Ard Hill

[NG 818 265]

A.J. Barber

Introduction

A 2 km-long coastal section along the northern shore of Loch Alsh at Ard Hill, Balmacara, exposes Torridonian sandstones of the Kishorn Nappe and overlying Lewisian gneisses of the Balmacara Nappe, juxtaposed along the Balmacara Thrust (Figure 5.57).

Feldspathic sandstones of the Torridon and Sleat groups are found in the west of the Lochalsh area. These rocks lie within the Kishorn Nappe, the lowest and most westerly of the thrust slices that make up the southern part of the Moine Thrust Belt. The Kishorn Thrust that underlies the nappe can be traced from Loch Kishorn to Skye, and its trace lies offshore to the west of Lochalsh (Bailey, 1955). The Torridonian rocks define a large-scale recumbent syncline, the Lochalsh Syncline, which has an E-dipping axial plane. The axial trace trends north–south and passes through Kyle of Lochalsh (Figure 5.52), so that over most of the Lochalsh area the overturned, eastern limb is exposed (Bailey, 1939; Coward and Potts, 1983). The core of the fold is occupied by sandstones of the Applecross Formation, which contain a spaced cleavage. These are structurally overlain by a gently dipping inverted succession of cleaved siltstones and sandstones of the Sleat Group, which become increasingly deformed towards the east.

East of Balmacara the deformed and locally mylonitic sandstones of the Kishorn Nappe are overlain by mylonitized Lewisian gneisses of the Balmacara Nappe. The intervening Balmacara Thrust is exposed in the shore section on the western side of Ard Hill (Figure 5.56) and is the focus of the GCR site. The Balmacara Nappe is much smaller than the Kishorn Nappe and consists mainly of Lewisian gneisses, with only minor amounts of Torridonian strata (Figure 5.52). Near Ard Hill the nappe has an outcrop width of about 2 km, but it pinches out both to the north-east near Strath Ascaig, and to the south beneath Loch Alsh. The 'roof thrust' to the Balmacara Nappe, the Moine Thrust, is not exposed along the coast, but crops out farther north at Hangman's Bridge (see GCR site report, this chapter).

The Lochalsh area was mapped by B.N. Peach and J. Horne in 1892–1893, as part of the primary geological survey of Scotland. The 1:63 360 map (Sheet 71) was published in 1909 (Geological Survey of Scotland, 1909), closely followed by the sheet memoir (Peach *et al.,* 1910). Bailey (1939, 1955) subsequently published a structural interpretation of the Moine Thrust Belt in Skye and Lochalsh based on the Geological Survey mapping. The Ard Hill area was remapped by A.J. Barber (1965, 1968) as part of a wider PhD study. Subsequently Coward and Whalley (1979) and Potts (1982, 1983) studied the microstructural development of the deformed Torridonian sandstones.

Description

Ard Hill forms a low rounded peninsula on the northern shore of Loch Alsh to the south of the A87 road. On its eastern and western sides the peninsula is surrounded by a wave-cut platform with raised beaches and cliffs with caves in which Torridonian and Lewisian mylonites are very well exposed. Mylonitic Torridonian sandstones are exposed on the western side of Ard Hill; mylonitic Lewisian gneisses on the east side. The mylonites are brecciated and brought together along the Balmacara Thrust, which is exposed in a raised cliff near the point of the headland (Figure 5.57).

In the Torridonian sandstones, a new foliation that dips uniformly east at *c.* 20° has been strongly overprinted on the bedding, giving the rocks a pervasive flaggy parting. Freshly broken foliation surfaces are covered by a thin film of glossy white mica and green chlorite, suggesting the foliation formed under greenschist-facies metamorphic conditions. A strong ESE-plunging penetrative mineral lineation defined by the elongation of small crystals and aggregates of quartz, feldspar, chlorite and white mica is developed. On some foliation surfaces the lineation has a similar appearance to slickensides. Few obvious folds relate to the lineation, although the axes of a few small vague folds within the foliation and some folded en echelon tension gashes plunge in the same direction.

