Dornie–Inverinate Road Section (A87)

[NG 883 258]–[NG 906 231]

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Introduction

The Dornie–Inverinate Road Section provides a highly accessible and well-exposed section through both the Western and Eastern units of the Lewisianoid Glenelg–Attadale Inlier and across the intervening shear-zone. Along strike it can be demonstrated that lenses of Moine metasediments were incorporated into this shear zone, indicating that at least the final juxtaposition of the two Lewisianoid units occurred after Moine deposition. The GCR site demonstrates the range of lithologies and structural features within the two rocks units. The site contains structures that are common to both Moine and Lewisianoid rocks and hence must post-date deposition of the Moine succession in the early Neoproterozoic. Examples of the Lower Devonian suite of lamprophyre dykes are found in the section. These relate to the Ratagain Pluton, which outcrops on the south-west side of Loch Duich. Dykes of the widespread Late Carboniferous camptonite–monchiquite suite are also seen (May *et al.,* 1993).

In the 1950s there was a major controversy among Highland geologists concerning the nature of inliers of Lewisianoid rocks within the Caledonian mountain belt, east of the Moine Thrust Belt. Some workers maintained that gneissose Lewisianoid rocks in the central part of the Northern Highlands, at Fannich, Scardroy and Monar, were an intrinsic part of the Moine stratigraphical succession (Sutton and Watson, 1953, 1954; Ramsay, 1954), rather than basement gneisses, as proposed by the earlier work of the Geological Survey (Peach *et al.,* 1913). This controversy was resolved by studies in the Glenelg–Attadale Inlier on the western margin of the mountain belt, where clear contrasts between the lithologies, structures and geological histories of the Lewisianoid gneisses and the surrounding metasedimentary Moine rocks were recognized (Peach *et al.,* 1910; Clifford, 1957; Ramsay, 1957b; Sutton and Watson, 1958; Sanders, 1972; Barber and May, 1976; Barber *et al.,* 1978; May *et al.,* 1993). The Dornie–Inverinate Road Section was described in detail by Barber and Soper (1973) and by Barber *et al.* (1978). It has been studied more recently by Storey (2002). Although the Archaean age of most of the Lewisianoid gneisses is now accepted, the relationship between the Western and Eastern units is not yet fully understood (e.g. see Storey, 2002; Storey *et al.,* 2004).

Description

A good section is provided by the exposures along the Dornie–Inverinate Road Section between Eilean Donan Castle at Dornie and the bridge across the An Leth Allt at Inverinate (Figure 7.14). The shear zone between the Western and Eastern units occurs about 800 m south-east of Eilean Donan Castle; the Western Unit is exposed for about 1 km north-west from here, whereas the Eastern Unit is exposed for some 3 km to the south-east. The Western Unit consists predominantly of pale-grey and pink, layered hornblende- and biotite-bearing felsic gneisses. The gneissose layering and foliation dip moderately to steeply to the east and a mineral lineation plunges to the north-east. Amphibolite occurs as thin layers, irregular clots, or thicker sheets within the gneisses, and pods of ultramafic rock are also present. An ultramafic pod, a few metres across, composed of a mass of randomly arranged dark-green actinolite crystals, occurs near the castle [NG 883 259]. The felsic gneisses are interlayered with large lenticular bodies of pink homogeneous granodioritic gneiss, representing felsic intrusions, and black and white speckled amphibolite, representing mafic intrusions. Within a *c.* 50 m-thick amphibolite mafic sheet at [NG 885 254], is a prominent white layer of coarse-grained meta-anorthosite, a few metres thick. It is composed largely of plagioclase with secondary epidote and garnet-pyroxene streaks, partly altered to amphibole (Barber *et al.,* 1978). The relict granulite-facies assemblages present in this large mafic sheet provide evidence of an early granulite-facies metamorphic event, which pre-dated the pervasive retrogressive amphibolite-facies metamorphism of the inlier.

