Ben More Assynt–Conival–Na Tuadhan

[NC 300 220]–[NC 324 198]

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Introduction to the Ben More Thrust

Of all the segments of the Moine Thrust Belt, it is the Assynt district that is the best known internationally. Two major thrust sheets occur in the Assynt district, the Glencoul Thrust Sheet and the overlying Ben More Thrust Sheet, both containing Lewisian gneiss in addition to Cambro–Ordovician rocks. The critical relationships of the Glencoul Thrust are described in the Glencoul GCR site report, this chapter (but see Krabbendam and Leslie, 2004; Butler *et al.,* 2006). The Ben More Thrust Sheet is represented in this GCR volume in two site reports that are closely linked; namely, the Ben More Assynt–Conival–Na Thadhan GCR site and the Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel GCR site (Figure 5.28).

The Ben More Thrust Sheet contains Lewisian gneiss, Torridon Group strata and the lower part of the Cambro–Ordovician sequence. It also contains the 'double unconformity' between Lewisian basement and the two cover successions of Torridonian and Cambro–Ordovician sedimentary rocks. In the north, it overlies the Glencoul Thrust Sheet, whereas south of Ben More Assynt it overlies imbricate thrust slices dominated by quartzite and carbonate rocks that lie structurally underneath the Glencoul Thrust. In this area, a series of klippen occur, some of which are described in the Cam Loch GCR site report (this chapter). Some of these klippen probably form outlying parts of the Ben More Thrust Sheet, with the intervening ground since eroded.

The classic status of the Assynt district was promoted by the Geological Survey, initially through the preparation of a three-dimensional model exhibited in its offices and in museums, and then by the publication of the 1:63 360 geological map as an Assynt special sheet in 1923 (Geological Survey of Great Britain, 1923). It is only recently that selective remapping and integration of areas mapped during academic studies in the 20th century have resulted in a new 1:50 000-scale geological map (British Geological Survey, 2007). For much of the period following the original survey work of Peach *et al.* (1907) there was relatively little reexamination of thrust structures in the district. Interest was rekindled by attempts to use the igneous intrusions of south-central Assynt to date thrust activity (e.g. Woolley, 1970; van Breemen *et ed.,* 1979a). Also, small areas were re-examined to elucidate the relationships between folds and thrusts, for example in the southern part of the Ben More Thrust Sheet (Milne, 1978). However, the work of the Geological Survey was finally reinterpreted on a larger scale by Elliott and Johnson (1980), and this, together with a general rise in interest in thrust tectonics, led to a spate of more-extensive studies in Assynt and throughout the thrust belt. However, the high ground of central Assynt (Figure 5.28) has remained unattractive for extensive modern structural investigations, presumably due to the combination of inaccessibility, poor weather and the perceived definitive status of the compilations by Peach *et al.* (1907). However, the area is frequently visited and is well covered by field guides (Johnson and Parsons, 1979; Allison *et al.,* 1988).

Introduction to the Ben More Assynt–Conival–Na Thadhan GCR site

The Ben More Assynt–Conival–Na Tuadhan GCR site, in conjunction with the grouped sites at Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel, provides a coherent picture of the thrust-dominated geology of central Assynt, particularly concerning the continuity of the Ben More Thrust and the evolution of structures in its hangingwall (Figure 5.28), (Figure 5.29). These structures have played a pivotal role in interlacing the tectonic and igneous events and hence in establishing a chronology of deformation in north-west Scotland (see Parsons, 1999). North of Loch Bealach a' Mhadaidh, the course of the Ben More Thrust is unclear, and Peach and Horne, Clough (in Peach *et al.* 1907), Bailey (1935), Elliott and Johnson (1980) and Krabbendam and Leslie (2004) propose different traces of the thrust in this complicated ground. However, on Na Tuadhan and farther south, the Ben More Thrust is a very clear and unambiguous thrust structure with spectacularly exposed fold structures in its hangingwall. It is also responsible for repetition of the

Cambrian quartzite sequence, so that the western slope of Conival (as seen for instance from Inchnadamph) is a high wall of quartzite.