Immediately below the Balmacara Thrust, asymmetrical folds with horizontal N-S-trending axes and a westerly vergence fold the mylonitic foliation and the associated lineation. The folds are tight with attenuated limbs and thickened, rounded hinges and amplitudes of between 2 m and 6 m. An associated axial-planar fracture/ spaced cleavage, which in parts is outlined by quartz veins, dips eastward more steeply than the mylonitic foliation. Fold limbs are commonly sheared along the cleavage and may be attenuated to the point where antiforms are juxtaposed and the intervening synform excised. A N-trending intersection lineation is also developed, and relict feldspars may be elongated parallel to this secondary lineation.

Where tight folds of the mylonitic Torridonian sandstones are absent, small-scale kink-folds are notably abundant. The folds range in amplitude from 1 cm to several metres and have interlimb angles of 90° or more. The hinges are sharp and angular with no limb attenuation or hinge thickening, and the folds are commonly fractured along their axial planes. Locally, conjugate kink-folds are present.

Mylonitic Lewisian gneisses in the hanging-wall of the Balmacara Thrust are well exposed in the shore section at the southern point of the headland and all along the east coast. The mylonites are typically pink, green and grey, finely laminated, extremely fine-grained rocks. The laminae range in thickness from millimetres to centimetres and represent attenuation of the original gneissic compositional layering. Alternating grey, white and pink layers represent quartzofeldspathic gneiss protoliths with thicker layers or lenses present where the mylonites were derived from coarse-grained pegmatites (Figure 5.58). The contrasting thin dark-green to black layers are rich in chlorite, epidote and iron oxides and represent hornblendic or biotite-rich gneiss protoliths. Large relict crystals of feldspar, hornblende and epidote commonly form augen structures. Mafic bodies are generally retrograded to chlorite schist, but larger bodies may preserve cores of the original amphibolite, with hornblende crystals showing cataclastic textures [NG 820 263].

The mylonitic layering in the gneisses dips generally eastwards, but minor later folding results in variations in dip and strike. A pervasive foliation defined by white micas, chlorite and quartz is developed generally parallel to the banding. In parts the layering is folded by millimetre- to metre-scale, tight to isoclinal minor folds with gentle ESE-plunging axes and accompanied by a pervasive mineral lineation.

As in the Torridonian mylonitic rocks, the early-formed structures are folded by asymmetrical, W-vergent folds, examples of which are well exposed on the shore platform on the eastern side of Ard Hill. In places refolded isoclines can be seen. The secondary folds are open in style, with fold axes that generally plunge to the south or south-east. Sharp angular 'ripples' in the foliation define a linear structure, and, more rarely, a quartz-feldspar rodding is developed parallel to the fold axes. Axial planes generally dip eastwards at a steeper angle than the foliation. A fracture cleavage is developed parallel to the axial planes and may contain quartz veins.

Large numbers of small-scale kink-folds, from metres to millimetres in size, are found throughout the Lewisian-derived mylonite outcrop. The abrupt changes in the dip of the foliation, for example the steep dips in the mylonite immediately above the Balmacara Thrust plane, may reflect large-scale folds of this type. The structures are similar to those described from the Torridonian-derived mylonites, but are much more abundant and range down in size to small ripples, reflecting the more finely laminated nature of the Lewisian-derived mylonites. Fold-axis orientations are extremely variable; individual fold hinges may curve some 40° on foliation surfaces and may diverge or converge, with interference effects where hinges cross each other. Conjugate kink sets are common. Kink folds occur less commonly where mylonites are affected by asymmetrical folds, but in places the kink folds affect the well-developed axial-plane cleavage in these folds, confirming that the kink folds were formed later.

