Excursion 11 The Moine Thrust Belt at Loch Eriboll

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Purpose:	Four transects to examine aspects of thrust belt geometry and the evolution of fault rocks.
Aspects covered:	Lewisian gneisses, Cambro-Ordovician stratigraphy, imbricate thrusts, duplexes, piggyback stacking and breaching sequences of thrusts, mylonites and other fault rocks.
Maps:	OS: Explorer series (1:25,000) sheets 445, 446 and 447; BGS 1:50,000 Scotland sheet 114W, Loch Eriboll.
Type of terrain:	Rocky coastlines, moorland, wet valley bottom, steep grassy slopes, scree, mountain crags and bare rock exposures
Distance and time:	2 full days: transect 1 (1 day); transect 2 (2 hours); transect 3 (4 hours); transect 4 (2-3 hours). Allow a further 30-45 minutes for the drive from Durness or Tongue.
Short itinerary:	Transect 2 for a major thrust, the Arnaboll Thrust and associated deformation features; transect 1 for a fuller range of geology if only one day is available.
	Note: all the localities described in this chapter are Sites of Special Scientific Interest and as such are protected. No outcrops should be hammered nor specimens collected, even from float.

The Loch Eriboll area (Figure 11.1) is hallowed ground not only for Highland geology but also for the discovery of thrust tectonics. It was here in the early 1880s that Charles Lapworth demonstrated that the sequence of rocks was not a simple stratigraphic order, but was repeated by folds and faults (Lapworth, 1883). In accepting Lapworth's geological interpretations, it was for this area that Geikie (1884) first coined the term 'thrust', inspired by the structures on Ben Arnaboll. Lapworth (1885) went on to describe how large shear strains associated with thrusting generate new types of rocks, coining the term 'mylonite' for these 'intensely milled' rocks. This work not only forms the foundation for much modern work (see Snoke & Tullis, 1998; Law & Johnson, 2010), it also established clearly that the layered structures in metamorphic rocks could be formed by deformation rather than simply mimic original sedimentary bedding. This opened the way for better interpretations of the geological structure of the interiors of mountain belts around the world. Lapworth's key sites are described here together with spectacular sections across these units at the Moine Thrust. The region is also important internationally for understanding the structure and geometric evolution of thrust belts. Early attempts to model the formation of thrusts using analogue materials were inspired by the spectacular imbricate structures on Foinaven (Cadell, 1888; see Butler, 2004a). A century later the same outcrops provided the type example for duplex structures (Boyer & Elliott, 1982). The whole area is protected as Sites of Special Scientific Interest, recently described by Butler (2009).

The overall aim of the combined transects described here is to introduce the key structural elements of thrust belts at a variety of scales, from the processes that form fault rocks that permit tens of kilometres of displacement on relatively narrow zones of movement, to the ways in which many faults can interact to create wonderfully complex stacks and piles of thrust sheets. Depending on the structural level within the thrust belt, the structures formed vary from simple localised fault zones to the broader zones of mylonites that characterise the higher structural levels of the thrust belt. The thickness of thrust sheets and slices varies considerably also, from a few centimetres where individual beds within the Pipe Rock are imbricated to several hundred metres of gneisses where Lewisian basement has been displaced. Indeed the Moine Thrust Belt is a classic place to study basement involvement in thrust belts (see Butler *et al*., 2006). Remarkably for such an intensively studied and relatively well-exposed thrust belt, there are still fundamental disagreements between researchers on such matters as the correlation and kinematic significance of certain thrusts and the protoliths of various mylonitic lithologies. The main issues are outlined at the appropriate points in these transects.

Transect 1: South Eriboll

The mountainous country south of Loch Eriboll (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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 ((Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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 (Figure 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.

Transect 2: Arnaboll

Along with Glencoul in northern Assynt, Ben Arnaboll is one of the most important geological sites in NW Scotland. It was here that Lapworth (1883) first demonstrated that the rock sequence was repeated by what were to become known as thrusts (Callaway did the same at Glencoul). Exposures of the Arnaboll Thrust in its type area, placing Lewisian gneisses onto Cambrian Pipe Rock, are justly famous and have inspired generations of both student and professional geologists for well over a century. Indeed Geikie (1884) first coined the term 'thrust' to describe these relationships. They are also Lapworth's (1885) type-locality for mylonites. The site was important in the 1980s for determinations of thrust sequences and for deducing the geometric evolution of rather complex thrust structures, especially by Coward (1980; 1984, 1988). It has continued to influence discussions of how basement comes to be incorporated into thrust belts (e.g. Rathbone *et al.*, 1983; Ramsay, 1997; Butler *et al.*, 2006). These inspirational outcrops form the cornerstone of this transect. The adjacent geology (Figure 11.7), chiefly concerned with imbricated Cambrian strata, is described to provide context.

The Arnaboll outcrops can readily be accessed over a period of a couple of hours, although diversions over Heilam can occupy a full day. In contrast with the southern end of the Loch, the weather in northern Eriboll is positively arid. However, the terrain is still rough and includes steep hillsides and cliffs. As ever, these outcrops should be treated with great respect and should not be hammered.

Park in the large lay-by on the A838 [NC 4520 5992], or on a portion of the old road opposite. Before starting the transect it is worth examining the view across Loch Eriboll from the parking area. The hillside on the western shore of the loch displays prominent slabs of Cambrian quartzite that incline down to the sea. This is a dip-slope, inclined at 12° which, although tilted, is essentially undeformed. These distant rocks form part of the foreland. The dip-slope can be traced southwards to the head of the loch, running down from the summits of Beinn Spionnaidh (773m) and Cranstackie (801m). The Cranstackie dip slope runs along the ridge towards the hill of Conamheall (482m). At the saddle between the hills the simple dip of bedding in the quartzites becomes disrupted. The rocks here have been imbricated, stacked up on thrusts. The lower edge of the simple dip slope is the approximate position of the Sole Thrust – the outer edge of the

Moine Thrust Belt. The rest of this area is described in transect 1 of the Eriboll excursion.

Although the chief objective of this transect is the Arnaboll Thrust, the approach route crosses an important tract of imbricated Cambrian strata (Coward, 1984; (Figure 11.7)). These are described on the approach. From the parking area take the old road for a few metres, then head SE across boggy ground to a grassy gully [NC 4568 5971] that leads up a short escarpment.

The southern (right) side of the gully includes a cliff of Fucoid Beds. These are thrust onto Durness carbonates seen to the north of the gully. At the top of the gully the terrain opens up, revealing low outcrops and some rather boggy ground. Ahead, to the southeast, the upper crags of Ben Arnaboll are visible. Between the gully and these crags lie imbricated Cambrian strata, chiefly Fucoid Beds and Salterella Grit together with a few metres of the uppermost Pipe Rock. The imbricates have an across-strike width of several hundred metres. Exploring geometry of these structures can be instructive. Directly ahead of the gully, across some marshy ground, lies a small outcrop of Pipe Rock, about 1m high, sandwiched between Fucoid Beds (Locality 11.2A, [NC 4574 5969]). The Pipe Rock slice can be traced to the north, on the western flank of a knoll. The thickness of the slice gradually increases to about 8m, implying that the imbricate thrust that carries it changes its stratigraphic position. Indeed all of the imbricate thrusts in this area display the same trend, carrying more Pipe Rock in the north than in the south.

After this diversion, scramble to the top of the knoll (Locality 11.2B, [NC 4581 5971]) for the view onto the western cliffs of Ben Arnaboll. This view is generally down the inferred direction of thrust transport so the variations in the structure seen in the cliff are lateral. The highest crags are Lewisian gneiss, with their characteristic massive appearance, that form the hanging-wall to the Arnaboll Thrust. They lie on a near-continuous cliff of bedded, cream-coloured rocks – the Pipe Rock. The bedding is not continuous, but terminates to form features that appear to be sedimentary channels. Closer inspection reveals that these are thrust structures, with the bedding terminations representing lateral ramps. The Arnaboll Thrust is clearly visible at the base of the Lewisian gneisses. It is folded by the underlying imbricates, a feature best appreciated at the small cave [NC 4596 5938]. In the foreground, forming the gentle ground beneath the cliffs, are imbricates of Fucoid Beds and Pipe Rock, readily identified from the characteristic vegetation and outcrop of these units.