Description

The Ben More Thrust, at the base of the sheet, can be traced around the western flank of the mountain Conival to its type area at the bealach (pass) between Conival and Na Tuadhan (Figure 5.29)a. Here, the Ben More Thrust has emplaced Cambrian quartzites in the hanging-wall on top of Pipe Rock in the footwall. The thrust dips east into Coire a' Mhadaidh, where Lewisian and Torridonian rocks are exposed in the hangingwall. These exposures show the intersection of the base of the Cambrian strata against the hangingwall of the Ben More Thrust (the so-called 'hangingwall cut-off line') to be subhorizontal and trending NNW–SSE. Stretching lineations in the deformed Lewisian gneisses along the thrust plunge gently to the east. The footwall units are imbricated, so that Pipe Rock and Fucoid Beds are juxtaposed on the poorly exposed high plateau to the northwest towards Beinn an Fhuarain.

On Na Tuadhan [NC 304 215] there are spectacular folds of Cambrian quartzites in the hangingwall to the Ben More Thrust (Figure 5.30). These famous structures face WSW and include earlier imbricate thrusts (Peach *et al.,* 1907, frontispiece; Johnson and Parsons, 1979, fig. 7). The imbrication has carried the quartzites onto poorly exposed Fucoid Beds by a combination of fore- and back-thrusts. The imbricate thrusts splay from a floor thrust, named here the 'Coire a' Mhadaidh Thrust', that can be mapped across the corrie to where Lewisian gneisses have been carried over a thin slice of Cambrian quartzites [NC 310 205]. Presumably the Coire a' Mhadaidh Thrust itself splays from the Ben More Thrust at depth. The continuation of the Na Tuadhan folds crop out to the south on the west ridge of Ben More Assynt [NC 310 201]. Thus these folds have NNW-trending axes, parallel to the hangingwall cut-off line of the base of the Cambrian against the Ben More Thrust.

The basal Torridonian sedimentary rocks within the Ben More Thrust Sheet are conglomeratic, with clasts up to 10 cm across. South-east of Conival these sedimentary rocks are deformed, with clasts flattened parallel to the gently ENE-dipping cleavage. This deformation relates to folding in the hangingwall to the Ben More Thrust (Butler, 1997; (Figure 5.29)b. It appears that the development of the thrust through the Lewisian and Torridonian units involved an important component of folding and distributed deformation, well illustrated in the Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel GCR site.

The relationships between Torridonian and Lewisian units within the Ben More Thrust Sheet are spectacularly exposed on the southern flank of Conival (Figure 5.29)a. Here the Cambrian unconformity steps across the older Torridonian–Lewisian unconformity (Peach *et al.,* 1907). However, on the slopes above the Bealach Traligill, Lewisian basement reappears at [NC 302 195]. The basal conglomeratic facies of the Torridonian abut this Lewisian slice, consistent with a faulted contact. Milne (1978) attributed these relationships to thrusting. However, the sub-Cambrian unconformity above, on Conival, shows no such deformation. Another explanation is that the Torridonian has been downthrown against the Lewisian by a normal fault that pre-dates both the Ben More Thrust and the sub-Cambrian unconformity (Figure 5.22)b; Butler, 1997). On the steep, south-west slopes of Conival it is difficult to verify this interpretation but in the upper part of Coire a' Mhadaidh the relationships are clearer (Figure 5.29)a. Here, the eastern boundary of the Torridonian with the Lewisian basement is faulted, with Torridonian conglomerate down-thrown to the south-west [NC 303 209]. The fault does not cut the sub-Cambrian unconformity.