The Balmacara Thrust that separates the Torridonian- and Lewisian-derived mylonites is exposed on the western side of Ard Hill, in the raised cliff close to the southern point of the headland [NG 818 263]. The thrust plane can be followed northwards from Ard Hill to the scarp face of Sgurr Mòr [NG 821 282] (Figure 5.52), (Figure 5.57). The thrust plane dips eastwards at *c.* 30°, but below the thrust the mylonitic foliation in the Torridonian dips uniformly eastwards at *c.* 20°, so that the thrust transects the foliation. The mylonitic foliation in the Lewisian-derived mylonites above the thrust is highly folded and vertical in places, so that the thrust cuts across the foliation in the Lewisian at a high angle and transects large-scale folds. In the cliff face, the thrust is marked by a 3–5m-wide zone of yellow-weathered gouge and breccia, containing fragments of mylonite up to 30 cm in size, mainly of Lewisian origin but also with minor Torridonian input.

Interpretation

The earliest Caledonian structure recognized in the Moine Thrust Belt in Lochalsh is the Lochalsh Syncline, a kilometre-scale fold, overturned towards the west. Kanungo (1956) related the generation of quartz-filled tension-gash sets, commonly found in the Torridonian sandstones near the hinge, to fold formation. A coherent axial-planar pressure-solution cleavage is developed in the core of the fold, but farther east in the inverted limb the bedding is transposed into a mylonitic foliation. The foliation is axial planar to folds that affect the quartz tension-gashes, suggesting that myloniti-zation occurred at a late stage in the development of the Lochalsh Syncline.

The structural features of the Lewisian-derived mylonites, namely compositional lamination, foliation, tight to isoclinal folding and ESE-plunging extension lineation, all suggest that the mylonites were developed during significant WNW translation in the thrust belt. The fabrics and mineralogy of the Torridonian-derived mylonites suggest that this predominantly ductile deformation occurred under greenschist-facies conditions at temperatures of 300°–400° C and depths of *c.* 15 km.

