Knockan Crag

[NC 186 083]–[NC 221 093]

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Introduction

For much of its outcrop length from Loch Eriboll to Skye, the basal contact of the Moine Thrust Sheet is poorly exposed. A glorious exception to this is found in the Knockan area, at a GCR site that is particularly fortunate in being very easily accessible from the road between Inchnadamph and Ullapool. Here, mylonites derived from metasedimentary rocks of the Moine Supergroup overlie carbonate rocks of the Durness Group (Figure 5.34). The section at Knockan Crag is deceptive in that it displays an apparently simple upward progression through the foreland Cambro–Ordovician strata into the apparently conformable Moine (Figure 5.35). Indeed it was critical for the old Murchison doctrine of stratigraphical continuity between the Cambrian and the Moine (Murchison and Geikie, 1861). However, following work at Eriboll, the basal Moine contact at Knockan Crag was recognized as being a thrust (Callaway, 1883). For the Geological Survey (Peach *et al.,* 1907) the Knockan area was important in defining the relationship between the major thrusts and the subsidiary imbricate zones. For them the overstepping of the imbricate zones by the Moine Thrust was clear evidence that this structure was the last to form in this area, a conclusion they transferred to the whole Moine Thrust Belt.

Since the 19th century the Knockan Crag GCR site has become one of the most visited localities of the Moine Thrust Belt and has gained international recognition (MacGregor and Phemister, 1948; Johnson and Parsons, 1979; McClay and Coward, 1981). It is now one of few sites in Britain, or indeed in Europe, with a purpose-built visitor centre and waymarked trail dedicated almost exclusively to the geology. The structural interpretations described in the Geological Survey memoir (Peach *et al.,* 1907) were largely unquestioned until the work of Elliott and Johnson (1980). They interpreted the overstep relationship as forming a roof to a duplex below the Moine mylonites, and inferred that the Moine Thrust moved first, with imbrication of the underlying Durness Group happening later. This prompted a programme of remapping by Coward (1985) and the definition of two types of Moine Thrust in southern Assynt. For the most part the Moine Thrust can be shown to be folded and to be cut by underlying thrusts, observations consistent with the hypothesis of Elliott and Johnson (1980). However, at Knockan the Moine Thrust clearly truncates the underlying structures, as described by Peach *et al.* (1907), so that here it is undoubtedly a late structure.

Description

The Knockan Crag GCR site contains four different structural units: the foreland Cambrian strata (Pipe Rock, Fucoid Beds and Salterella Grit members); imbricated Durness Group carbonate rocks and pre-tectonic microsyenite sills; the Uamh Mhòr Klippe of Cambrian quartzites; and the Moine Thrust Sheet (Figure 5.35). At Knockan Crag the Moine lies directly upon Durness Group carbonate rocks that form the upper part of the foreland succession (Figure 5.36). Indeed, the Moine Thrust alone represents the entire thrust belt here. Within a few metres of the thrust, carbonate rocks of the Durness Group are sheared and cut by cataclastic seams and veins, although deformation structures are absent below. In contrast, the overlying Moine is dominated by crystal-plastic deformation mechanisms as displayed by a tract of mylonites over 100 m thick. Within about 1–2m of the thrust surface the mylonites are brecciated and re-cemented by a green-grey, fine-grained phyllonitic gouge. These cataclastic fault rocks are themselves foliated, possibly implying a return to ductile shearing, within a few centimetres of the thrust surface. The thrust surface is sharp, marked by a few centimetres of dominantly carbonate gouge. It is the ready weathering of the gouge that results in the sharply incut expression of the fault surface at Knockan Crag.

