The Moine Thrust Belt at Loch Eriboll. Transect 1: South Eriboll - an excursion

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By Rob Butler

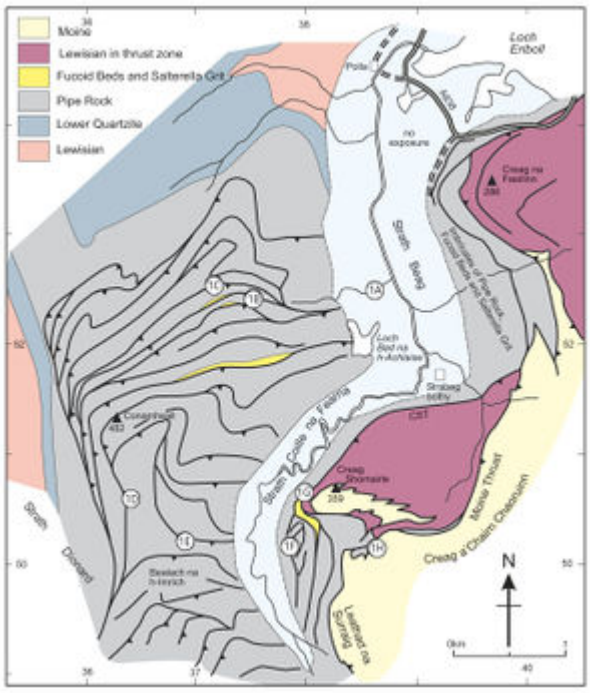

Fig. 11.2 Simplified map of the south Eriboll district, showing the positions of sites visited on transect 1. Located as 1 on Fig. 11-1. CST = Creag Shomhairle Thrust.

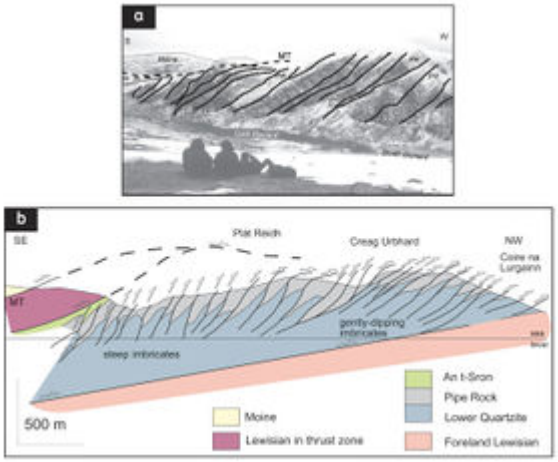

Fig. 11.4 Annotated photograph (a) and cross-section (b) of the Foinaven-Meall Horn ridge, illustrating the imbricate structure of

Cambrian quartzites. (after Butler, 2004b.)

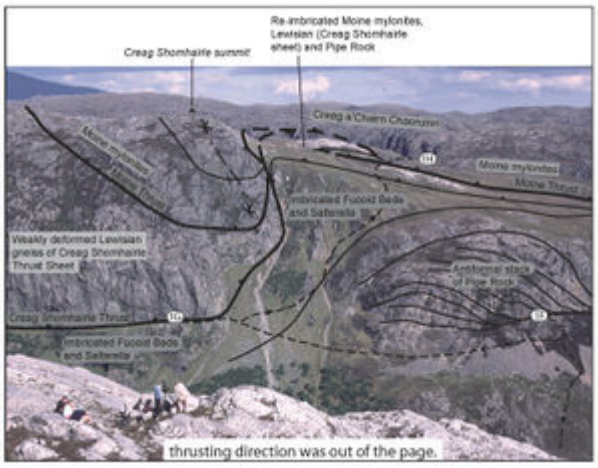

Fig. 11.5 Annotated photograph of Creag Shomhairle (from Location 11.1E; after Butler, 2004b) showing the culminations in imbricated Cambrian strata that fold higher thrust sheets (Creag Shomhairle and Moine).
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Excursion 11 The Moine Thrust Belt at Loch Eriboll. Transect 1: South Eriboll