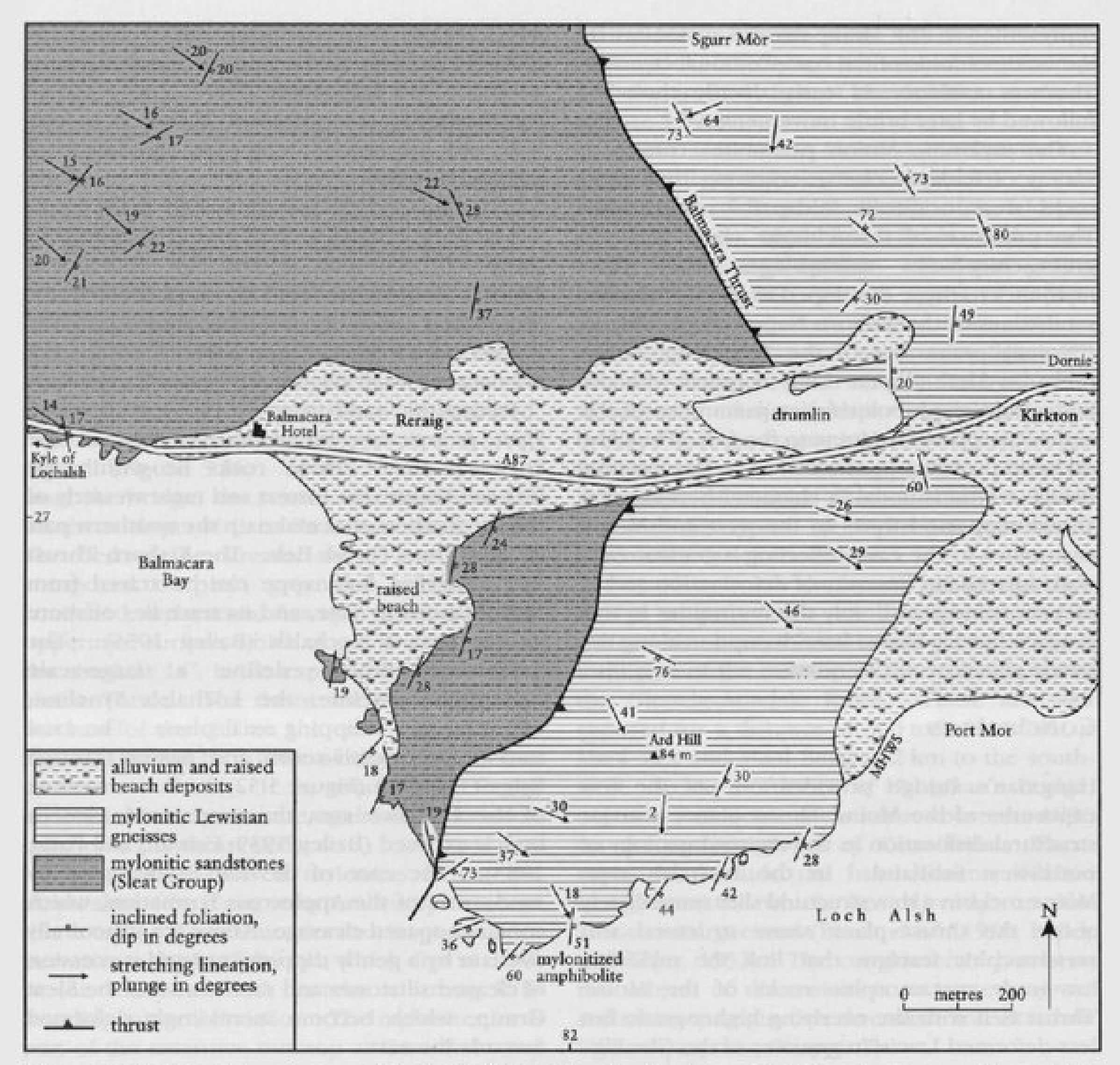
Continued east-west compression resulted in the formation of a secondary cleavage in the siltstones of the Kinloch Formation and asymmetrical folds in the Torridonian- and Lewisian-derived mylonites of Ard Hill. This secondary cleavage dips more steeply than bedding and the sub-parallel mylonitic foliation on the inverted limb of the Lochalsh Syncline. The asymmetrical folds have a westerly vergence (S-profile looking north), incompatible with their position on the inverted limb of the syncline. Hence, the cleavage and asymmetrical folds were superimposed on the already inverted limb of the Lochalsh Syncline and on the mylonites. The limited degree of associated recrystallization and strain-slip and fracture cleavages indicate that deformation occurred under lower metamorphic temperatures and pressures, signifying progressive uplift and exhumation during thrusting. The presence of kink folds testifies to a later and yet more-brittle phase of deformation.

The final stage of deformation in this area generated the Balmacara Thrust, which in its present form cross-cuts the mylonite zone but juxtaposes Lewisian-derived mylonites onto uniformly dipping Torridonian-derived mylonites. The thick zone of breccia along the thrust plane indicates that movement occurred under very shallow conditions, possibly at depths of only 1 km or so. The predominance of Lewisian blocks in the breccia zone reflects the considerable angular discordance between the thrust plane and the foliation in the Lewisian-derived mylonites.

