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## Excursion 6 Knockan Crag and the Knockan Klippen

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*Purpose:* To study the late, brittle Moine Thrust, where rocks of the Moine Supergroup are brought almost directly above undisturbed Cambro-Ordovician sedimentary rocks, and to see the Moine mylonites. The second part of the excursion looks at the relationships between the Moine Thrust and klippen of underlying thrusts.

*Aspects covered:* The Cambro-Ordovician sedimentary sequence, thrust geometries and mylonites.

*Maps:* OS: 1:50,000 Landranger sheet 15 Loch Assynt; 1:25,000 Explorer sheet 439 Coigach and Summer Isles. BGS: 1:50,000 special sheet, Assynt district.

*Terrain:* The first part of the excursion concentrates on Knockan Crag, the location of a SNH visitor centre and walking trail. The excursion follows a short circular route from the Knockan Crag car-park, along a well-built path, the lower part of which is suitable for wheelchairs. The Knockan Crag visitor centre is targeted at the general public and provides some interesting exhibits. The second part of the excursion involves a walk over open moorland, much of which is rather boggy. Up to 100 m of ascent on rough ground is involved and, in poor weather, careful navigation may be required.

*Time:* First part of the excursion, the trail at Knockan Crag, will occupy most groups for 1–2 hours. The second part of the excursion requires around half a day.

*Access:* The Knockan Crag trail is open to visitors all year round. The second part of the excursion crosses crofted land; it is important that parked vehicles in this area do not block gates or tracks, and that all gates are left as they are found. Dogs should be kept firmly under control, or ideally left at home. Knockan Crag is a National Nature Reserve and there should be no hammering or sampling at outcrops in this excursion.

### Excursion 6a: Knockan Crag

#### Locality 6.1 Knockan Crag visitor centre and Moine Thrust trail. [NC 188 092]

Park in the Knockan Crag car-park, which has toilet facilities, and follow the waymarked trail to the visitor centre. The trail starts with the 'Knockan Puzzle', a wall illustrating all the rock-types of the Assynt region. The puzzle is, of course, how the metamorphosed, Proterozoic Moine psammites have come to lie on top of the younger, unmetamorphosed, Cambro-Ordovician sedimentary rocks. Continue along the trail as it passes through the small SNH visitor centre, which is always open.

The lowest exposures on the trail above the visitor centre are good outcrops of the orange-brown weathering Furoid Beds Member in a small quarry (Figure 47). Boulders of Pipe Rock are on display here, but the best outcrops of this rock-type occur lower down the slope, in the road cut by the car-park entrance. The Furoid Beds are followed in upward sequence by thin layers of the Salterella Grit Member, which can be seen where the trail crosses a small bridge. Just above here, in a mossy waterfall, the Furoid Beds are repeated by a minor thrust.

The trail continues upwards to the Moine Thrust plane, a striking feature at which dark-grey, fractured Moine mylonites rest on top of brecciated, buff-coloured dolostones of the Eilean Dubh Formation (Figure 48). Steps have been built up to allow visitors to 'bridge' the thrust with their hands; continuing a few metres along the trail from this point actually allows access to a better exposure of the thrust. The thrust forms a clear plane, which is inclined towards the south-east at an angle of 8–10°. A thin breccia, containing fragments of mylonite, occurs along the thrust.

Although the Moine Thrust here at Knockan is a very clear plane, it actually only represents the last part of a complex sequence of deformation. The Moine Thrust was initiated as a ductile structure, which formed the mylonites in the cliff.

However, the thrust that is seen here is a later, brittle fault. Evidence for this comes from the intense fracturing of the mylonites and from the presence of breccia, and locally fault gouge, along the thrust plane, which formed during the late-stage movements. The exact nature of the late, brittle movement is rather uncertain. Coward (1985) argued that the brittle movement was related to extensional movement as the thrust pile collapsed. An alternative explanation is that the brittle movement is simply the latest part of progressively colder and shallower level movements in the thrust zone. The ductile and brittle movements at Knockan would all work along the same plane, whereas in the Assynt Culmination the movements were partitioned along different thrust planes. Freeman *et al.* (1998) have suggested that ductile deformation on the Moine Thrust at Knockan ended at c.430 Ma (latest Llandovery, early Silurian).

## **Locality 6.2 Viewpoint at top of Knockan Crag. [NC 194 094]**

From the thrust plane exposures, follow the trail northwards up onto the top of the crag where mylonites are well-exposed, and take a short spur off to a viewpoint on the left. On a fine day there is a wonderful view from here of the peaks to the west, with Cùl Beag and Cùl Mòr prominent in the foreground and Stac Pollaidh protruding beyond. Canisp and Suilven can also be clearly seen to the north-west. The double unconformity, with pale grey quartzites of the Eriboll Formation overstepping well-layered Torridon Group sandstones which lie on hummocky Lewisian gneisses, can be seen particularly well on the slopes of Cùl Mòr and Canisp.