The excursion now visits the exposures of the Arnaboll Thrust. From the knoll, head down the heathery slope to the southeast and then ascend the steep slope between the crags to the Lewisian of the Arnaboll Thrust sheet. This ascent is aided by an indistinct track, but beware slippery rocks amongst the heather. A brief diversion can be taken to the north to find exposures of the Arnaboll Thrust plane ([NC 4617 5951]; see White 1998). However, great care should be taken here on this steep ground. Otherwise continue onto the plateau and walk northeast along the top of the cliffs.

The outcrops hereabouts are Lewisian gneisses that show little sign of Caledonian deformation. Structures, including the gneissic banding, developed under and preserve amphibolite facies metamorphic assemblages. They are cross-cut by, presumably, late Laxfordian (Palaeoproterozoic) granitic pegmatites. At the northern end of the plateau [NC 4611 5951] there is a spectacular viewpoint north up the coast towards Whitten Head and, in the immediate ground, onto Ben Heilam (Figure 11.1). The general 'grain' of the geology, picking out the trend of the imbricate thrusts of Pipe Rock and Fucoid Beds discussed above, can be traced across Heilam. To the NE lies typical Moine outcrop.

From the plateau drop carefully down to the west for a few metres. Here are the outcrops of the Arnaboll Thrust (Locality 11.2C, [NC 4615 5958]; (Figure 11.8)). This internationally-important site should be treated with the utmost respect. According to Teall (see White, 1998), the site was important for Lapworth's (1885) first descriptions of mylonites. Lewisian gneisses rest tectonically upon a footwall formed of Pipe Rock. Bedding is clearly visible within these quartzites, parallel to the thrust contact. *Monocraterion* burrows show the Pipe Rock to be the correct way up, demonstrating that the presence of Lewisian gneisses above requires the contact to be tectonic, rather than, say, an upside-down unconformity. Despite the recognition of sedimentary structures, the Pipe Rock has been sheared with the prominent Skolithos burrows inclined with respect to bedding. Given the assumption that these burrows formed perpendicular to bedding, they constitute excellent markers by which the deformation can be quantified (see Fischer & Coward, 1982). This deformation penetrates for at least 2m below the thrust. The sense of deflection clearly indicates a top-to-the-WNW shearing which presumably reflects the tectonic transport direction of the Arnaboll Thrust sheet.

The Arnaboll Thrust plane itself is a discrete, knife-sharp surface, although it is locally warped by minor thrust structures within the Pipe Rock below. Its hanging-wall is marked by a narrow zone of dark, chlorite-rich mylonite about 50cm wide. More than about 3m above the thrust plane the Lewisian shows few effects of Caledonian deformation (as seen on the plateau). So the thrust zone shows a dramatic gradient, not only in deformation but also in the intensity of the greenschist overprint (Wibberley, 2005). The deformation can be tracked using the pegmatites embedded within the gneisses that are progressively more streaked out and deflected towards the thrust.

If time and the inclination permit, it is instructive to walk out the Arnaboll Thrust across the slopes to the SE of Locality 11.2C as far as Locality 11.2D [NC 4626 5933]. The thrust is cut repeatedly by thrusts that climb out of the underlying Pipe Rock and up into the overlying Lewisian ((Figure 11.7)b). This type of geometry is described as 'breaching' (Butler, 1987) and gives a clear indication of the relative sequence of thrust development: the Arnaboll Thrust sheet was emplaced onto the Pipe Rock before the imbricates within it developed. One of the clearest examples of this geometry is to be found in the small natural amphitheatre [NC 4622 5953]. Further along the outcrop trace, the Arnaboll Thrust can be inferred to have been folded (Figure 7b) so that it maps out as a vertical contact. At the end of the short walk (Locality 11.2D) outcrops of the Pipe Rock, from the footwall to the Arnabol Thrust, can be found with similarly sub-vertical dips. Careful searching reveals Monocraterion burrows that, as at Locality 11.2C, young towards the Lewisian rocks of the Arnaboll Thrust sheet.

From this outcrop area head back across the plateau of gneiss, carefully locating the way through the crags on the steep escarpment that was used for the ascent, and hence return to the vehicles. An alternative route back is to walk north, joining the A838 and following this for a couple of kilometres back to the parking area.

Transect 3: Kempie

Parking is available in the large lay-by on the A838 [NC 4441 5800] where there is room for about six cars. The transect running up the hillside from Kempie follows in the footsteps of Lapworth (1883). It covers the transition from folded Cambrian quartzites and their Lewisian basement through a dramatic deformation gradient that increases upwards into mylonites associated with the Moine Thrust. The lower parts of the transect are concerned with less deformed units and include excellent introductory outcrops for parts of the Cambrian stratigraphy. Indeed the coastal outcrops include the type section for the An t-Sron Formation units. This transect lies exclusively within the hanging-wall to the Arnaboll Thrust sheet. Therefore it provides a continuation from transect 2 into progressively higher structural levels within the Moine Thrust Belt. The whole section contains a number of informative outcrops that can be used to build up a structural interpretation from first principles. Consequently the area has been much used for student training exercises. It has been described most recently by Butler *et al*. (2006). This transect provides an introduction to some of the critical elements and is illustrated by a sketch geological map (Figure 11.9) and cross-section (Figure 11.10). It is described so that visitors can appreciate the geological interpretations based on individual outcrops that can build up into a coherent structural model through this part of the thrust belt. As described, this transect takes about 4 hours, involving ~2km of walking and ~200m of ascent with some steep terrain.

Start on the shore below the parking area, on the headland of An t-Sron (Figure 11.9). Walk down to the headland to reach clean outcrops of Cambrian Pipe Rock (Locality 11.3A, [NC 4431 5817]). These quartzites lie in the core of a large anticline. Moving west along the coast (passable at all but the highest part of the tide) provides an excellent introduction to the stratigraphy of Cambrian strata. The stratigraphic top of the Pipe Rock, passing abruptly up into the Fucoid Beds, is found at the base of the low sea-cliff (Locality 11.3B, [NC 4417 5814]). In detail, this boundary is deformed. Bedding planes show evidence for slip and some of the finer-grained layers in the Fucoid Beds are cleaved. Within the Eriboll area, the base of the Fucoid Beds can be inferred to have acted as a detachment horizon from which imbricate thrusts have splayed to repeat Fucoid Beds and the overlying Salterella Grit. Here on the An t-Sron shore line there are no such imbricates, but examples are encountered on the Arnaboll transect described below. There are, however, minor thrust structures, chiefly directed towards the east ('back-thrusts') that cut up from the Pipe Rock into the Fucoid Beds (see Coward, 1988).

Continuing along the wave-cut platform (*beware slippery rocks*) is a journey up stratigraphic section. There are excellent outcrops of the sedimentary structures within the Fucoid Beds that are commonly difficult to study in the sparse outcrops of this formation inland. Towards the top of the Fucoid Beds at Locality 11.3C [NC 4405 5809], there are some spectacular yet enigmatic folds and thrusts with trends that are strongly oblique to the regional orientations.

The Salterella Grit Member on An t-Sron has a significantly lower thickness compared to other parts of the NW Highlands (<5m as opposed to the usual 8-10m). These clean quartzites are well exposed in the low sea cliff section and capped by the Ghrudaidh Formation – the gritty dolostones that form the basal unit of the Durness Group carbonates. Bedding within the dolostones is markedly disturbed – well exposed examples lying on the low rocky promontory, Locality 11.3D [NC 4393 5807]. These structures have been variously interpreted as formed by extensional faults or by backthrusts. The latter of these is preferred here, as there are examples of such structures along the foreshore section and many other contractional structures can be proven within the dolostones in the ground above the shore. The development of thrust structures within the dolostones of the Ghrudaidh Formation, but not in the Salterella Grit, requires the presence of a detachment horizon near their geological boundary. Evidence for this in outcrop include cleavage development (foreland-vergent) and local slip surfaces.