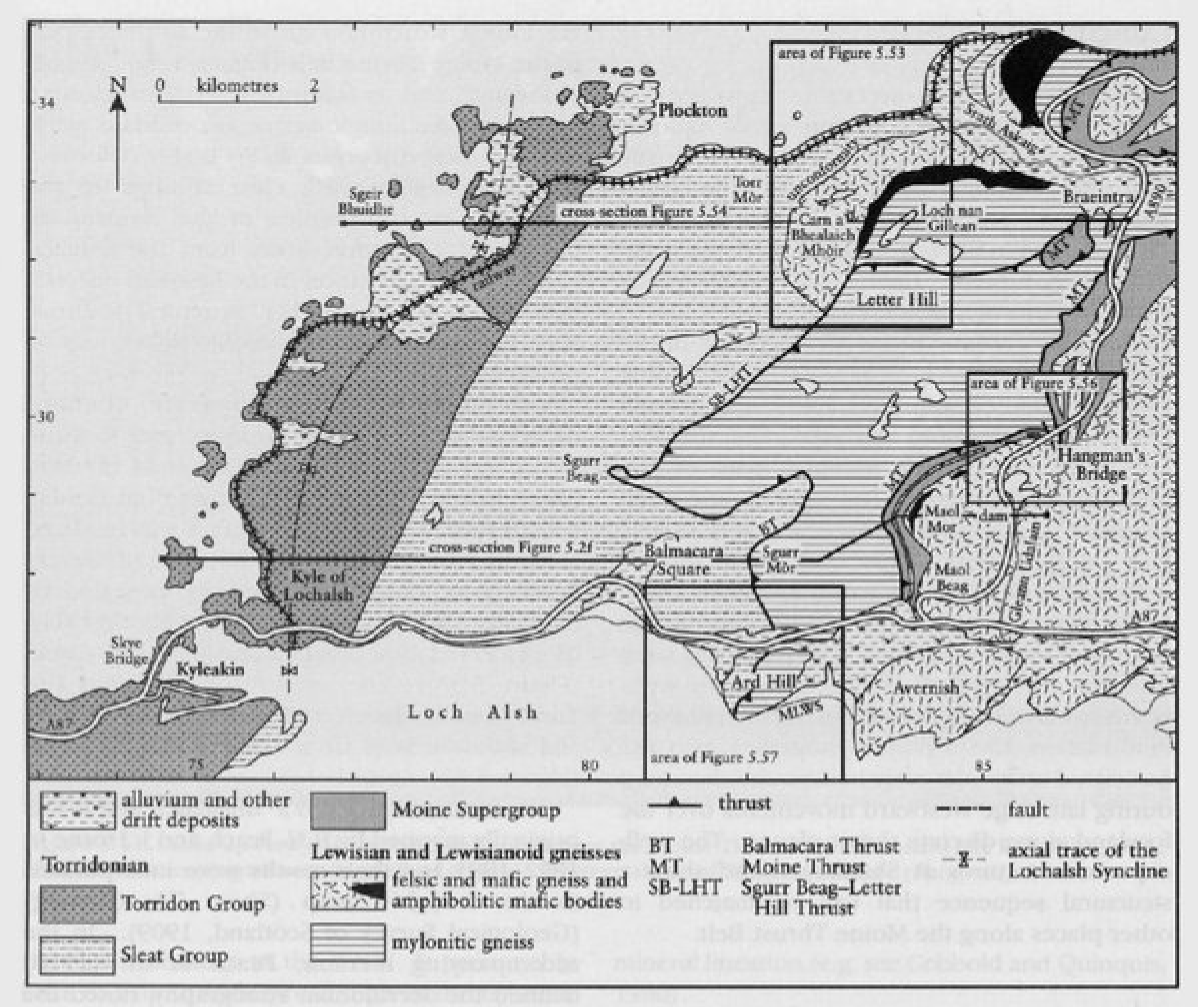
Conclusions

The Ard Hill GCR site provides excellent exposures of the Balmacara Thrust and both footwall and hangingwall mylonites derived from Torridonian sandstones and Lewisian gneisses respectively, clearly demonstrating the complex nature of the structural history of the southern Moine Thrust Belt. Mylonite formation is related to the generation of the Lochalsh Syncline, which dominates the geological structure of Lochalsh and southern Skye. Two subsequent fold phases can be recognized in the mylonites, and their geometry and related fabrics show that renewed westward movements occurred under progressively lower temperatures and pressures during exhumation of the Moine Thrust Belt. The Balmacara Thrust, which carries the Balmacara Nappe over the inverted limb of the Lochalsh Syncline, represents a more-brittle phase of deformation that terminated movements in this part of the thrust belt. The site is of national importance and remains suitable for teaching and for further work.