The Moine Thrust can be traced eastwards from Knockan Crag around to the stream section (Figure 5.35) that runs down to the swallow hole of Poll Eoghainn [NC 206 094]. The mylonitic foliation in the Moine rocks is generally concordant with the thrust plane, dipping gently southwards but containing an intense ESE-plunging mineral lineation. Bedding in the carbonate rocks of the Eilean Dubh Formation in the footwall dips eastwards. The values of dip are highly

variable, and the stratigraphical succession, together with pre-tectonic micro-syenite sills, is repeated on E-dipping imbricate thrusts. For the most part these thrusts presumably climb up from a floor thrust lying along the base of the Durness Group. Certainly the underlying An t-Sron Formation units are not imbricated in the cliff section above the A835 [NC 196 099]. However, Salterella Grit is found within the imbricate slices farther east, at the sinkhole at Poll Eoghainn, implying that towards the hinterland the floor thrust lies within this unit (Figure 5.35). Bedding in the Eilean Dubh Formation seen in the stream section at [NC 201 094] is highly discordant to the Moine Thrust, strongly suggesting that the Moine Thrust truncates the imbricate zones in its foot-wall.

The imbricated Durness Group carbonate rocks are overlain tectonically by Cambrian quartzites of the Uamh Mhòr Klippe. The contact is commonly correlated with the Ben More Thrust (e.g. Johnson and Parsons, 1979), although this is rather uncertain. Consequently it is termed here the 'Uamh Mhòr Thrust'. At the sinkhole which lends its name to the klippe [NC 217 092] and the adjacent cave (Uamh an Tartair), the carbonate rocks in the footwall to the Uamh Mhòr Thrust are exposed in the core of an antiform, wrapped by quartzites of the klippe. The ridge to the north-west (Cnoc a' Choilich Mor, [NC 211 097]) consists of imbricated Pipe Rock and False-bedded Quartzite members. Bedding within these imbricate slices is oblique to, and presumably truncated by, the Uamh Mhòr Thrust. In contrast, bedding within the carbonate rocks in its footwall here lie generally parallel to the thrust. These relationships are well exposed at the ESE margin of the klippe, at the rising of the Abhainn a' Chnocain [NC 217 091]. The relationships (Figure 5.35) suggest that the thrust carrying the klippe postdates the overlying imbricate zones but predates those in its footwall.

The relationship between the klippe and the Moine Thrust is less clear, as the critical ground on the southern bank of the Abhainn a' Chnocain is very poorly exposed. However, there is no indication of folding within the Moine mylonites, which might be expected if the Moine Thrust pre-dated the klippe. As the Moine Thrust here truncates the imbricate zones within the Durness Group, which themselves appear to post-date the klippe, it is likely that the Moine Thrust also post-dates, and hence truncates, the klippe.

Interpretation

Although the main units at Knockan Crag are readily seen and interpreted, there has been controversy over their relationships, particularly with respect to the implied sequence of thrusting. Much of the controversy arises from attempts to reach a unified explanation of thrust sequences for the entire thrust belt. The field relationships at Knockan Crag seem clear. The Moine Thrust clearly truncates the imbricate zones in the Durness Group of its footwall, as seen in the stream section some 2 km east of Knockan Crag. The relationships of the Moine Thrust to the Uamh Mhòr Thrust and to the imbricate zones, both in its hangingwall and footwall, are less obvious. On balance it is likely that the Uamh Mhòr Thrust cut through a previously developed imbricate stack of Cambrian quartzites, carrying the upper portions of this stack onto undeformed carbonate rocks of the Durness Group. These carbonate rocks were then imbricated, folding the klippe, before the Moine Thrust truncated the composite structure.

The above structural history is rather more complex than that of Elliott and Johnson (1980). Coward (1985) interpreted the discordant relationship between bedding in the quartzites and the mapped margins of the Uamh Mhòr Klippe as due to a combination of thrusting and extensional faulting. As these inferred extensional faults do not offset the trace of the Moine Thrust but do offset some other thrust structures, he deduced that extensional and compressional tectonics operated broadly together. As such, the model is similar to the one he proposed for the Stack of Glencoul (see Glencoul GCR site report, this chapter). However, at Knockan Crag the field relationships are not as clear, and the widespread development of extensional faults within this part of the thrust belt remains somewhat speculative.