From the shore, return to the roadside of the A838. A useful exercise is to trace the geological boundary between the dolostones and quartzites of the Salterella Grit. This is picked out by vegetation and confirmed by scattered outcrops. The final climb to the road (at a crash barrier) breaks out opposite a small spring and water trough that lie between cuttings with dolostones (west) and Salterella Grit (east: [NC 4437 5799]). For those wishing to find more evidence for deformation within the dolostones, the road cuttings to the west along the A838 provide sections through complex thrust stacks. However, unless experienced with carbonates, it may be difficult to distinguish between depositional bedding surfaces and tectonic surfaces in these sections.

The remaining objectives for this transect lie to the east and up to the Moine Thrust. This route is described in detail so as to identify the necessary evidence for the structural relationships depicted on (Figure 11.10). The road section opposite the parking lay-by (Locality 11.3E, [NC 4439 5798]) is made of Fucoid Beds that are variably thickened up by thrusts. These structures lie in the crest of the An t-Sron Anticline, the western limb of which has formed the focus of attention so far. The excursion now moves into its eastern limb. Regrettably this is rather poorly exposed at the level of the road, but can be proven down on the coast (below the cottages of Kempie). The first outcrop to the east along the road, next to the small stream next to the woods (Locality 11.3F, [NC 4453 5787]) are quartzites partly covered in moss that are interpreted to be Salterella Grit. Bedding is sub-vertical. The adjacent road outcrops to the east are Fucoid Beds [NC 4455 5787]. Consequently the interpretation here is that the Salterella Grit and Fucoid Beds young to the west and therefore lie on the eastern limb of a synform whose axis runs through the dead-ground between these outcrops are the lay-by. This structure is the Kempie Bay Syncline. Cleavage within the Fucoid Beds in the road section here verges east, consistent with the syncline interpretation.

It is worth working carefully eastwards along the low road cutting below the trees, watching carefully for traffic. For the most part the section consists of steeply-dipping Fucoid Beds with inclined, east-vergent cleavage. After 40m [NC 4460 5786] there is a screen of vertically-bedded quartzites with prominent Skolithos burrows, deduced to be the Pipe Rock that stratigraphically underlies the Fucoid Beds. The burrows are sheared with a sense consistent with the vergence of the cleavage in the Fucoid Beds. Similar vergence can be determined for cleavage in the shaley units in the Pipe Rock here. For enthusiasts it is possible to trace the boundary between Pipe Rock and Fucoid Beds, and the Fucoid-Salterella boundary encountered to the west up the wooded hillside to the south of the road.

Given the stratigraphic thickness (>150m) of the Cambrian quartzites, the expectation moving east along the road from the previous outcrops at the stratigraphic top of the Pipe Rock should be to remain in quartzites. However, within a few metres the road section returns to Fucoid Beds. This unit can be found in a small damp gully (Locality 11.1G, [NC 4470 5784]). Just to the east, at the sharp bend in the A838 [NC 4472 5785], is a return to Pipe Rock. As with the Pipe Rock found to the west on the road, the *Skolithos* burrows here are also sheared with an eastward vergence. Consequently the panel of Fucoid Beds caught between the Pipe Rock outcrops is interpreted as having been incorporated by thrusting rather than in a syncline hinge (Figure 11.10). This is called the Kempie Thrust. It is inferred to lie on the western side of the Fucoid Beds at Locality 11.1G, while their eastern side is interpreted as the original stratigraphic contact at the top of the Pipe Rock, now tilted to be vertical. Note that the inferred Kempie Thrust has also been tilted to vertical, an important corollary that will be explored at the end of this excursion. Thrusting within the Cambrian stratigraphy deduced from consideration of these road sections means that the Kempie Syncline is difficult to prove as there are no simple geological boundaries that can be traced around this fold. Further structural com-plexity can be investigated on the rocky shore at Kempie [NC 4464 5795].

The plan now is to follow the structure eastwards, working back across strike. In doing this, the route is predicted to run down stratigraphic section, through steeply-dipping Cambrian quartzites on the steep, eastern limb of the Kempie Bay Syncline. The thin slice of Fucoid Beds described above (Locality 11.3G) cannot be followed far away from the road and consequently will not add to the structural complexity! To access this ground, return back along the road a few metres to the most western slice of Pipe Rock and follow an indistinct path up into the trees. A number of different routes can be taken up the steep heathery hillside, but the target is the narrow, north-south-trending hanging valley that ends at an elevation of about 130m. It is worth checking the outcrops of quartzites, confirming the general orientation of bedding (subvertical) and the presence of *Skolithos* burrows (confirming the status of these rocks as being Pipe Rock). The burrows display elliptical bedding sections, with the long axes sub-parallel to strike, implying significant bed-parallel shortening strains. With care, upon entering the hanging valley, it is possible to pick the stratigraphic boundary with the underlying Lower Quartzite. The key distinction lies in identifying mm-scale depositional lamination and therefore the absence of the intense burrowing that characterises the Pipe Rock. Good examples can be found at Locality 11.3H [NC 4478 5771]. It is worth studying these rocks in some detail. Cross-bedding can be identified here and used to determine the westward younging of these strata. Individual sedimentary grains can be readily identified either with the naked eye or through a hand-lens. They are undeformed and show a good granular texture. It might be instructive to collect a small sample of these quartzites from surface detritus for comparison with equivalent rocks further up the section.

Lapworth (1883) interpreted the structure further up the hanging valley in terms of fold structures, the western of which are the An t-Sron Anticline and Kempie Bay Syncline described above. The next fold hinge is found in the cliffs on the east side of the hanging-valley at Locality 11.3I (best seen from [NC 4472 5757]). This anticline shares its steep western limb with the Kempie syncline. Quartzites of its eastern limb dip gently eastwards, indicating that the fold axial surface is inclined to the east (Figure 11.10). The interlimb angle (the measure of fold tightness) is about 100 degrees.

Continue up the hanging-valley consulting outcrops, especially on its northern side. Towards the top of the valley (e.g. [NC 4478 5743]) bedding in the Lower Quartzite dips moderately towards the WNW, with younging determined by cross-lamination towards the WNW. Consequently a synclinal fold axis may be inferred to have been crossed ((Figure 11.10); it can be mapped through the adjacent ground, see (Figure 11.9)). Good clean outcrops of quartzites are to be found at Locality 11.3J [NC 4488 5743]. Here the beds dip at about 50° to the ESE but young westwards, indicating that they are upside-down. Careful inspection reveals that the sedimentary grains are flattened, creating a weak to locally intense protomylonite deformation fabric that is approximately axial planar with respect to the main folds that were encountered on the traverse. A few metres to the east are out-crops of pegmatite-rich Lewisian basement (e.g. [NC 4492 5741]) which also show a weak schistosity defined by chlorite and epidote that is sub-parallel to the foliation in the quartzites. It may be deduced that the contact between the Lewisian and the quartzites is an overturned unconformity. A slight diversion along the plateau reveals this contact in outcrop [NC 4501 5756].

Returning to Locality 11.3J, the next objective is to work carefully up section, best achieved walking south. The small knoll (219m OD) about 200m SSW of Locality 11.3J forms a useful landmark, with outcrops lying along a small escarpment facing the plateau area (Locality 11.3K; [NC 4487 5726]). The upper part of the escarpment consists of distinctive folded mylonites, and again the interpretation (Barber & Soper, 1973; Butler *et al*., 2006) put forward here is that these were chiefly derived from Moine psammites, although others favour a foreland Lewisian protolith (British Geological Survey 2002; Holdsworth *et al*., 2006). They contain a strong linear fabric defined by elongate quartz aggregates that plunges towards the ESE. The base of these mylonites is considered by Butler *et al*. (2006) to be the Moine Thrust. Below lie more mylonites of distinct compositions, arranged in bands of about a few metres thickness. One type of mylonitic layer is highly quartzitic. Others are essentially chloritic phylonites with thin feldspathic seams. Where evident, these units also show stretching lineations that plunge ESE.