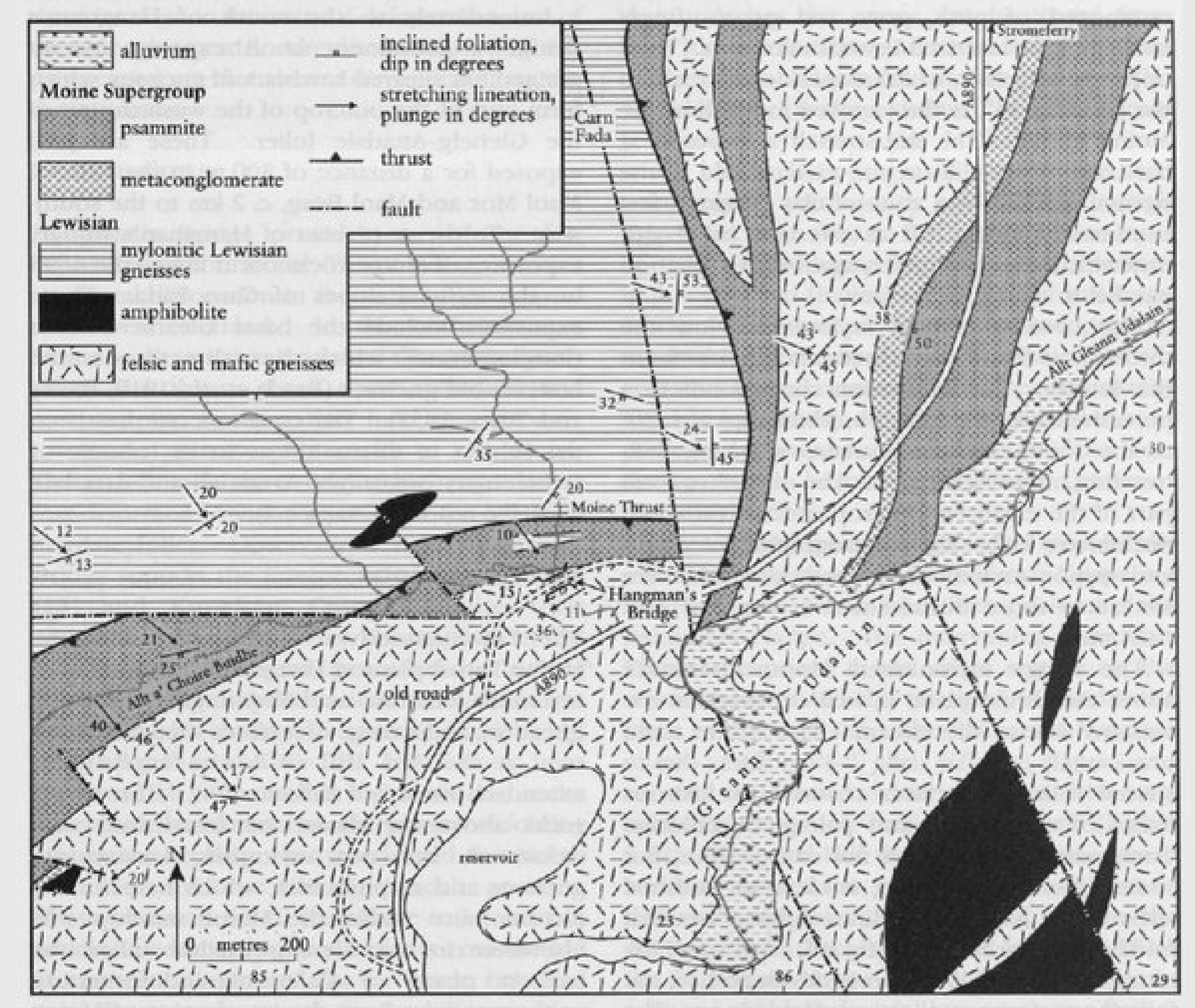
References



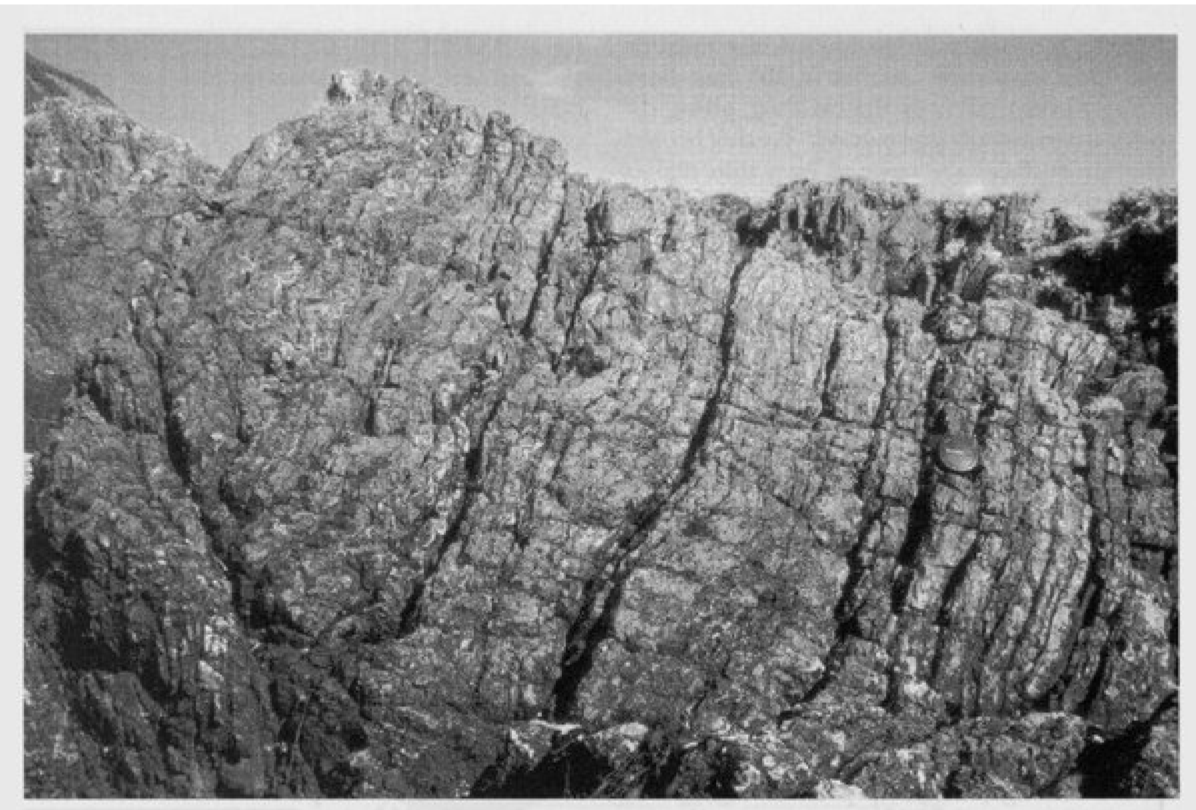
(Figure 5.57) Map of the area around the Ard Hill GCR site. The location of this figure is shown on Figure 5.52.



(Figure 5.52) Map of the Lochalsh peninsula, showing the overall geology. Positions of Figures 5.53, 5.54, 5.56 and 5.57 are indicated. Based on Barber and May (1976) and Institute of Geological Sciences (1976a). Trace of Lochalsh Syncline after Coward and Potts (1985).



(Figure 5.56) Map of the area around the Hangman's Bridge GCR site. The location of this figure is shown on Figure 5.52.



(Figure 5.58) Laminated mylonite with alternating quartzofeldspathic and chloritic (dark) laminae, derived from layered Lewisian gneiss, Moine Thrust Zone, southern point of Ard Hill, Lochalsh. (Photo: A.J. Barber.)