Interpretation

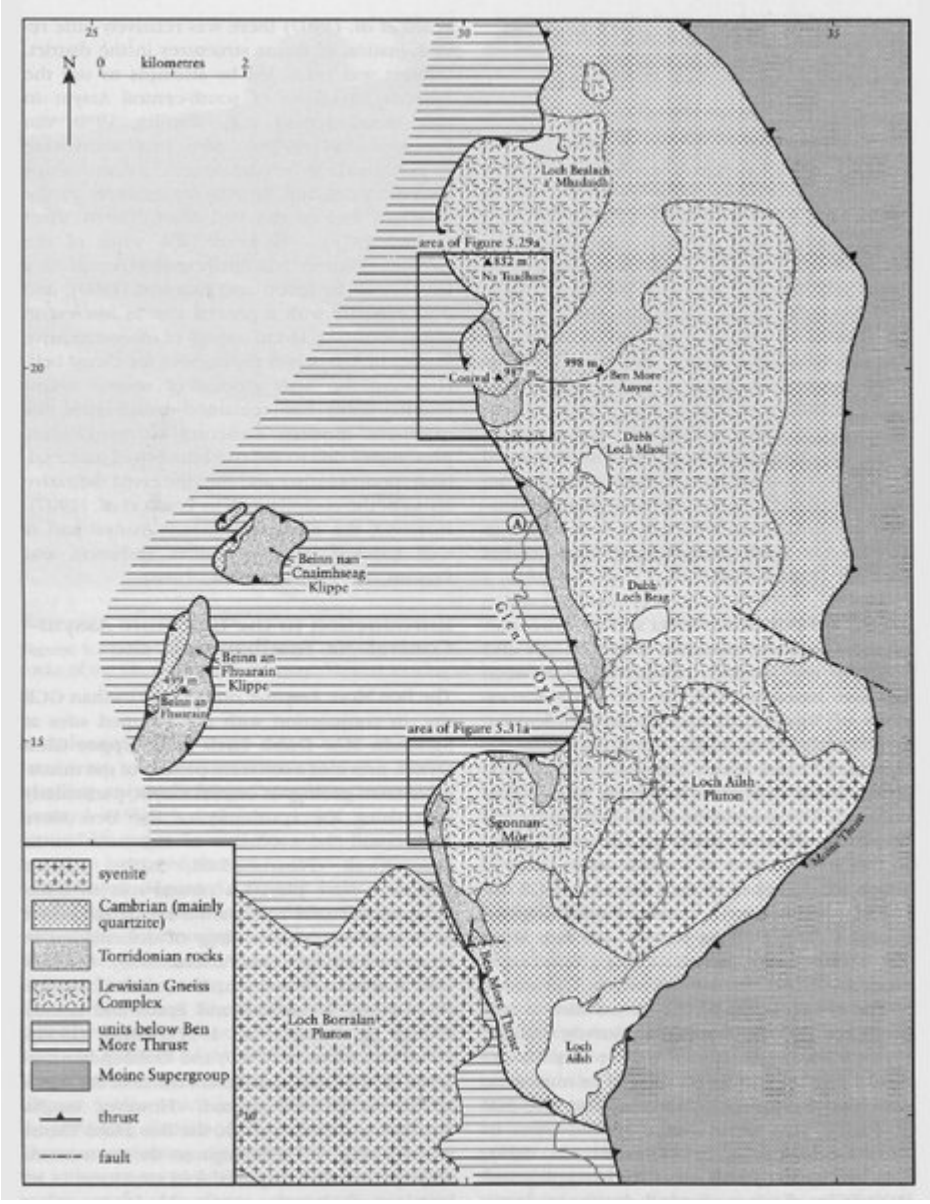
Folds within the Ben More Thrust Sheet, such as the fold pair on Na Tuadhan, have been interpreted previously as having formed during an early deformation episode that pre-dated thrusting (e.g. Johnson and Parsons, 1979; Elliott and Johnson, 1980). The observations presented above make this rather unlikely. The Na Tuadhan structures include imbricate thrusts that are folded by the antiform–synform pair. The folds have a simple geometrical relationship to thrust kinematics. It is likely that the folds formed during the growth of the thrust ramp that formed as the Ben More Thrust climbed from basement into the Cambrian cover. Throughout the central Assynt area the Ben More Thrust is characterized by heavily deformed Torridonian sedimentary rocks and possibly by Precambrian faults in its hanging-wall.

It is tempting to speculate that the ramp climbing up out of the Precambrian rocks was controlled by pre-existing basin structures (Butler, 1997; Butler *et al.,* 2006; (Figure 5.29)a,b; see also Sgonnan Mòr–Dubh Loch Beag–Upper Glen Oykel GCR site report, this chapter). This behaviour, of thrust ramps initiating along preexisting basin faults, is a feature of many mountain belts (e.g. Cooper and Williams, 1989).