About 1 km to the south-east of the castle at [NG 887 252], there is a rapid transition from Lewisianoid gneisses, through badly weathered material, into mica-schist with a pervasive E-dipping schistosity. The schist contains *c.* 30 cm-long

amphibolite lenses and small, scattered, white feldspar augen, and is interpreted as a 'tectonic schist', marking a major shear-zone developed under amphibolite-facies conditions. The shear zone that separates the Eastern and Western units, extends for over 4 km to the north-east where it joins the main outcrop of the Moine near Loch Long, and for over 12 km south-westwards through Glenelg to Loch Hourn (Figure 7.2). The nature of the rocks in the shear zone varies considerably along strike. They include lenses of Moine psammite, schistose pelite and semipelite with deformed pebbles, representing the basal meta-conglomerate and basal semipelite of the Moine succession, and lenses of migmatitic gneiss and amphibolite, derived from the underlying Western Unit. Large lenses of felsic and mafic Lewisianoid rocks occur within the shear zone at Creag nan Spor [NG 891 262], and lenses of Moine psammite and semipelite occur at Creag nan Carrachan [NG 898 266] (Figure 7.14).

South-east of the shear zone is the Eastern Unit of the Glenelg–Attadale Inlier. Like the Western Unit, the Eastern Unit consists predominantly of hornblende- and biotite-bearing felsic gneisses, but it also includes a great variety of other rock-types, mainly of sedimentary origin, such as metacarbonate rocks ('marbles), kyanite-bearing gneissose pelites, graphite schistose pelites and iron-rich rocks. It also includes mafic and ultramafic meta-igneous rocks, now amphibolite and eclogite (see Totaig GCR site report, this chapter). In the road section, the tectonic schist passes rapidly south-east into blastomylonitic gneiss. The blastomylonite is layered on a millimetre- to centimetre-scale with alternating felsic and mafic layers, enclosing augen of garnet and feldspar porphyroclasts and rock fragments. At road level, the blastomylonitic layering is seen folded into long-limbed isoclinal folds. Adjacent to the contact with the schist, the layering is concordant with the schistosity, but within a few tens of metres it is folded on the scale of tens of metres, as seen in the road cutting at [NG 888 249]. The resultant folds have vertical axial planes and E-plunging axes, but are refolded on horizontal axial planes. In the lower part of the cliff, folded mylonites are cut by quartzofeldspathic veins, which themselves are folded in the upper part of the cliff.

To the south-east, the blastomylonites pass gradually into fine-grained felsic gneisses with thin layers of amphibolite, still strongly folded on E-plunging fold axes, with mullions and folded rods exposed in the cliff face [NG 896 242]. Similar outcrops are well exposed farther to the NNE on Creag nan Spor (Figure 7.15). The gneisses enclose mafic lenses and rounded bodies of coarser amphibolite and eclogite. Outcrops of forsterite-bearing metalimestone ('marble'), some with diopside nodules, and calc-silicate rocks occur in the grass slopes adjacent to the road below Carr [NG 894 244] and [NG 902 237]), and more extensively in the hill-slopes above the road (Figure 7.16). A 1 m-thick diopside-rich calc-silicate layer forms a vertical reaction zone between pink meta-limestone ('marble) and quartzofeldspathic gneiss in the cliff at [NG 896 242]. The southeastern part of the section is composed predominantly of garnetiferous biotite-kyanite pelitic gneiss. The presence of kyanite suggests an origin as aluminous muddy sediments and attests to high-pressure metamorphism (see also Druim Iosal GCR site report, this chapter). At [NG 905 233] garnetiferous kyanite-biotite gneissose semipelites are interfolded with hornblendic quartzofeldspathic gneisses. In places the gneissose semipelites contain veins of white quartz-feldspar pegmatite. Pegmatites concordant with the foliation are typically recrystallized, whereas cross-cutting pegmatites are folded or broken up into boudins; in one instance boudins pass around a fold in the layering, suggesting that the pegmatite was affected by two phases of deformation.

An ENE-trending brick-red lamprophyre dyke cuts the shear zone in the road section at [NG 887 252]. It belongs to the radial swarm related to the Silurian-age Ratagain Pluton, which outcrops on the south-western side of Loch Duich (Nicholls, 1951; May *et al.,* 1993). Two NE-trending, vertical basalt dykes with xenoliths, belonging to the late Carboniferous camptonite-mochiquite swarm cross-cut the Western Unit at [NG 884 257].