The derivation of the mylonites beneath the Moine Thrust can be established by briefly tracing out a deformation gradient. Return to Locality 11.3J. The plan is to walk out these quartzites and the neighbouring Lewisian for a few hundred metres to the WSW, along the strike (Figure 11.9). As seen previously, at Locality 11.3J, the quartzites retain visible bedding but also display moderate protomylonitic deformation fabrics. Further WSW the deformation increases (e.g. [NC 4470 5731]) to become fully mylonitic with the same ESE-plunging stretching lineation as seen at Locality 11.3K. Thus these mylonites are products of progressive deformation that, at lower strain states, involves folding of the Cambrian quartzites and their Lewisian basement (Figure 11.10). Elsewhere (e.g. [NC 4417 5713]) the shearing focuses onto a discrete thrust that carries mylonites derived from the Cambrian quartzites and their Lewisian basement onto more outlying parts of the fold belt crossed on this transect. Further description of these forms of structural relationship is reserved for the next transect. Return to vehicles by carefully descending the slopes to the A838.

Many interpretations of structural evolution in crustal-scale shear zones, such as the Moine Thrust Belt, assume that there is a simple progression from ductile deformation, manifest by mylonites development into brittle deformation and cataclasis as rocks become progressively exhumed. However, the transition from ductile to brittle deformation need not be controlled simply by depth (or temperature), but also by strain rate. The structural evolution on this transect illustrates this complexity. The main folds (An t-Sron Anticline, Kempie Bay Syncline and un-named folds seen higher on the transect) face WNW. Their axial surfaces become increasingly inclined up-section as the deformation state increases, culminating in mylonite formation directly beneath the Moine Thrust. Therefore these folds formed before or during the latest ductile movements on the Moine Thrust (Butler *et al*., 2006). Yet the folds deform earlier thrust structures such as those that are now found facing downwards on the steep eastern limb of the Kempie Bay Syncline. These earlier structures represent periods when deformation was strongly localized. It is not clear what the timing of the folding is relative to slip on the Arnaboll Thrust, although it is plausible that this structure is folded by the Kempie Bay Syncline (e.g. Coward, 1984). However, there were periods in the structural evolution of this part of the thrust belt when ductile shear was partitioned strongly onto the Moine Thrust, then distributed across the fold belt, then onto the Moine Thrust again. Thus the deformation has alternated between ductile and brittle styles.

Transect 4 – Creagan Road

(contributed by Rob Strachan, Bob Holdsworth and Ian Alsop)

This is a short traverse to examine the internal tectonostratigraphy of the mylonite belt (Figure 11.11) that occupies a high structural level in the Moine Thrust Belt (Barber & Soper, 1973; Soper & Wilkinson, 1975; Evans & White, 1984; Law *et al*., 1986; Holdsworth *et al*., 2006). The description here makes an interesting counterpoint to that for the Kempie transect in that the naming of thrusts and correlative approaches are different. This debate has continued since the work of Peach *et al*. (1907; see Barber & Soper, 1973). The traverse involves 2-3 hours of moderate walking on tracks and hillsides.

Park (with permission) adjacent to the entrance to Eriboll Estate at [NC 4323 5630], taking care not to block any gateways or entrances. There is sufficient space for a coach or four to five cars. Take the track (the 'Creagan Road') that leads southwards from the telephone box through a gate. Pause further on at a second gate to look northeastwards to the crags in the trees of steeply dipping Durness Limestone on the overturned limb of the Kempie Bay Syncline. After going through the gate, follow the fence southwards and then walk across the hillside to the low-lying crags that form Locality 11.4A [NC 4301 5577]. Here is exposed the tectonic lower boundary of the mylonite belt which is termed the Lochan Riabhach Thrust by Holdsworth *et al*. (2006). They propose that it is a late, out-of-sequence brittle structure that everywhere underlies the mylonite belt and is entirely distinct from the Moine Thrust that is exposed at a higher structural level. It is a sharp, gently-dipping fault that emplaces intensely deformed quartzo-feldspathic mylonites that are here interpreted to be of Lewisian origin onto largely undeformed and probably inverted Cambrian Salterella Grit. Small pips of carbonate lie along the thrust plane and are interpreted as detached slices of Durness Limestone. The thrust cuts obliquely across the inverted limb of the Kempie Bay Syncline, to rest discordantly on Durness Limestone in the stream section a few hundred metres to the southwest. Walk from here northeastwards, cutting uphill to the first hairpin bend in the Creagan Road. Continue along the track, passing outcrops of Cambrian Pipe Rock, the unexposed Lochan Riabach Thrust and, above that, further outcrops of Lewisian-derived mylonite between the second and third hairpin bends. Pass through a gate and continue along the track.

Locality 11.4B [NC 4356 5534] is by the track, where 'Oystershell Rock' mylonites are well exposed. These are platy, white mica-chlorite phyllonites with numerous lunate quartz segregations – the superficial resemblance of the latter to fossil shells gave rise to the informal term that has continued to be used for this lithology (Peach *et al*., 1907; Soper & Wilkinson, 1975; Holdsworth *et al*., 2001a, 2006). The protolith for the Oystershell Rock has long been considered as Lewisian (e.g. Barber & Soper, 1973; but see also Soper & Wilkinson, 1975). Holdsworth *et al*. (2001a) have confirmed a metamorphic protolith and a Lewisian one seems most likely. The phyllonites carry well-developed shear band fabrics (McClay & Coward, 1981) that indicate a top-to-the-west sense of displacement parallel to a locally developed mineral and extension lineation. Continue uphill, passing further outcrops of the Oystershell Rock, some containing early syn-mylonitization isoclinal folds ('F_2') that are refolded by asymmetric folds ('F_3'). Just beyond the telegraph poles, the track starts to flatten by low outcrops of Oystershell Rock [NC 4367 5525]. At this point, head across the hillside due east towards Am Feur Loch, walking over more low outcrops of Oystershell Rock. Pause at [NC 4388 5530] to view the loch and surrounding outcrops. The steep crags on the east side of the loch comprise in their lower part quartz mylonites derived most probably from deformation of the Eriboll Sandstone Formation. These are separated by what Holdsworth *et al*. (2006) and others before have interpreted to be the Moine Thrust from overlying mylonites derived from Lewisianoid basement. Exposures of the latter have a characteristic blotchy pale colouration due to greater amounts of lichen cover compared to the more homogeneous grey quartz mylonites.

Whilst there is agreement on the protolith of these quartz mylonites, the problem of their structural setting is central to current debate on the structural evolution of this part of the Moine Thrust Belt. According to Holdsworth *et al*. (2006), the quartz mylonites overlie an original (albeit highly tectonized) unconformity with the Lewisian protoliths of the Oystershell Rock, both of which are assigned to the Caledonian foreland (British Geological Survey 2002; Holdsworth *et al*., 2006). An alternative view, consistent with Butler's (1982) interpretation on Creag Shomhairle (see transect 1), is that the quartzites have been imbricated into the Oystershell Rock. This could mean that the Moine Thrust and the Lochan Riabhach Thrust described here are essentially the same structure repeated by displacement on a breach thrust. If this is the case, the Oystershell Rock need not be derived from the foreland, but could form part of the far-travelled Moine Thrust sheet.

Alternatively some or all of these contacts could be minor structures associated with distributed shearing, as found at the top of the Kempie area (transect 3).

