the lowermost thrust does in fact correspond to the Moine Thrust (Peach *et al.*, 1907; Butler 2009).

## Locality 14.18 Creag Thairbhe. [NC 4040 6850]

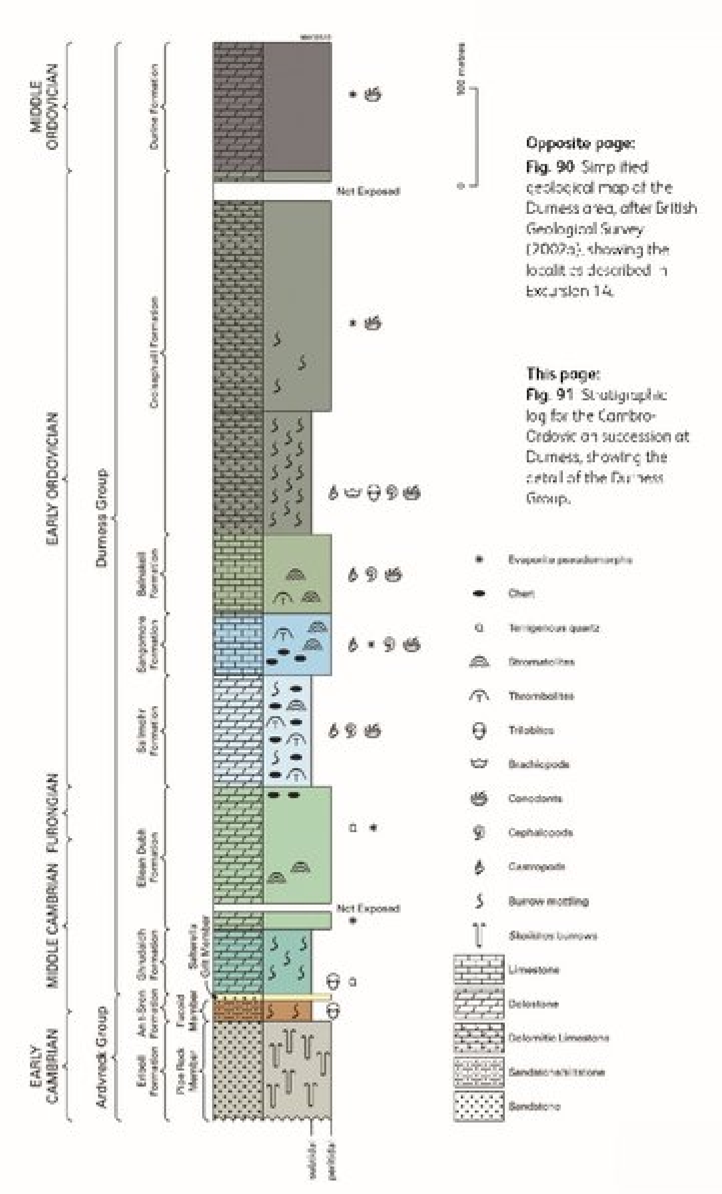
Return to the top of the cliff and, following the fence, walk approximately 500 m north-west along the cliffs of Durness Group towards the cliffs extending inland from Creag Thairbhe [NC 4040 6850]. The steep cliffs here define the trend of the WNW–ENE-trending Faraid Head Fault that down-faults the main Faraid Head outlier of Moine rocks and the Moine Thrust Zone mylonites that outcrop to the north (Holdsworth *et al.*, 2007; Wilson *et al.*, 2010). Most of the cliff comprises variably brecciated carbonate, 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 14.13, 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 Durness Group carbonates, but clasts of Moine psammite, mylonitized Lewisian gneiss and quartzite mylonite are also present. At least two units of infill are recognised based on differences in grain-size and sorting.

The ages of the sedimentary infills at Localities 14.13 and 14.15 – and hence the age of extension – are uncertain, but a 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 (see Wilson *et al.*, 2010, and references therein). Detailed studies of the normal faulting along the north coast in the Durness–Cape Wrath area (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.