Interpretation

The Dornie–Inverinate Road Section GCR site provides a continuous outcrop across the two units of the Lewisianoid Glenelg–Attadale Inlier and the intervening shear-zone. The Lewisianoid basement contains relics of its pre-Caledonian history, demonstrating that it represents continental fragments of different origins, ages, and with varied metamorphic and structural histories. It also demonstrates the extent to which the basement was subsequently deformed and metamorphosed, first during the Knoydartian event, and later during the Caledonian Orogeny.

Both the Eastern Unit and the Western Unit have been metamorphosed to very high grades: the Eastern Unit under eclogite-facies conditions at temperatures of 7000–800° C and pressures of 16–20 kbar (Sanders, 1988, 1989; Storey *et al.,* 2005); the Western Unit under granulite-facies conditions, at similar temperatures but at pressures of < 10 kbar (Storey, 2002). Isotopic ages show that metamorphism in the Eastern and Western units occurred at different times. The major metamorphic events within the Western Unit have been dated at between 2800 Ma and 2600 Ma and at *c.* 1750 Ma, with some evidence of disturbance at *c.* 1000 Ma (Moorbath and Taylor, 1974; Storey, 2002; Friend *et al.,* 2008). The ages obtained from the Western Unit are similar to those from Lewisian rocks of northwest Scotland and the Outer Hebrides, which form the Caledonian Foreland (e.g. Cohen *et al.,* 1991; Corfu *et al.,* 1994; Friend and Kinny, 1995). In contrast, the Eastern Unit underwent pervasive eclogite-facies metamorphism between 1100 Ma and 1000 Ma (Sanders *et al.,* 1984), and subsequent retrogression at *c.* 995 Ma (Brewer *et al.,* 2003; Storey *et al.,* 2005). Before this Grenvillian event, there is evidence of a *c.* 1450–1500 Ma metamorphic event and possibly of Archaean protoliths, but there is no evidence of any event at *c.* 1750 Ma (Storey, 2002). The evolution of the Eastern Unit has parallels with that of the Grenville Province, which forms the eastern margin of the Canadian continental shield (Rivers, 1997).

A possible interpretation of these relationships is that an easterly extension of the Lewisian basement was affected by an orogenic event at approximately 1050 Ma, corresponding to the Grenville Orogeny of eastern Canada. In this scenario the highly deformed zone between the Eastern and Western units in the Glenelg–Attadale Inlier would represent the Grenville Front, a zone of overthrusting marking the western limit of structural and metamorphic reworking of the older basement. It is also possible that the Eastern and Western units originated quite independently as separate segments of continental crust, tectonically juxtaposed during the Grenville Orogeny. In either case, the two units were certainly in proximity before deposition of the Moine Supergroup, which now unconformably overlies both units. The Grenvillian shear-zone boundary was reactivated during the Caledonian Orogeny.

The central part of the Western Unit shows only minor evidence of Caledonian reworking and granulite-facies assemblages and earlier intrusive and structural relationships in the gneisses are still present (see also Avernish GCR site report, this chapter). Towards the upper boundary of the Western Unit, the strike of the lithological units (e.g. the amphibolites) and the early foliation curve to become concordant with the overlying shear-zone. The Moine rocks within the shear zone have been strongly recrystallized and display a penetrative schistosity parallel to its margins. In the immediate hangingwall, the Eastern Unit is deformed and recrystallized into blastomylonite. Isoclinal folds of the layering that are seen in the road section relate to this mylonite formation event. Blastomylonite is also locally developed at the upper contact of the Eastern Unit with the main Moine outcrop (Figure 7.14). Farther south-west, near Glenelg, Storey *et al.* (2004) reported various shear-sense indicators, including delta-shaped porphyroclasts and shear bands cutting pegmatite stringers, which suggest a top-to-the-W shear sense across the main shear-zone.

In the central part of the Eastern Unit, in the hills above the road section, the original Lewisianoid rock-types and relationships have been preserved, but lithological units are folded into large-scale reclined folds with E-plunging axes (Figure 7.14). These folds also affect the Lewisianoid–Moine boundary on the eastern side of the inlier and the Moine rocks in the hangingwall; hence they must post-date Moine deposition. The folds mark a broad zone of deformation along the eastern margin of the Eastern Unit. Fold vergence is towards the north along this zone, but the dominant ESE-plunging extension lineation indicates that shearing was accompanied by transport towards the WNW, resulting in the rotation of fold hinges into the extension direction.