To the north, the view extends across Cam Loch to the peaks of Conival and Ben More Assynt beyond (Figure 49). The quartzite-dominated Breabag Dome lies in front of Ben More Assynt. In the foreground, immediately in front of the viewpoint, are peat hags with scattered outcrops of Moine mylonite. Beyond these is a green, grassy knoll with outcrops of pale grey dolostone of the Eilean Dubh Formation. The Moine Thrust runs between these two contrasting areas of ground.

## **Locality 6.3 Eagle Rock. [NC 188 086]**

Continue southwards along the cliff-top path over exposures of finely banded, grey-weathering Moine mylonites. It is worthwhile taking the short detour to Eagle Rock, where particularly good mylonite exposures can be seen in the low cliffs (Figure 50). With careful examination of faces parallel to the ESE–WNW transport direction, shear-sense indicators can be seen in the mylonites. After studying the outcrops, return from here along the path to the car-park.

## **Excursion 6b: The klippen at Knockan**

Drive some two kilometres north-east from Knockan Crag to the hamlet of Knockan, and park in a large lay-by on the left of the road [NC 212 106]. Walk about a hundred metres south-east along the road, and then follow a narrow tarred road towards the east, passing some crofts. At a sharp bend, go through a gate and continue for about 500 m along a track that runs south-east across grazing lands. Where the track crosses a small stream, leave the track and follow the stream in a south-easterly direction to a low hill, Cnoc a'Choilich Mhor [NC 2056 0962].

## **Locality 6.4 Cnoc a'Choilich Mhor Klippe. [NC 2056 0962]**

The low hill of Cnoc a'Choilich Mhor is composed of quartz arenites of the Eriboll Formation (mainly Pipe Rock Member, although pipes can be difficult to find). These outcrops represent a small klippe of a thrust, which carries the Eriboll Formation over the imbricated Durness Group carbonate that underlies all the surrounding low ground to the north and east. The carbonates in this area are characterised by the presence of sink holes.

From here, walk in a WSW direction towards a stream valley south of Druim Poll Eòghainn, passing outcrops of Eilean Dubh Formation dolostones. Variations in the dip of the dolostones indicate that they are part of an imbricate stack, known as the Elphin imbricates.

## **Locality 6.5 Moine Thrust exposures. [NC 200 093] to [NC 204 094]**

The east-west stream section here follows the Moine Thrust, and the thrust can be studied at several places in the stream valley. At [NC 201 094], easterly dipping beds of Eilean Dubh Formation dolostone form the bed of the burn, and are overlain by mylonites which are well exposed in a low cliff (Figure 51). The thrust plane itself is not actually exposed, but the ground immediately above the stream contains some excellent outcrops in which small-scale structures associated with the Moine Thrust can be seen. The mylonites commonly contain strung-out quartz ribbons, and close to the thrust the mylonitic fabric is locally overprinted by a fracture cleavage or dense fracturing (e.g. at [NC 2069 0927]). The dolostones close to the thrust are fractured and locally show incipient brecciation. The fabric in the mylonitic Moine psammite dips south here and strikes parallel to the outcrop of the (brittle) Moine Thrust itself. This shows that the later, brittle Moine Thrust does not cross-cut the ductile, mylonitic Moine Thrust (cf. Coward, 1985).

## **Locality 6.6 Uamh an Tartair Klippe. [NC 213 092] to [NC 217 092]**

From the thrust exposures, walk eastwards to the prominent right-angle bend in the Abhainn a'Chnocain (the Knockan Burn) at [NC 213 092]. Here the outcrops change from carbonate into quartz arenite as the unexposed Uamh an Tartair thrust is crossed. At [NC 2153 0911] Basal Quartzite Member can be recognised within the Uamh an Tartair Klippe. The Moine Thrust occurs only just to the south and must decapitate this klippe.

Continue along the stream to the east to [NC 2164 0912], taking great care as you approach an abrupt small gorge and a large sinkhole, which betray the presence of Durness Group carbonate, lying beneath the thrust.