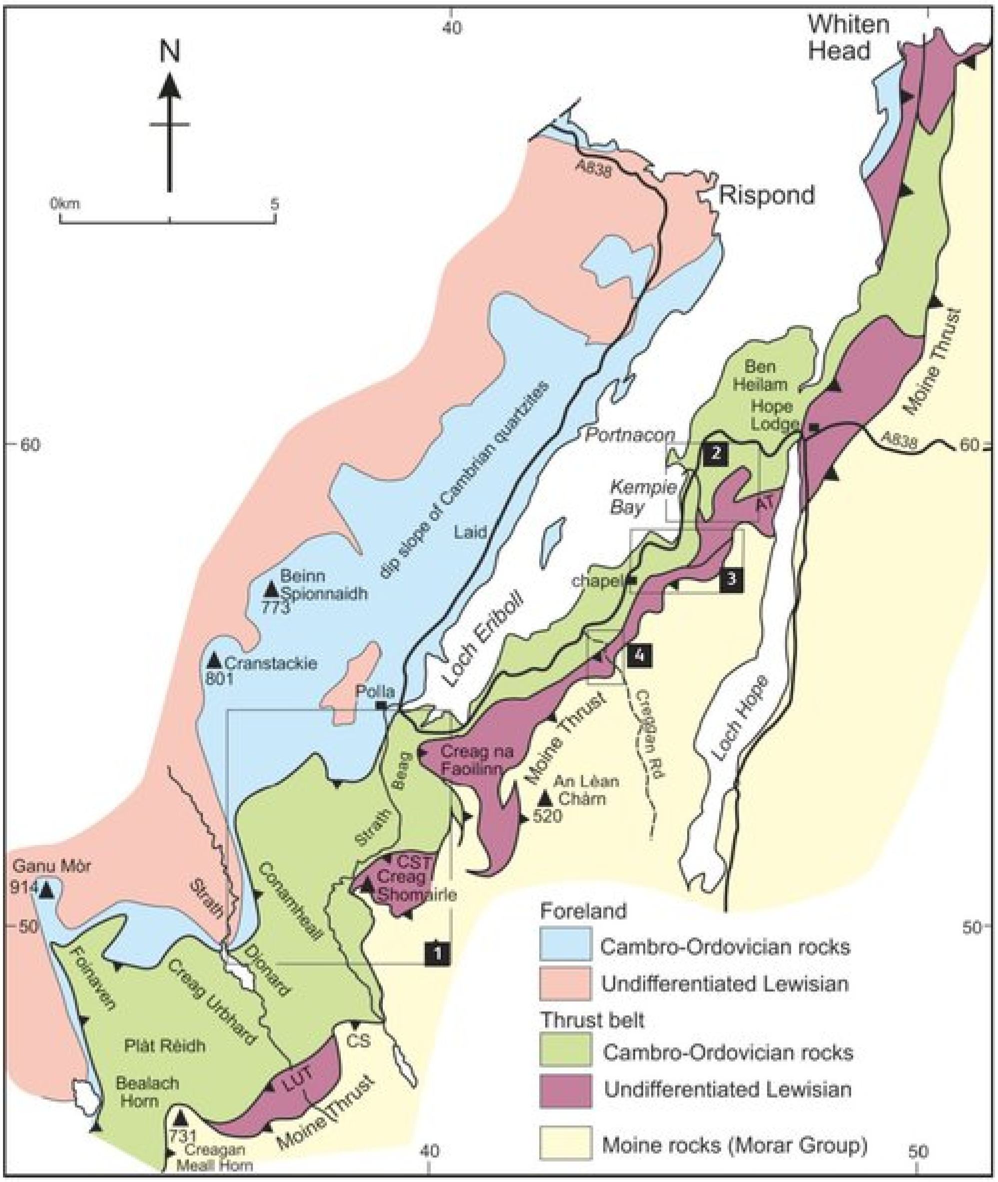
Walk to Locality 11.4C [NC 4395 5525] at the low crags to the north of the loch. The lowest exposures are spectacular quartz mylonites; an intense mylonite fabric dips gently to the ESE and carries a mineral and extension lineation that plunges down-dip. Asymmetrically sheared quartz veins indicate a top-to-the-west sense of shear parallel to the lineation. West-verging, open F_3 folds deform the mylonite fabric and associated lineation.

Quartz veins vary from intensely mylonitic to apparently undeformed. Some discrete thrusts are associated with late folds. Higher parts of the crags expose the Moine Thrust as a sharp contact between the white quartz mylonites and grey to cream coloured Lewisianoid-derived mylonites. The latter contain quartz, feldspar and mica, and lack the continuous banding that is a prominent feature of the quartz mylonites. The contrast between the evidently ductile nature of the Moine Thrust here, located within a broad belt of mylonites, and the brittle Lochan Riabhach Thrust, is the rationale for Holdsworth *et al*. (2006) regarding the structures as entirely separate and not the same thrust repeated by breaching.

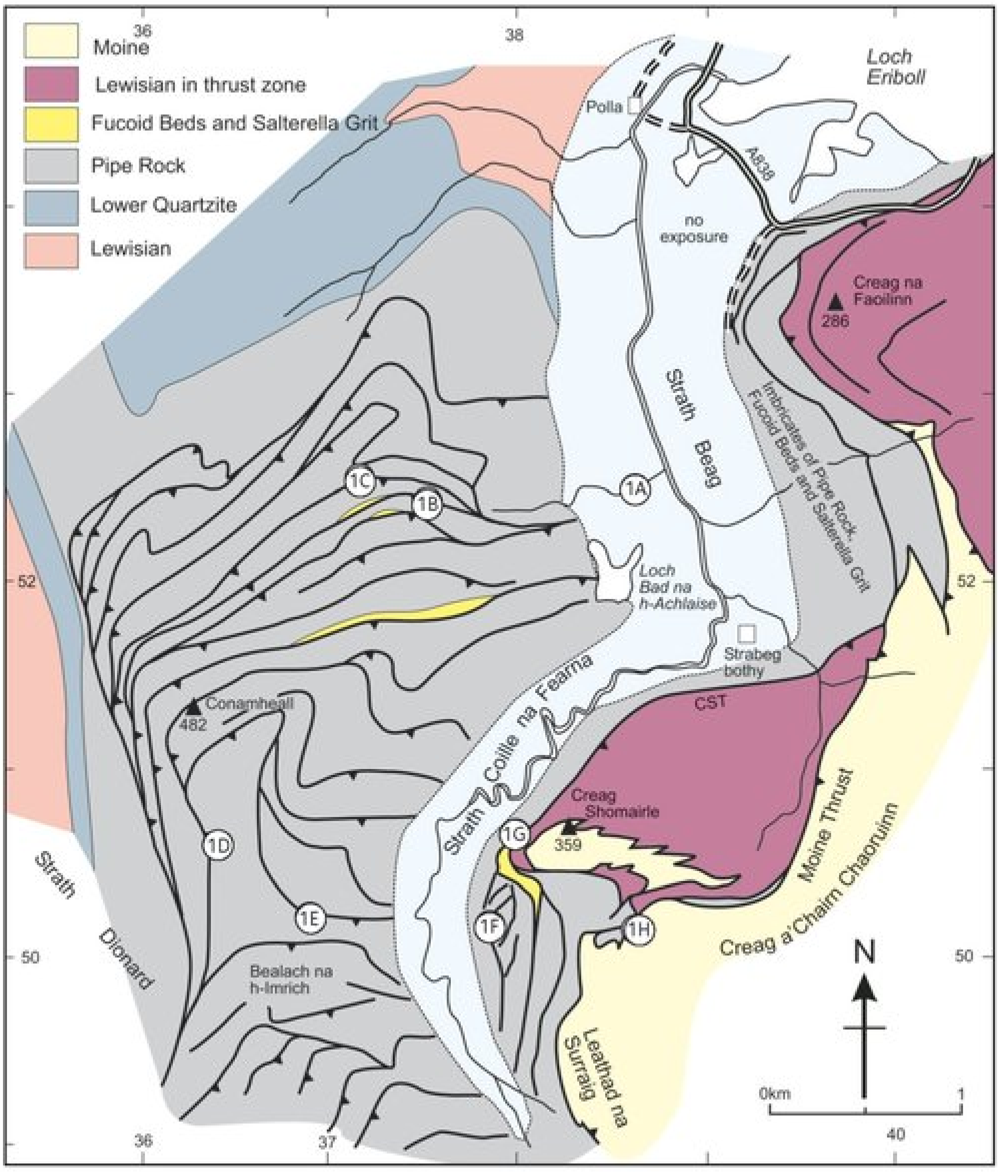
Head northwestwards upslope to small outcrops 50m away of quartz mylonite at Locality 11.4D [NC 4388 5545]. These expose excellent examples of F_3, tight-to-open, asymmetric S-folds of the mylonite fabric and associated lineation (Figure 11.12). Fold hinges are variably oriented: some are almost parallel to the lineation, others are normal to the lineation (Evans & White, 1984). Also visible are isolated F_2 isoclinal folds that formed during mylonitization; note that the mylonite fabric is appreciably more intense on the fold limbs than in the hinges. Numerous quartz veins are present, some elongated parallel to lineation. The F_2 and F_3 folds are interpreted as resulting from continuous, progressive deformation within the evolving mylonite belt (Holdsworth *et al*., 2006).