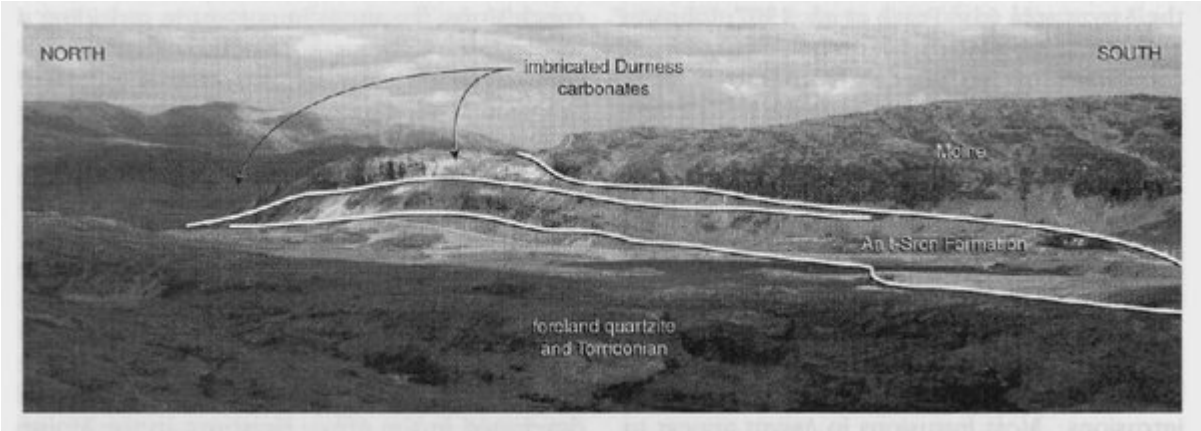
Conclusions

The Knockan Crag GCR site is one of the finest places, and certainly the most accessible, to view the Moine Thrust and examine it at close quarters. The visitor centre and waymarked trail highlight its national and international importance. Although it has traditionally been visited because of its historical interest, it is also the best place to establish unequivocally that locally the Moine Thrust post-dates structures developed in its footwall, and hence it remains a critical part of the Moine Thrust Belt. This 'transgressive' nature for the Moine Thrust raises important issues about the

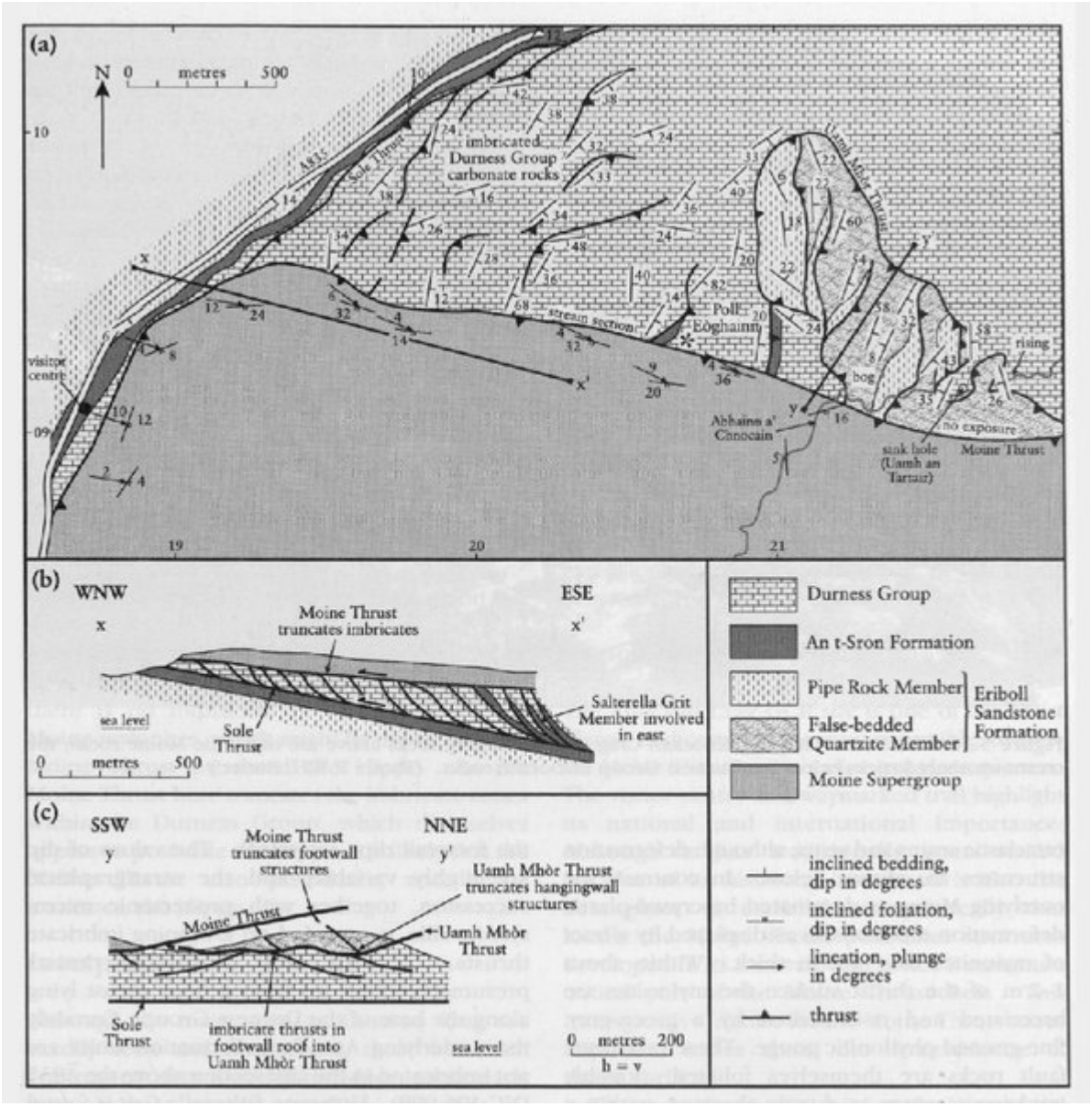
nomenclature of thrust surfaces.