Transect 1: South Eriboll

The mountainous country south of Loch Eriboll (Fig.11.2) contains some of the finest examples of thrust geometry in the British Isles. Although the area can be visited for a few hours, by hiking up the ridge of Conamheall (*c.*480m OD, [NC 363 514]) for panoramic views, especially of Foinaven, a full day is required to get an appropriate appreciation of the geology. The excursion described here visits the key structural domains of the Moine Thrust Belt, from the lowest-level imbricates made by slices of Cambrian quartzites, to major refolded duplex systems, thrust sheets of Lewisian basement and culminates in the Moine Thrust with its associated mylonites. Apart from examining the large-scale structural geometry of thrust systems, there are also sites that provide excellent outcrops of

key types of fault rock. The excursion involves a full day out in terrain that includes rugged upland bounder fields, boggy valleys and steep hillsides. As described, the route involves fording the Strath Beag river which should not be attempted in times of flood. The area is particularly prone to harsh weather and river levels can rise quickly. Regrettably, and in common with many parts of the Scottish Highlands, once-open countryside in upper Strath Beag is being fenced to restrict deer movement. These high obstacles also restrict people – please take care if you need to cross any fences.

Park at Polla [NC 3865 5458], taking care not to obstruct access to the farm and associated activities. Further parking is available adjacent to the A838 [NC 3908 5535]. Regardless of the choice of parking place, pause to look up the valley. The view is described in a counter-clockwise direction, starting on the western side of the valley. Here lies the gently-inclined slope of Cambrian quartzites dipping down from the summit of Cranstackie (800m OD, [NC 3505 5560]). These rocks constitute part of the foreland but, in tracing their continuity leftwards along the ridge leading to Conamheall (482m OD), the bed structure appears disrupted. This transition into more complex structure is across the most western thrusts in this part of the thrust belt, with the Sole Thrust (structurally lowest thrust) lying on the dip slope. With diligence a number of imbricate thrust faults and related folds can be identified from this distance. The imbricate slices incorporate the Pipe Rock, repeating this unit many times. Butler & Coward (1984) estimate that this stack of imbricates originally represented a distance of over 50km, now telescoped into about 6km on the Conamheall ridge. The first part of this excursion will examine some of these structures and their most dramatic expression on Creag Urbhard, Foinaven.

On the east side of Strath Beag the geology is rather different to that on the west. The large cliff seen due south of Polla is part of Creag Shomhairle. The cliffs are in Lewisian gneiss, part of a thrust sheet emplaced onto the now-imbricated Cambrian quartzites described above. The base of the Creag Shomhairle Thrust sheet lies in the lowest part of the crag, but is better seen further up the valley to be visited during the transect. Up behind Creag Shomhairle is a corrie overlooked by the dark cliffs of Creag a' Charn Chaoruinn. These are mylonites, although whether they are derived chiefly from Moine metasediments (Butler, 1982) or Lewisian gneisses (British Geological Survey, 2002; Holdsworth *et al*., 2006) has been debated. They lie above the structure interpreted by the present author as the Moine Thrust that runs through the obscured ground behind Creag Shomhairle. Continuing the panorama to the left, the cliff of Creag na Faoilinn lies to the SE of Polla. The structure of this hill is complex but in many ways comparable to that on Shomhairle. The northern part of the main cliff is made from Lewisian gneisses thrust onto Cambrian sediments that form the grassy lower slopes. The southern part of the Faoilinn cliff is made of more Cambrian strata, including Pipe Rock quartzites, imbricated many times beneath the Lewisian sheet. In summary, the Strath Beag transect provides a complete cross-section through the Moine Thrust Belt and contains examples of all of its main structural elements.

From Polla it is possible simply to head up onto the foreland quartzites and then walk out the Conamheall ridge. However, it can be difficult to find some of the key outcrops by this route. Consequently the excursion as described follows the valley for about 2km to where a small stream (Allt a' Chuilinn, [NC 3865 5250]; Locality 11.1A) runs down from the quartzites. The hillside to the west (Fig. 11.3) contains numerous imbricate slices that incorporate at most about 15m of Pipe Rock. These thrust slices bunch up to form a prominent antiformal structure seen towards the WNW. The stream section gives access to one of these thrust slices with superb beddingplane exposures of *Monocraterion* trace fossils (trumpet pipes; e.g. at [NC 3765 5240]). The northern branch of the stream leads steeply up onto the plateau. For much of its length the stream contains excellent exposures of cataclasites, formed by strongly fractured quartzites. These fault rocks can be either pasty cream or bluish in colour (colloquially termed 'bruised'). These textures show evidence for