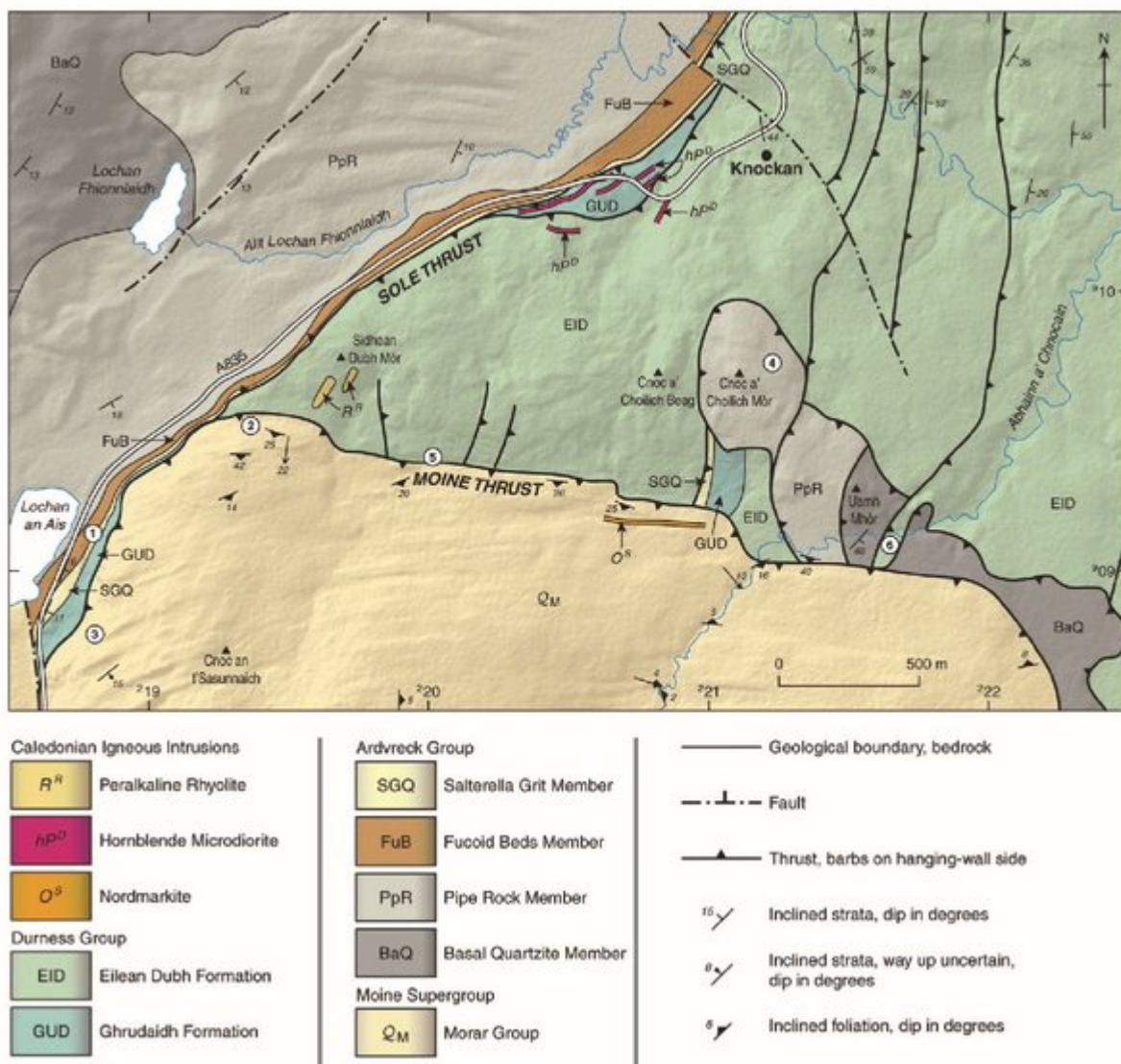
However, the small hillock 50 m to the east is again composed of quartz arenite. Several explanations, including normal faulting, could explain this apparent repetition of the thrust. However, on the south side of the stream it can be demonstrated that the carbonate overlies the Basal Quartzite Member to the west (i.e. young over old). This arrangement is best explained by breaching, in that a thrust within the underlying carbonate breached the Uamh an Tartair Thrust and emplaced carbonate over quartz arenite.

The overall sequence of events that can be established from Localities 6.4–6.6 is as follows:

- (1) Ductile movement along the Moine Thrust, forming mylonitic fabric;
- (2) Movement along the Uamh an Tartair Thrust, emplacing quartz arenite over Durness Group carbonate;
- (3) Imbrication within the Durness Group carbonate, forming the Elphin imbricates, with some thrusts breaching the overlying Uamh an Tartair Thrust;
- (4) Decapitation of the Uamh an Tartair Thrust Sheet and the breaching thrusts by the (reactivated) brittle Moine Thrust.

From Uamh an Tartair it is best to go north, passing two large sinkholes along the way, to pick up the track back to Knockan and the main road.

## **[References](#)**



(Figure 47) Simplified geological map of the Knockan area, after British Geological Survey (2007), showing the localities described in Excursion 6.





*(Figure 48) The Moine Thrust at Knockan Crag, placing Moine mylonites over fractured dolostones of the Eilean Dubh Formation. (BGS photograph P531955, © NERC)*



*(Figure 49) View north over the Assynt Culmination from the top of Knockan Crag (Locality 6.2). In the foreground, pale grey dolostones of the Eilean Dubh Formation lie immediately beneath the Moine Thrust. In the distance are the prominent quartzite ridges of Conival, Ben More Assynt and Breabag. (BGS photograph P667671, © NERC)*





*(Figure 50) Moine mylonites at Eagle Rock, Locality 6.3. (BGS photograph P512960, © NERC)*



*(Figure 51) The Moine Thrust in the area of Locality 6.5, with Moine mylonites resting on dolostones of the Eilean Dubh Formation. (BGS photograph P537568, © NERC)*