Splendid views may be had of Ben Hope and Ben Loyal to the east, and Cranstackie and the dip-slope of the Cambrian quartzites to the west. Return to the lochside and walk back down the Creagan Road to the vehicles, leaving all gates as you find them.

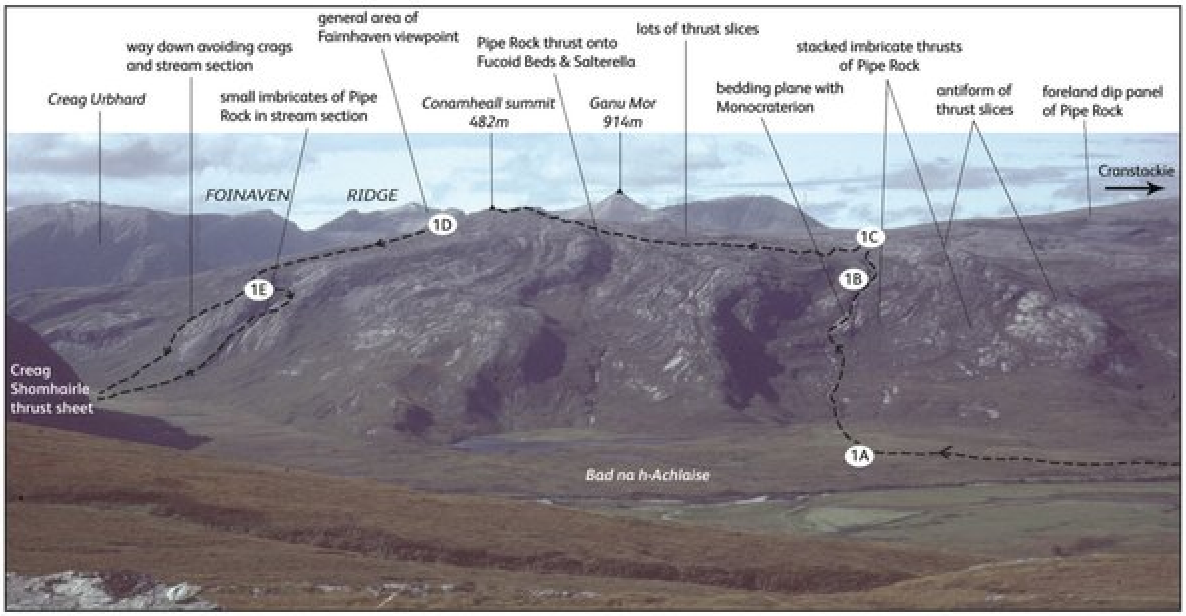
References



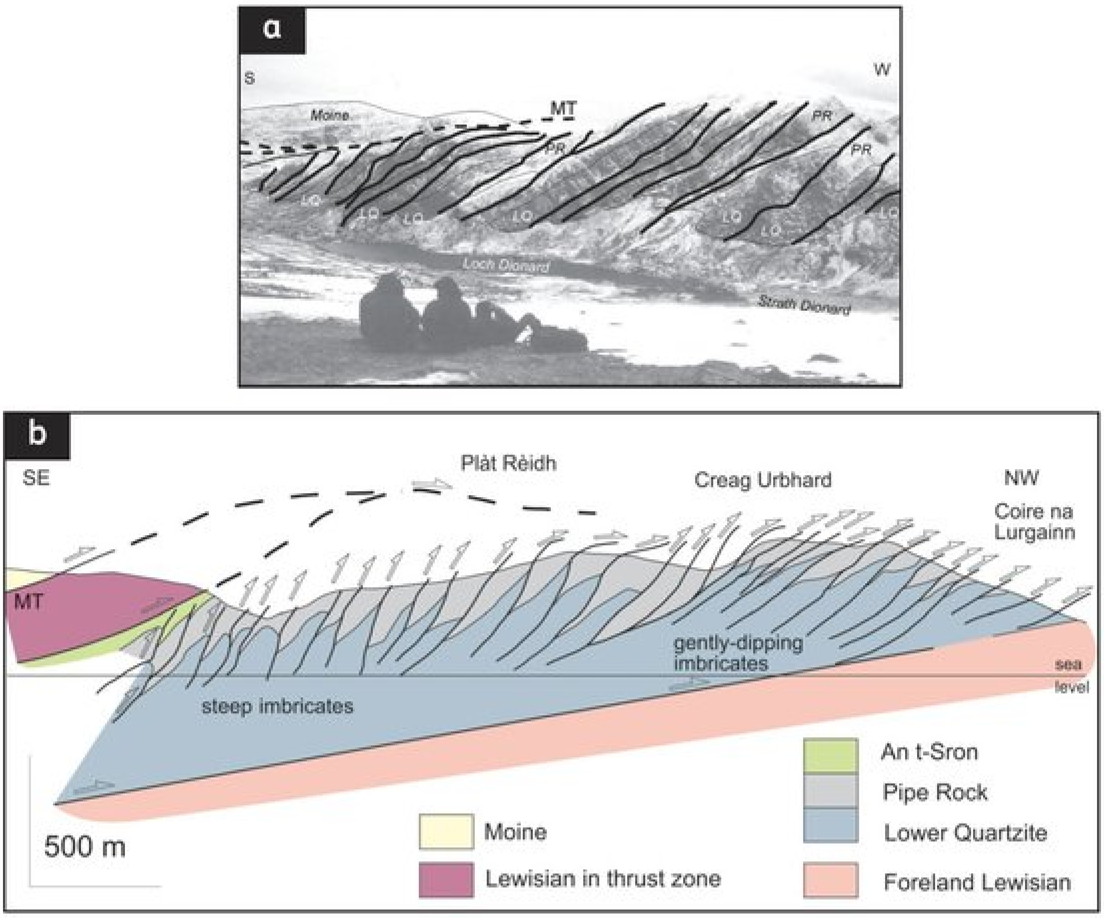
Simplified geological map of the northern part of the Moine Thrust Belt, in the vicinity of Loch Eriboll, Foinaven to Whiten Head. The sites of the four transects are indicated by boxed areas (1-4). AT = Arnaboll Thrust; CST = Creag Shomhairle Thrust.