The Moine rocks exhibit granoblastic and schistose textures both in the marginal shear-zone and farther east, compatible with deformation and recrystallization under the lower- to middle-amphibolite-facies conditions. The Lewisianoid rocks must also have experienced the same metamorphic conditions, but new fabrics only developed where the Knoydartian/Caledonian deformation was pervasive. Elsewhere in the Western and Eastern units, relict pre-Caledonian textures and mineralogy are commonly preserved.

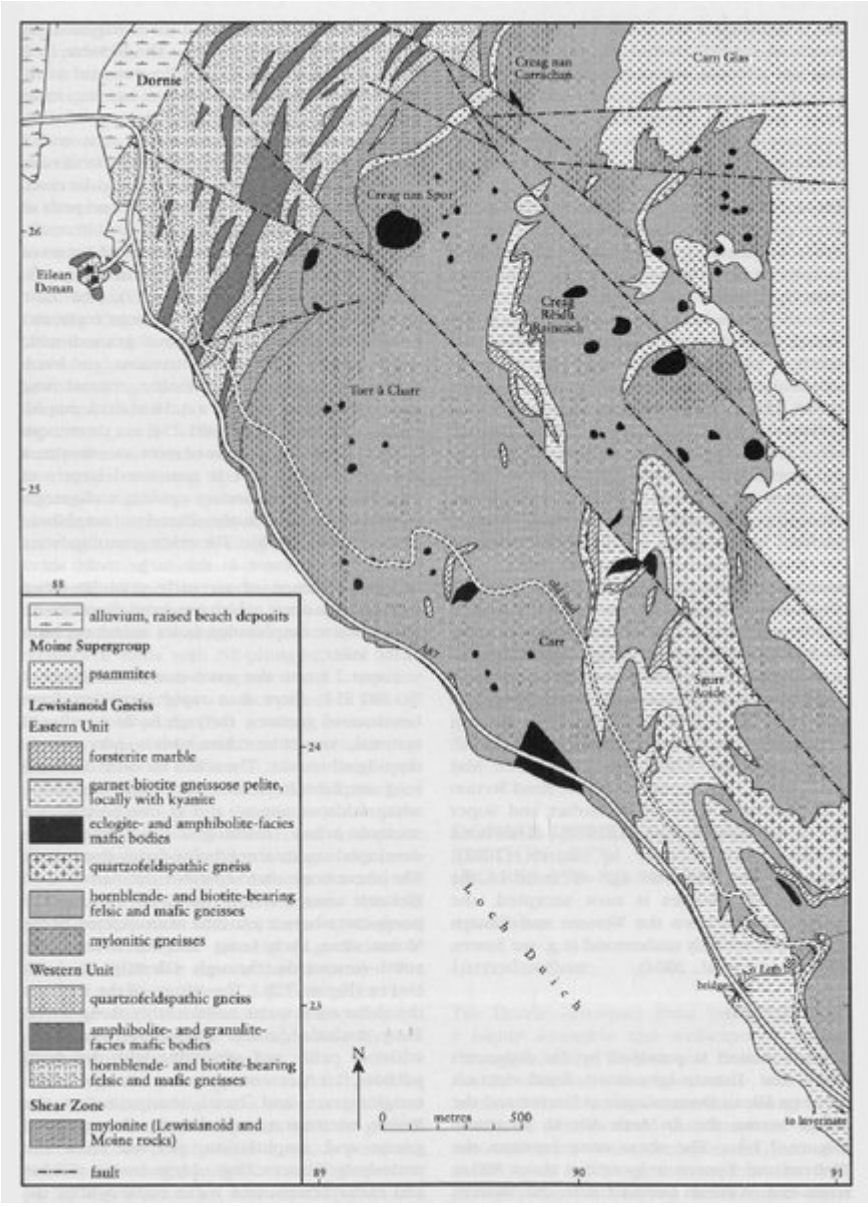
Conclusions

The Dornie–Inverinate Road Section site lies at the western margin of the Caledonian Orogen of northern Scotland just east of the Moine Thrust Belt. It provides a well-exposed cross-section through the Eastern and Western units that make