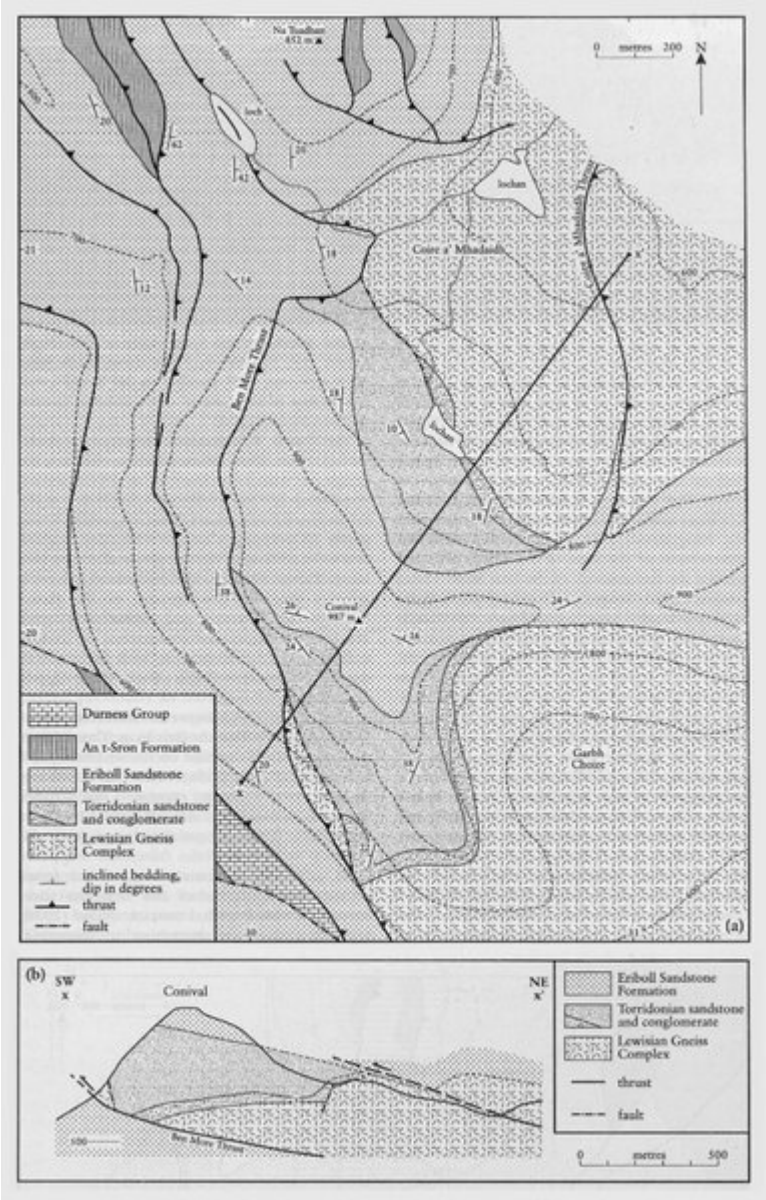
Conclusions

On Ben More Assynt, Conival and Na Tuadhan, which form the highest ground in central Assynt, are spectacular exposures of the Ben More Thrust and its associated structures. The folds in the hangingwall in the southern face of Na Tuadhan represent one of the classic views of Scottish geology, and hence this GCR site is of international importance. The Ben More Thrust is one of the major structures of the Moine Thrust Belt. In this GCR site, it emplaced a thrust sheet containing Lewisian gneisses, Torridon Group sandstones and conglomerates and Cambrian quartzites on top of a footwall mainly composed of Cambrian quartzites. The famous 'double unconformity' — between the Lewisian gneisses, Torridonian and Cambrian strata — also occurs in this GCR site. Exposures in its type area around the head of Coire a' Mhadaidh are critical in relating the geometry of the thrust to structures developed in the hangingwall of the Ben More Thrust. Folding was related to thrust stacking and to buckling, as thrust ramps climbed out of the Lewisian basement into the Cambrian cover.