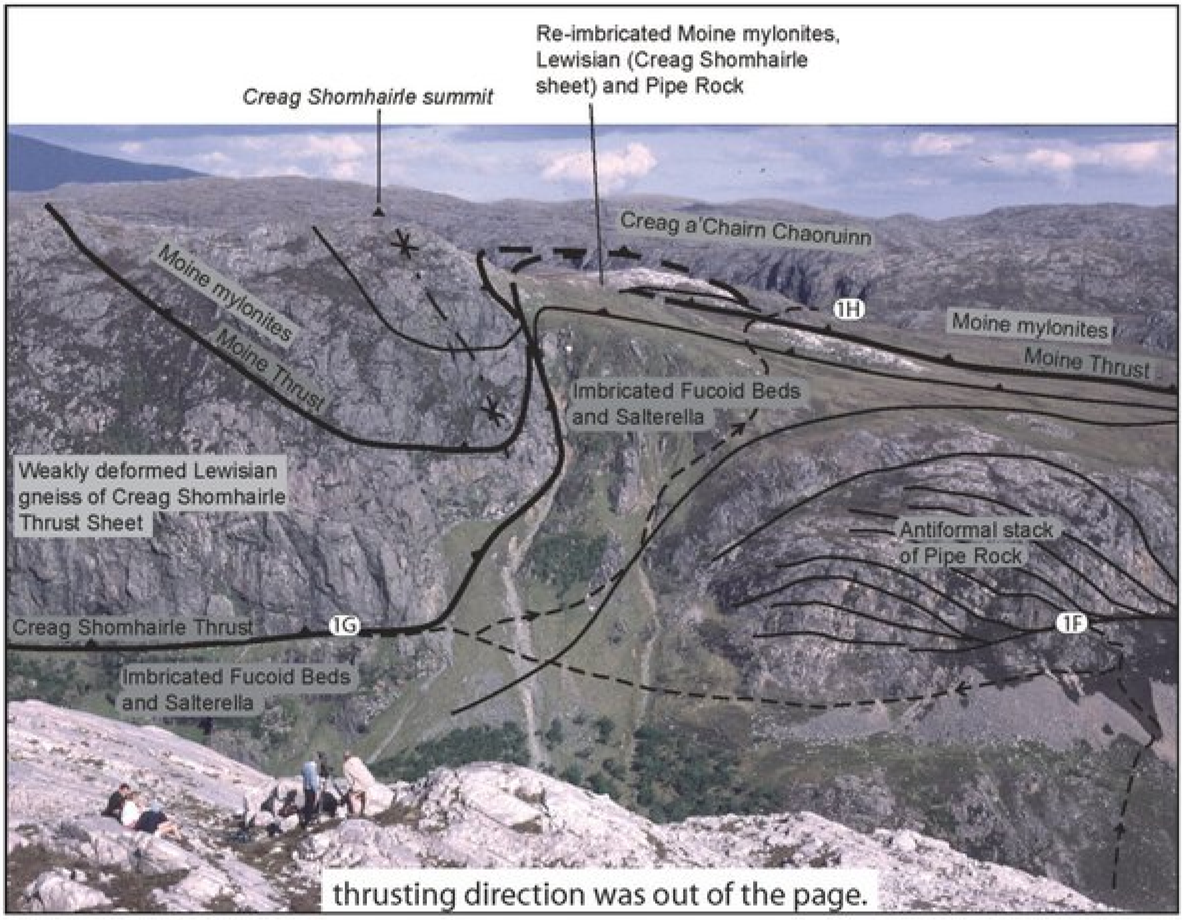
Simplified map of the south Eriboll district, showing the positions of sites visited on transect 1. Located as 1 on Figure 11-1. CST = Creag Shomhairle Thrust.



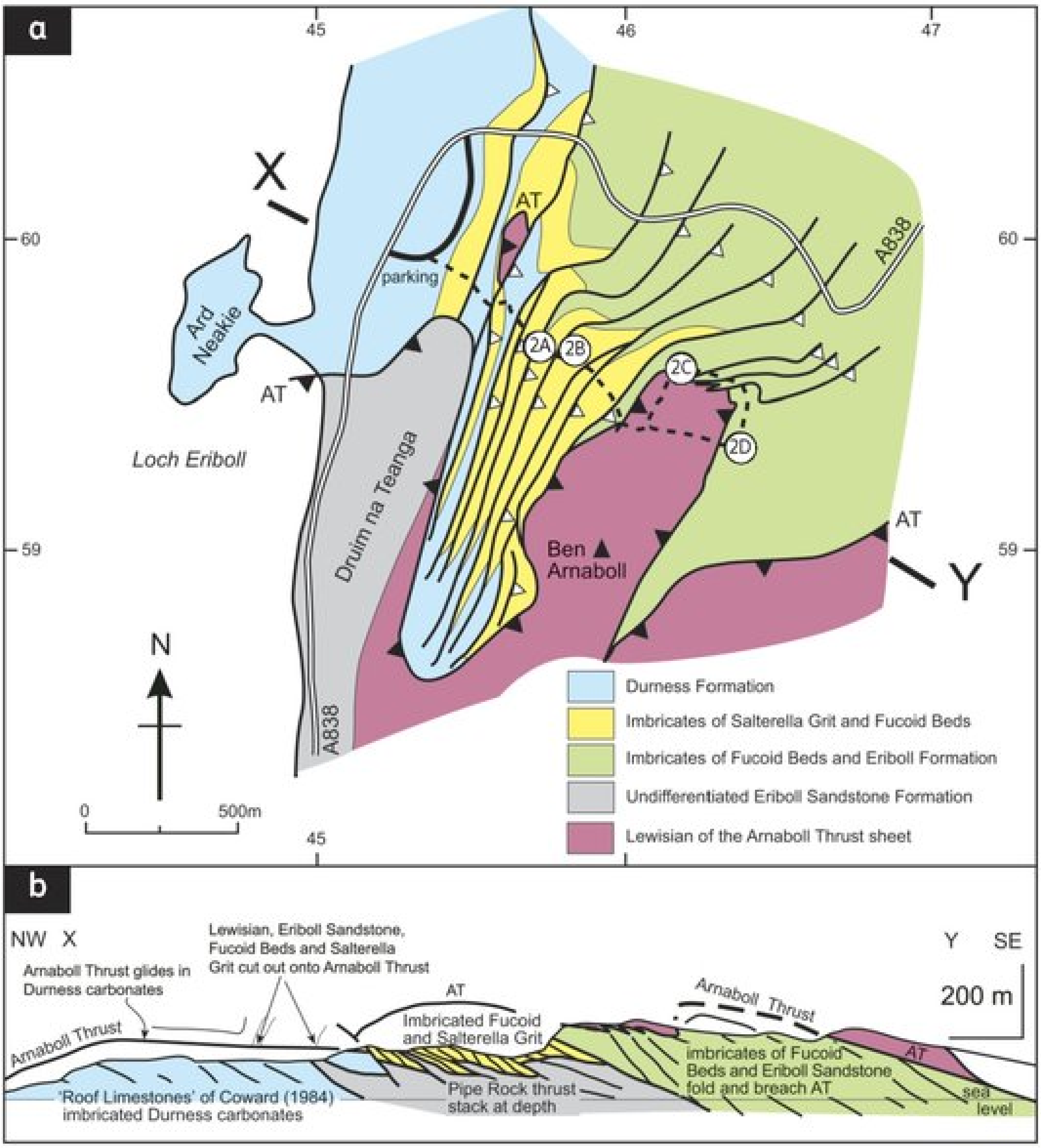
Annotated photograph view SW from slopes of An Lean Charn (e.g. [NC 406 526]) onto Conamheall – showing some of the outcrop locations from transect 1. (Note that this viewpoint is not part of the excursion, but can be visited readily by *hiking up from Strath Beag bothy or from the southern end of the Creag na Faoilinn crags. For photographs the best lighting is generally in the morning).*