multiple fracturing and grain suturing processes with both brittle and ductile processes recorded in thin section. Through these sections imbricate thrusts are intraformational, carrying Pipe Rock onto Pipe Rock. However, at higher levels the thrusts climb upsection into the Fucoid Beds and Salterella Grit that tend to form gullies in the hillside (e.g. Locality 11.1B; [NC 3730 5245]). The Fucoid Beds are particularly easy to identify as they generate yellow screes with lush vegetation. Yet there are more thrusts present in this area than those that involve Fucoid Beds. About 200m to the north of the gullies underlain by Fucoid Beds lies the antiformal stack of thrust slices exclusively in Pipe Rock. A short diversion to examine some of these structures is rewarding, with exceptional exposures of small thrust-related folds and bedding planes containing weakly flattened *Skolithos* and *Monocraterion* burrows (Locality 11.1C; [NC 3730 5257]). The strains are however barely detectable in *Skolithos,* but *Monocraterion* are generally visibly distorted presumably reflecting a greater propensity for the host gritty beds to deform. However, in profile these burrows are generally perpendicular to bedding. In general it may be deduced that thrust stacking has been accomplished with barely any internal distortion of the thrust slices.

So far the examination of thrust structures on Conamheall has focussed on relatively small scale examples. However, the entire ridge is made of thrust repetitions. This can be appreciated by gaining a view of Foinaven's Creag Urbhard which provides an equivalent, but historically more important, profile through the thrust belt. Walk SE onto the summit area of Conamheall, then move a few hundred metres further south to obtain uninterrupted views (Fig.11.4) into Strath Dionard and across onto Foinaven (Locality 11.1D, e.g. [NC 3612 5105]). Large numbers of imbricate slices can be identified in Creag Urbhard section, repeating the Cambrian quartzites (see Butler, 2004b, figure 6). The crags are aligned such that the view is nearly parallel to the inferred direction of thrust sheet emplacement. It was this view that inspired Cadell (1888) to model thrust tectonics (see Butler, 2004a; and Boyer & Elliott, 1982) to formalise the duplex model of imbricate thrusting. In apparent contrast to Conamheall, the Foinaven section involves repetition of the lower part of the quartzites (note that all BGS maps since those of the 1880s have wrongly shown Creag Urbhard to be made exclusively of Pipe Rock, although Cadell's field slips indicate both quartzite units) suggesting that the Sole Thrust cuts laterally down-section to the south to incorporate more stratigraphy in the imbricate slices.

Strath Dionard ends in a headwall that exposes the thrust sheets that cap the imbricated quartzites of Foinaven (Fig.11.4). The upper part of the headwall forms Meall Horn (777m OD) with its north facing crags. These are mylonites with the Moine Thrust lying below. Beneath this thrust, and separating it from imbricate quartzites seen at the head of Strath Dionard, is a slice of Lewisian gneisses equivalent to but not continuous with those of Creag Shomhairle and Creag na Faolinn in Strath Beag. From the viewpoint over Dionard return eastwards across the shattered quartzites of Conamheall and descend carefully towards Strath Beag. A small bluff overlooking the valley provides a useful landmark (Locality 11.IE, [NC 3718 5095]). This vantage point gives spectacular views onto the west face of Creag Shomhairle (Fig.11.5) and into upper Strath Beag. Repetitions of Pipe Rock, similar to those seen on Foinaven, form craggy ridges running from the ridge (Beallach a' Chonnaidh) down leftwards (NE) into Strath Beag. Further to the SE lies Creag Staonsaid (454m OD), whose crags are made of mylonites associated with the Moine Thrust. These are broadly continuous with the mylonites to Meall Horn and Creag a' Chairn Chaoruinn, permitting the observer to trace the Moine Thrust through the landscape.