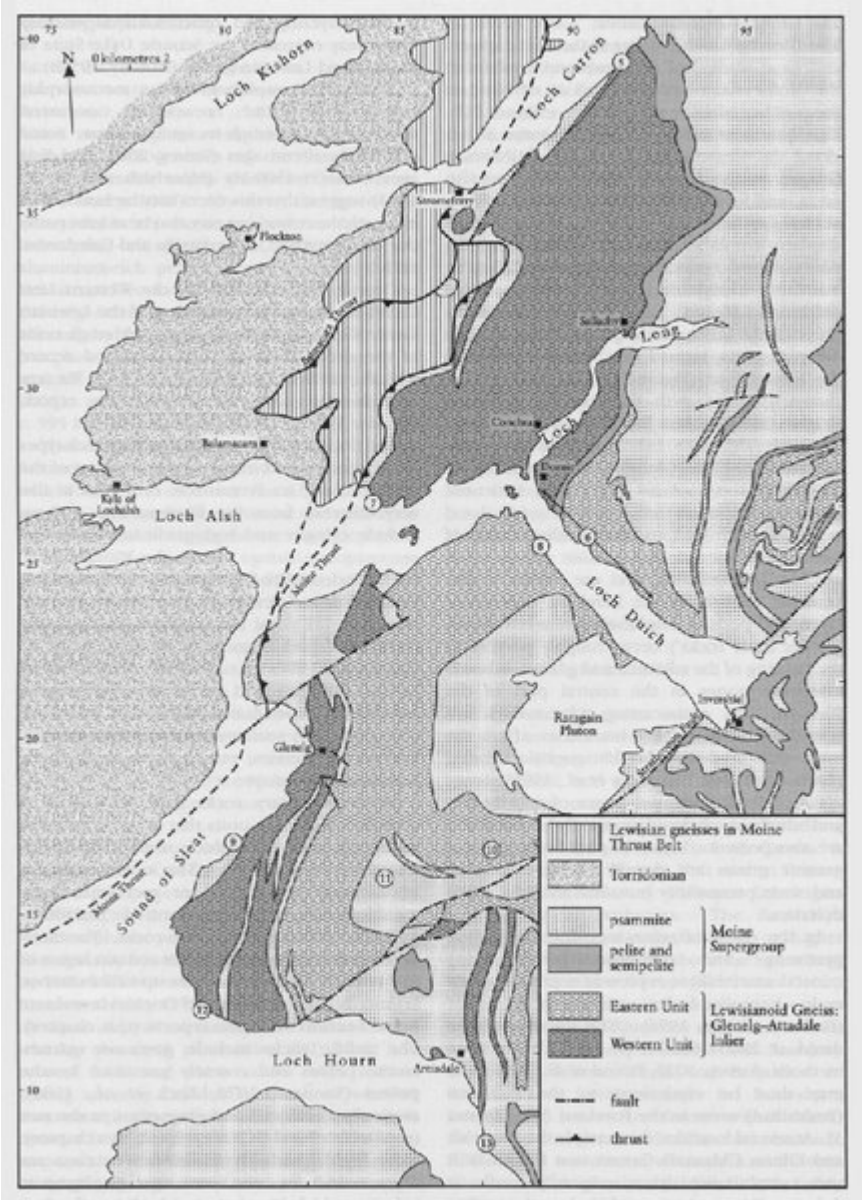
up the Lewisianoid Glenelg–Attadale Inlier, the largest Lewisianoid basement inlier in the Caledonian Orogen. Moine rocks occur on either side of the basement inlier and in a narrow shear-zone that separates the Eastern and Western units. The varied nature of the Lewisianoid basement gneisses is very well displayed in the road section. Hornblende- and biotite-bearing felsic gneisses with subsidiary amphibolites and quartzofeldspathic gneisses dominate in the Western Unit. It was metamorphosed under granulite-facies conditions and shows an overall evolution similar to the Lewisian Gneiss Complex of the Foreland to the west. The Eastern Unit also contains hornblende-and biotite-bearing felsic gneisses, but it is unique in that it contains eclogite and forsterite-bearing metadolostone and metalimestone units ('marble'). It was metamorphosed under eclogite-facies conditions during the Grenvillian Orogeny and shows evidence of a very different evolution from the Western Unit. Although the two units were in close proximity prior to Moine deposition, they were subsequently juxtaposed along a shear zone that incorporates the Moine rocks. The shear zone may have formed during the Neoproterozoic Knoydartian event, and was certainly reactivated during the Caledonian Orogeny. Parts of the Lewisianoid gneisses were also deformed during these events, but along the road section there are low-strain zones that preserve the earlier-formed Archaean and Palaeoproterozoic relationships.