The tectonic discontinuity at the base of the Moine Thrust Sheet at Knockan Crag has been termed the 'Moine Thrust' since the original geological survey. Yet, while it does clearly juxtapose the Moine succession against the Cambrian foreland sequence, the thrust structure exposed is clearly distinct from the Moine Thrust at Eriboll or Dundonnell for example. This distinction is reflected not only in the relationship between the discontinuity and the surrounding structures but also in its fault-rock characteristics. Where the Moine Thrust is early, both hangingwall and footwall are mylonitic. At Knockan Crag, where the thrust is late, there is a multi-stage evolution of fault rocks. Ductile mylonites are carried on a carpet of brittle cataclasite containing brecciated fragments of mylonites that are themselves locally re-sheared. So the exposures on Knockan Crag are important not only in illustrating the role of thrusting and thrust sequences in building complex structures, but also in linking grain-scale processes to the larger-scale tectonic features.

References



(Figure 5.34) View eastwards towards the Knockan Crag from the slopes of Cul Mor. To the right (south), the Moine Thrust rests directly on the foreland succession; to the left (north) is the southern termination of the Assynt Culmination, with imbricated slices of Durness Group carbonate rocks separating the Moine Thrust from the foreland. (Photo: R.W.H. Butler.)



(Figure 5.35) (a) Map and cross-sections through the Knockan Crag GCR site. (b) Section x—x' is constructed parallel to the inferred direction of thrusting. The nature of the Moine Thrust (MT) shown here, truncating imbricated thrust slices of Durness Group and An t-Sron Formation in its footwall, is based on the stream section shown on the map. (c) Section y—y' is perpendicular to the inferred direction of thrusting. It shows the Uamh Mhòr Thrust truncating thrusts in its hangingwall but being folded by imbricate thrust slices in its foot-wall. All structures are cut by the Moine Thrust which here dips gently towards the south.

(Figure 5.36) The Moine Thrust at Knockan Crag. The dark-grey rocks above are mylonitic Moine rocks; the cream-weathered rocks below are Durness Group carbonate rocks. (Photo: R.W.H. Butler.)