The main purpose of the viewpoint is to consider the structure on Creag Shomhairle (Fig.11.5). This view looks directly back down the inferred direction of thrust transport and therefore gives an ideal perspective on how thrust sheet geometry may vary perpendicular to displacement. The lowermost slopes of Creag Shomhairle contain Pipe Rock, the upper parts of the imbricate structures that are found on Conamheall. These imbricates form a small culmination, about 100m high, on the southern

end of the cliffs. The internal structures of thrust slices are very well-exposed within the culmination ((Fig. 11.6); see Butler, 1987 for discussion). Separating the culmination of Pipe Rock from the main cliffs of Creag Shomhairle is a complex gullied area that is partly wooded. This ground is made of steeply dipping and thrust-repeated slices of Fucoid Beds and Salterella Grit. These imbricates are folded over the Pipe Rock culmination and beneath the main cliff of Creag Shomhairle return to a subhorizontal attitude. The main cliffs are largely composed of Lewisian gneisses of the Creag Shomhairle Thrust sheet (Fig.11.5). The basal thrust of this sheet is also folded by the culmination of Pipe Rock so that, as with the Fucoid Beds and Salterella Grit imbricates, it is sub-vertical in the gully area. However, the summit area of Creag Shomhairle is made of mylonites that occupy the core of a synform. The interpretation favoured here (Butler, 1982, 2004b) is that these mylonites are derived from the shearing chiefly of Moine psammites. Thus the Moine Thrust marks the lower boundary of these mylonites with the less sheared

Lewisian of the Creag Shomhairle Thrust sheet. However, a Lewisian parentage has been suggested (British Geological Survey 2002; Holdsworth *et al*., 2006) which sites the Moine Thrust at structurally higher levels. Regardless of this controversy, the summit mylonites on Creag Shomhairle are carried by a major thrust. In detail the structure is still more complex (Butler, 1982), with strongly mylonitised quartzites, presumably derived from the Cambrian, lying between the Moine and Lewisian units. All three units are interleaved by small thrusts that are themselves folded around the synform.

The field relationships on Creag Shomhairle were important for demonstrating the sequence of thrust sheet emplacement in NW Scotland (Butler, 1982, but see Butler, 2004b). As higher thrust sheets are either re-imbricated or folded over underlying ones, it implies that these were emplaced first, with underlying ones developed sequentially in turn. This is classically termed piggy-back thrusting and is now widely assumed to be the normal way in which thrust belts develop. The outcrops on Creag Shomhairle and their access are discussed shortly. However, the descent into Strath Beag provides opportunities for observing some thrusts in the Pipe Rock.

The stream that flows steeply into Strath Beag on the north side of the bluff of Locality 11.1E provides arguably the finest exposures of small-scale thrusts and their related fault rocks in the region. However, great care is needed to access these, especially in the normal, damp conditions. If in doubt the best way down hereabouts is to remain on the south side of the stream (see (Fig.11.3)). However, the watercourse follows a thrust surface that can only be appreciated from its north side. The bedding plane of the stream bed is also a thrust plane and is decorated by photogenic examples of fault breccia and other cataclasites. The southern retaining wall of the stream contains imbricated Pipe Rock on the bed-scale. These include slices approximately 2m thick together with a ‘microduplex’ [NC 3628 5098] that incorporates about 10cm of stratigraphy. More description is unnecessary and the reader is left to discover these informative outcrops themselves. Continue down into the boggy valley bottom, choosing a fording point for the river that is appropriate to the conditions. In the event of high water levels, discretion is strongly advised. The remainder of the excursion should be abandoned and road regained by a 5km walk back along the river’s west bank. However, if possible, the next goals are outcrops of fault rocks on the western slopes of Creag Shomhairle that were seen from Locality 11.1E. The first target lies within the culmination of Pipe Rock at the southern end of the cliffs. Recently erected deer fencing has hindered access here. Scramble up the heathery and scree-covered slopes to the foot of the Pipe Rock cliffs at Locality 11.1F ([NC 3785 5024]; see (Fig.11.5)). The floor thrust to this culmination is well-exposed with excellent sections through the cataclasites that decorate it. In many places these fault rocks are foliated. In the cliffs above there are numerous examples of both footwall and hanging-wall ramps of the culmination’s constituent imbricate thrusts.