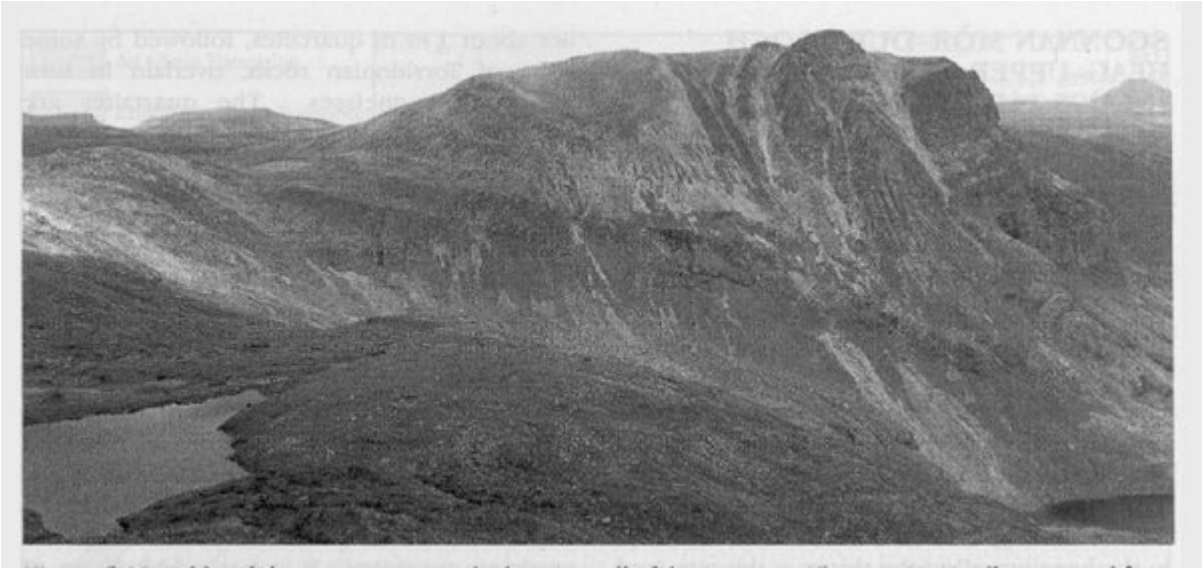
References



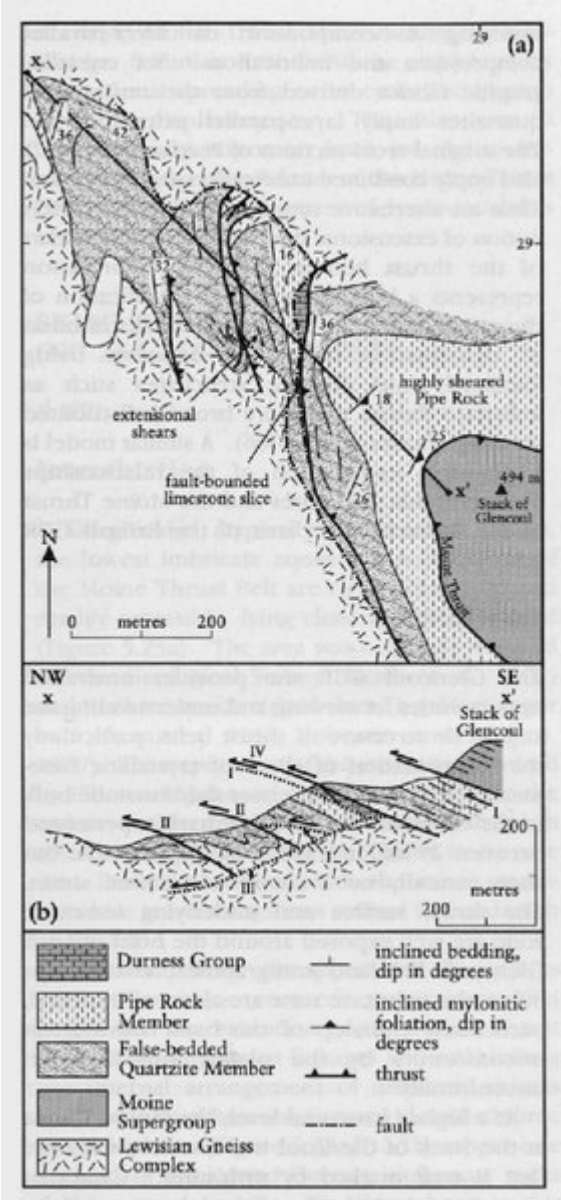
(Figure 5.28) Map of the Ben More Thrust Sheet in the Assynt District of the Moine Thrust Belt. A = Allt an Dubh Loch Mhoir. The locations of Figures 5.29a and 5.31a are indicated. After British Geological Survey (2007).



(Figure 5.29) (a) Map of the Ben More Thrust Sheet at Conival. Location shown on Figure 5.28. Topographical contours in metres. After Butler (1997). (b) Cross-section through the Ben More Thrust Sheet at Conival (location: x-x' on (a). After Butler (1997).



(Figure 5.30) Fold and thrust structures in the hangingwall of the Ben More Thrust at Na Tuadhan, viewed from Conival. (Photo: R.W.H. Butler.)



(Figure 5.22) (a) Map of the ground to the west of the Stack of Glencoul see Figure 5.21 a based on remap-ping by the author. (b) Schematic cross-section (x-x') through the map area of (a) showing the relationships between layer extensional (dotted) and contractional (solid) faults. These are grouped and numbered in the inferred order of displacement (I-1V in time). The relative timing of the Moine Thrust is uncertain but it probably moved broadly simultaneously with these other shearing deformations.