The Dornie–Inverinate Road Section provides crucial evidence of the complex history of different basement units that became incorporated into the Moine rocks during the Caledonian and earlier Knoydartian orogenic events. The Eastern Unit provides an important link with similar Grenvillian rocks in Canada and Scandinavia; thus the site is of international importance.

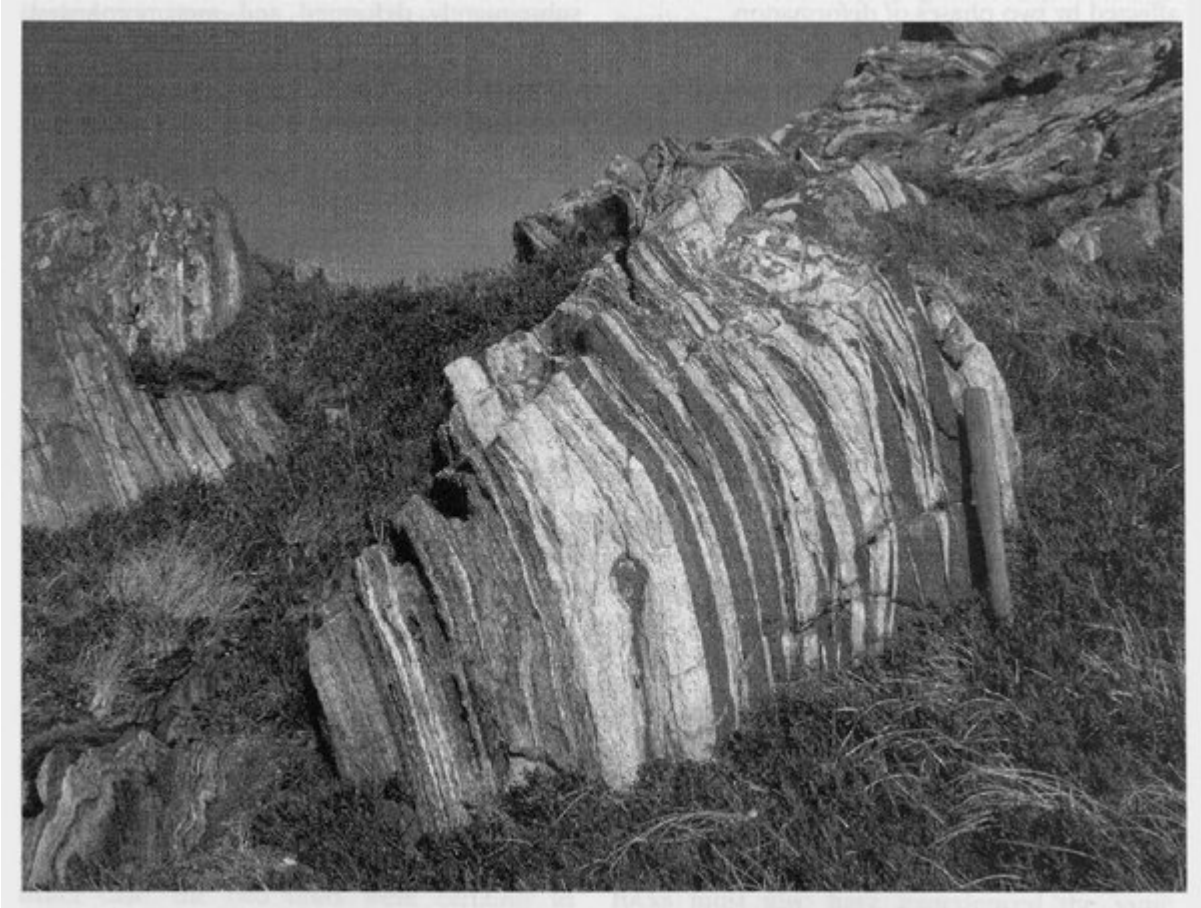
References



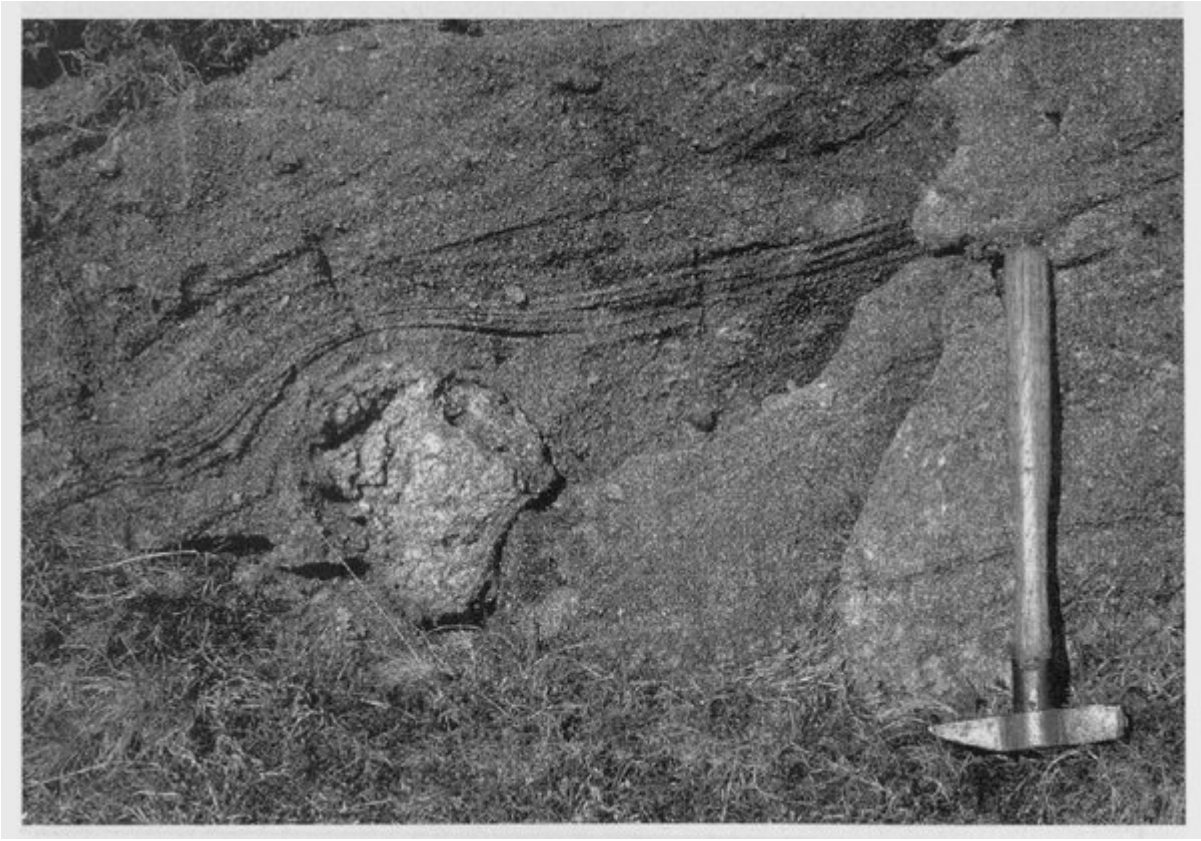
(Figure 7.14) Map of the Dornie–Inverinate Road Section GCR site. Based on field mapping by A.J. Barber.



(Figure 7.2) Geological sketch map of the Glenelg–Attadale Inlier and surrounding area (after Barber and May, 1976), showing the location of the GCR sites within or marginal to the Glenelg–Attadale Inlier. 5 — Attadale; 6 — Dornie—Inverinate Road Section; 7 — Avernish; 8 — Totaig; 9 — Allt Cracaig Coast; 10 — Druim Iosal; 11 — Beinn a' Chapuill; 12 — Eilean Chlamail—Camas nan Ceann; 13 — Rubha Camas na Cailinn.



(Figure 7.15) Layered gneiss produced by strong attenuation of quartzofeldspathic gneiss and amphibolite, Eastern Unit, Creag nan Spor. The hammer shaft is 33 cm long. (Photo: A.J. Barber.)



(Figure 7.16) Diopside nodule enclosed in layered forsterite marble, Eastern Unit, Creag Reidh Raineach. The hammer is 37.5 cm long. (Photo: A.J. Barber.)