To observe outcrops of the Creag Shomhairle Thrust it is necessary to access a narrow ledge

beneath the main cliff to the north (Locality 11.1G; [NC 3800 5059]; see (Fig. 11.5)). With care it is possible to follow animal tracks, contouring around beneath the Pipe Rock culmination, traversing below outcrops of Fucoid Beds and Salterella Grit, and crossing some unstable scree shoots. It may be preferable to return to the valley bottom and re-ascend to the ledge, thus avoiding the traverse. However, while exposed, the ledge provides comfortable access to the Creag Shomhairle Thrust in its sub-horizontal attitude, overlying strongly sheared Fucoid Beds. The Lewisian immediately above the thrust plane is strongly retrogressed with dark, chloritic seams and epidotic veins. Cataclasitic seams are also evident. However, penetrative forms of this thrust-related damage are restricted to within only one or two metres of the thrust plane. Otherwise the gneisses are largely unaffected by thrusting, apart from having experienced a presumably substantial displacement. More intrepid visitors may choose to access the steeply inclined parts of the Creag Shomhairle Thrust that are found in the steep gully ([NC 3804 5048]; see (Fig.11.5)) to the south of the ledge. High in this gully the thrust zone includes a slice of strongly deformed quartzites that increases dramatically in size to the south, away from Creag Shomhairle. However, this is very steep, potentially hazardous ground and access is not encouraged. The lower parts of this approach is up scree shoots largely formed of blocks of the Moine (*sensu* Butler, 1982) mylonites from high on the cliff. Many samples contain thin seams of iron oxides that cross-cut the mylonitic foliation. Veining and fracturing presumably happened when these mylonites, after their emplacement, were folded into the major synform seen on Creag Shomhairle (Fig.11.5).

The upper structural levels of the Moine Thrust Belt in Strath Beag may be accessed in the ground SSE of Creag Shomhairle, reached via a steep path above the culmination of Pipe Rock (Fig.11.5). The grassy slopes at the top of the gully lead eastwards up towards Creag a'Chairn Chaoruinn. As outcrop improves, this route crosses low crags of variably sheared Cambrian quartzites and mylonites. Good examples are found on the hillsides overlooking the col between Shomhairle and Chairn Chaoruinn (Locality 11.1H; [NC 3860 5022]). These relationships are interpreted as representing imbrication of the rocks on either side of the original Moine Thrust (Butler, 1982). If time permits, it is instructive to trace out some of these slices. They are not laterally persistent. Further north the slices incorporate tracts of sheared Lewisian, at least some of which can be traced into the Creag Shomhairle sheet. Although in detail these geological relations are very complex, they show how major thrusts (in this case the Moine) can be strongly disrupted during later parts of their history by other thrusts. Consequently, in many places it is very difficult to trace out continuous thrust surfaces. A feature of the outcrops at Locality 11.1H is the intense, polyphase ductile deformation. In many cases the strongly mylonitic foliation, found in all units, is crenulated. While the mylonitic fabrics presumably reflect penetrative shearing associated with the emplacement of the Moine Thrust sheet, the crenulations have been related to a combination of the re-imbrication and the refolding by underlying culminations (Butler, 1982). The Strath Beag transect has taken the visitor from the Sole Thrust to the Moine Thrust with increasingly ductile deformation and structural complexity. This trend is taken to show that the structurally over-lying thrusts (e.g. the Moine and its re-imbrications) formed at relatively deep crustal levels (*c.*10-15km) at warm temperatures (*c.*300-350°C). As thrusting continued, the tectonic overburden presumably eroded so that later structurally underlying thrusts formed at shallower crustal levels, at progressively lower temperatures, faster strain rates and correspondingly more 'brittle' conditions. Although this is a common motif in thrust belts, these variations are not uniform and thick thrust sheets can be incorporated with very little internal distortion. The Creag Shomhairle sheet is one such example. If time and enthusiasm permit, it is informative to walk over the summit of Creag Shomhairle ([NC 3814 5052]; excellent views onto Conamheall) and down onto the rocky slopes to the NE. Abundant clean outcrops of Lewisian gneiss are to be found, preserving structures and metamorphic states otherwise encountered in the foreland. The easiest way back to the road is to walk down into the corrie between Shomhairle and Chairn Chaoruinn, crossing deer fences and descending to Strathbeg bothy. A path then continues down the valley, passing beneath Creag na Faoilinn and

reaching the A838 [NC 3940 5391]. This can then be followed back to Polla.

References

> At all times follow: The Scottish Access Codeand Code of conduct for geological field work

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