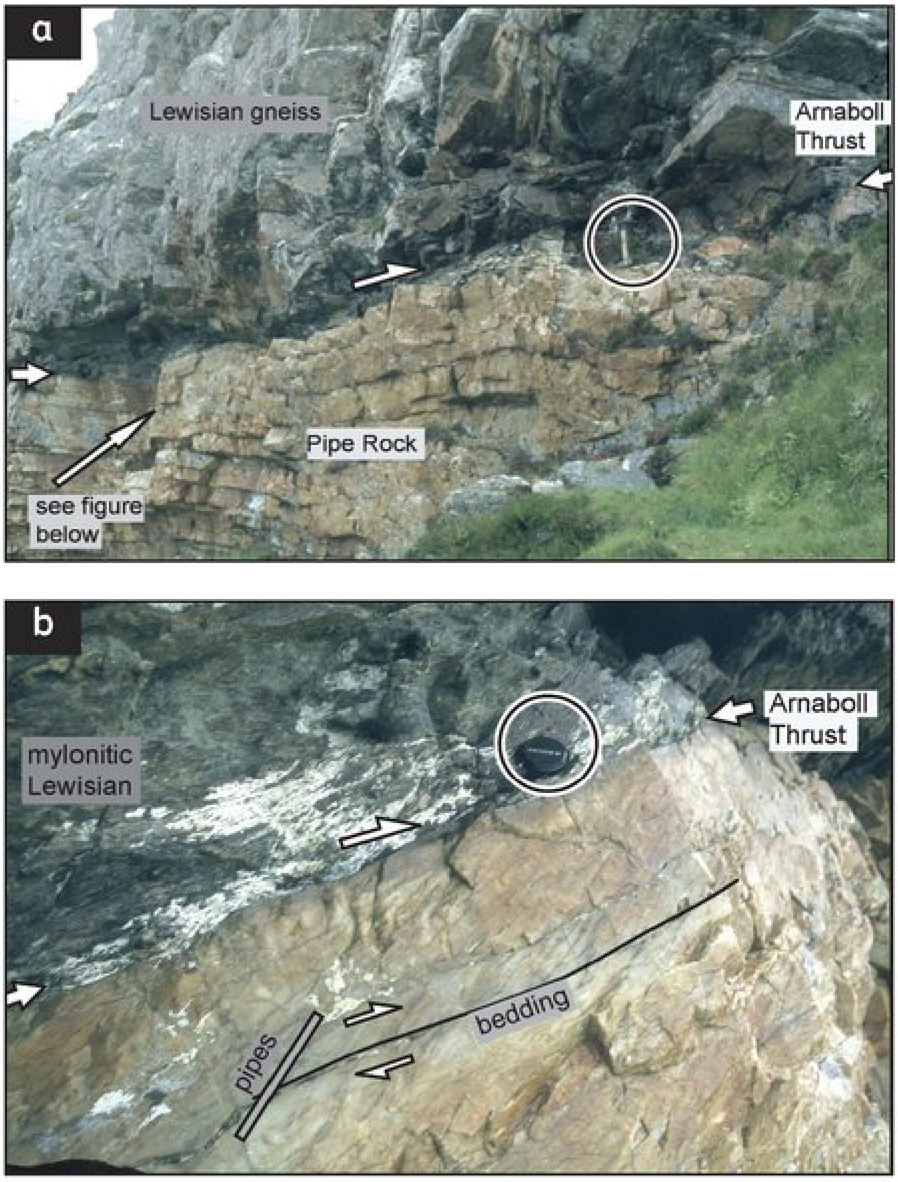
Annotated photograph (a) and cross-section (b) of the Foinaven-Meall Horn ridge, illustrating the imbricate structure of Cambrian quartzites. (after Butler, 2004b.) LQ = Lower Quartzites; PR = Pipe Rock; MT = Moine Thrust



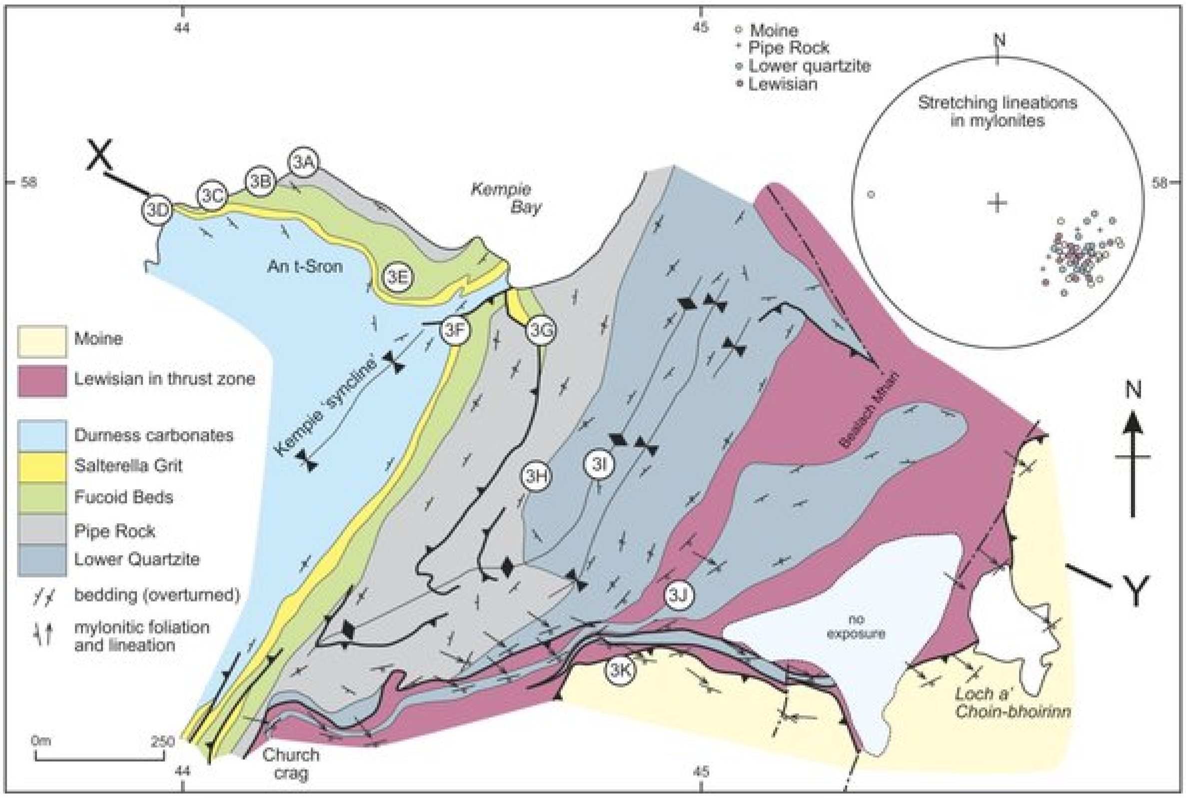
Annotated photograph of Creag Shomhairle (from Location 11.1E; after Butler, 2004b) showing the culminations in imbricated Cambrian strata that fold higher thrust sheets (Creag Shomhairle and Moine).



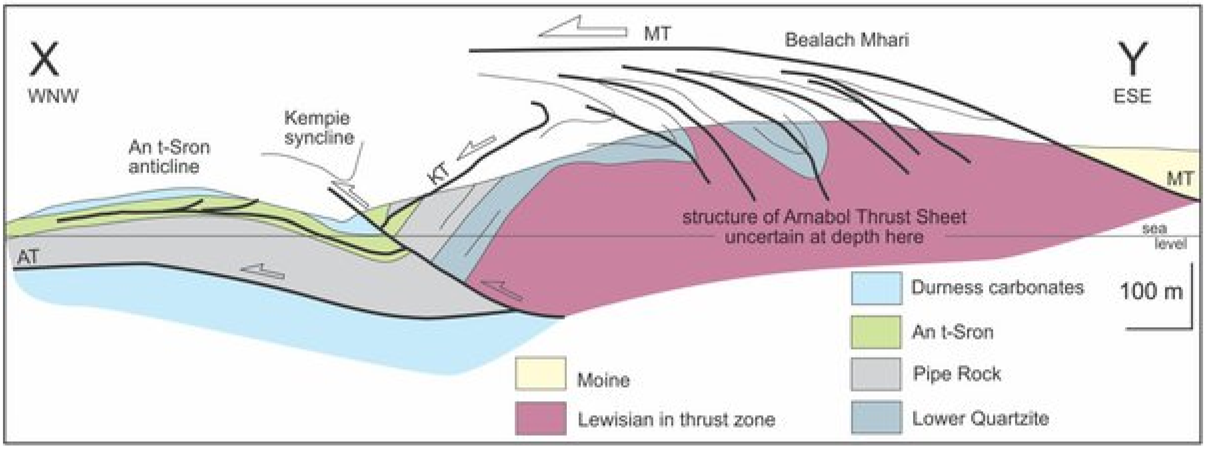
Simplified geological map (a) and cross-section (b) of the Arnaboll hill area. Modified after Coward, 1984 (but see recent interpretation by Wibberley & Butler, 2010, of the structural relations between Lewisian and adjacent quartzites). AT = Arnaboll Thrust.



The classic location (2C) of the Arnaboll Thrust and of Lapworth's (1883) mylonites: (a) general aspect of the thrust, carrying Lewisian gneisses onto Pipe Rock; hammer (circled) for scale (b) detail of the Arnaboll Thrust, showing deflected Skolithos (pipes) that indicate the sense of shear (top to WNW); scale from lens cap (circled)



Geological map of the Kempie area (modified after Butler et al., 2006). X-Y is the section line of (Figure 11.10).



Geology of transect 4 through the mylonite belt along the Creagan Road.

Simplified geological map of the Durness-Faraid head area (modified from British Geological Survey, 2002). MT = Moine Thrust.