[References](#)




*(Figure 90) Simplified geological map of the Durness area, after British Geological Survey (2002a), showing the localities described in Excursion 14.*




(Figure 91) Stratigraphic log for the Cambro-Ordovician succession at Durness, showing the detail of the Durness Group.


*(Figure 92) Flake conglomerate comprising reworked intraclasts of local carbonates within the Eilean Dubh Formation at Locality 14.1, [NC 376 687]. The brown weathering of the clasts indicates a component of detrital quartz silt within the early cemented carbonates, derived from supratidal flat facies. (Photograph: © R. J. Raine)*

(Figure 93) Cavities formed from the dissolution of evaporite pseudomorphs in Eilean Dubh Formation dolostone [NC 376 687]. The euhedral crystal shape indicates that the mineral was originally gypsum or anhydrite, but the cavities are now filled with non-ferroan calcite in unweathered material. (Photograph: © R. J. Raine)

*(Figure 94) Dark grey dolostones of the Sailmhor Formation at Locality 14.5 [NC 3788 6881]. The 1m yellow rule marks the boundary between two shallowing upward parasequences. The lower part comprises lighter grey, finer grained intertidal dolostones with domal stromatolites, commonly with prominent cherts between stromatolite mounds; the cherts preserve stromatolite laminae as pale–dark alternations. Above the rule, darker subtidal dolostones show characteristic 'leopard rock' texture. (Photograph: © M. P. Smith)*

(Figure 95) View of the Sailmhor–Sangomore formation boundary at Locality 14.6 [NC 3836 6885], looking NE towards the head of Balnakeil Bay. The formation boundary occurs at the prominent notch, which contains a distinctive sandstone composed entirely of reworked dolomite crystals. The overlying Sangomore Formation is characterised by being paler than the Sailmhor Formation and by the presence of orange-brown cherts and chert breccias. (Photograph: © M. P. Smith)

*(Figure 96) Columnar branching thrombolite–stromatolite interactions forming small bun-shaped mounds at the base of the figure. With continued growth, these coalesced to form an over-arching large stromatolite with crinkly lamination, reflecting the control of microbialite growth by sediment supply and relative sea-level. Uppermost Sangomore Formation, Locality 14.9 [NC 3887 6876]. (Photograph: © M. P. Smith)*

(Figure 97) Typical acid Lewisianoid mylonite in the Faraid Head outlier, with asymmetric S-C fabrics giving top-to-the-WNW (left) senses of shear consistent with Caledonian thrusting. Note the asymmetric sigma-shaped wrap-ping of the pegmatitic pod in the centre of the image. Viewed looking to the NNE, in a vertical section sub-parallel to the mineral lineation, Locality 14.12. (Photograph: © R. E. Holdsworth)

(Figure 98) Flat lying shear bands cutting ESE-dipping mylonitic foliation in chlorite-muscovite phyllonite unit (Oyster-shell Rock). Consistent with top-to-the-WNW (left) Caledonian thrusting. Viewed in vertical face looking NNE, Locality 14.12. (Photograph: © R. E. Holdsworth)


(Figure 99) View east towards the cliffs of Poll a' Geodha Bhain from Locality 14.13, showing the ductile Moine Thrust separating striped Lewisianoid mylonites in the hangingwall from dark green Oystershell Rock in the footwall.

(Photograph: © R. E. Holdsworth)

(Figure 100) A stack of shallowing upward parasequences in the upper Sailmhor Formation at Pocan Smoo, Locality 14.15. Within each parasequence there is a thick dark grey subtidal base overlain by a thin lighter grey peritidal cap. The Sailmhor– Sangomore formation boundary is marked by the prominent white chert at the cliff top, adjacent to the fence. (Photograph: © M. P. Smith) Locality 14.3 [NC 3769 6880]

(Figure 101) Roadside exposure of sub-vertical carbonate-cemented red breccia-sandstone (?Permo-Trias) and white carbonate vein infill of cavity in Durness Group dolostone oriented parallel to the Sangobeg Fault, Locality 14.16. View looking north. (Photograph: © R. E. Holdsworth)