Excursion 7 East Glenelg and Loch Duich

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Purpose:	To investigate the distinctive Grenvillian eclogite facies rocks of the eastern Glenelg basement inlier, the exhumation history of the inlier and its relationship with adjacent Moine units.
Aspects covered:	Lewisianoid orthoand paragneisses with eclogite facies mineral assemblages; mylonites; Moine metasediments; polyphase folds and fabrics; granite and pegmatite intrusions.
Useful information:	Hotel, B&B, hostel and campsite facilities are available in the Shiel Bridge-Dornie area; accommodation is also available in Glenelg village.
Maps:	OS: 1:25,000 sheet 413 Knoydart, Loch Hourn and Loch Duich; BGS: 1:50,000 sheets 71E Kyle of Lochalsh and 72W Kintail.
Type of terrain:	Roadside, rocky coastline and moorland exposures.
Distance and time:	The excursion could be followed from either Glenelg or the Dornie-Shiel Bridge area, taking 2 days. See each locality for suggested times.
Short itinerary:	Locality 7.2 for a traverse across the shear zone contact between the western and eastern Glenelg inliers, incorporating intervening Moine rocks; Locality 7.3 for a similar roadside traverse across the sheared contact between the eastern and western Glenelg inliers, without intervening Moine rocks.

The eastern Glenelg basement inlier (Figure 7.1) contains eclogites formed during the *c*.1.1-1.0 Ga Grenvillian orogeny, enclosed within orthogneisses that resemble those found within the Lewisian Gneiss Complex of the Caledonian foreland. The inlier also contains abundant metasediments and there are some important lithological and metamorphic differences between the eastern inlier and the Lewisian, and also the adjacent western Glenelg inlier described in Excursion 6. This area is unique in the Scottish Caledonides in preserving evidence for high-grade metamorphism during the Grenvillian orogeny. The aims of this excursion are to: (1) investigate the nature and evolution of the pre-eclogite crust; (2) observe a variety of lithologies and structures that formed at eclogite facies and therefore provide insights into deep crustal processes; (3) examine the ductile shear zones that border the eastern Glenelg inlier and provide evidence for its exhumation history; and (4) understand the relationships of the inlier to structurally underlying and overlying Moine rocks.

Locality 7.1 North of Glen More [NG 8397 2039] to [NG 860 234]

North of Glen More (Figure 7.2). A range of characteristic lithologies within the eastern Glenelg inlier, including spectacularly preserved eclogite facies assemblages and deformation fabrics.

From Glenelg village, drive east up Glen More and after ~3km park opposite a small farm (Iomairaghradain) that is on the south side of the road close to the Lamont Holiday Homes at Creag Mhor. Parking here is limited to two cars or one minibus, but passing places are closely spaced along the road so further vehicles could be parked close by. Allow a whole day for this locality.

A path leads up on the north side of the road through a gate and skirts the east side of Cnoc Mór which is Locality 7.1A [NG 836 203]. To the right (east) of this path, on the hillside, black-weathering marble contains numerous disharmonic folds. Head westwards uphill towards the summit where eclogite and retrograde amphibolite are widely exposed. Coarse-grained dark green omphacite and dark red garnet are preserved in patches, often transected by mm-scale veinlets where the rock has been converted chiefly to pargasitic amphibole. The best preserved eclogite occurs where the amphibolite veins are less intense. Where the mafic rock has a strong fabric, wholesale retrogression has generally occurred and often the only remnant of the high-pressure paragenesis is in the form of kelyphitic (symplectic) amphibole and plagioclase rims partially replacing garnet.

Head WNW towards Creag Dubh [NG 826 207], approximately 1km from Cnoc Mór. On the highest point of Creag Dubh, Locality 7.1B, are exposures of interlayered felsic and mafic rock. The mafic layers occasionally contain relict garnet surrounded by kelyphites (symplectites), but generally are retrogressed completely to amphibolite and epidote-amphibolite. In places, mafic layers are very quartz-rich and omphacite is sporadically preserved. This may indicate dehydration reactions that occurred during eclogite facies metamorphism, particularly in the surrounding felsic gneisses. Garnet is mostly only preserved in the felsic gneisses as relicts or pseudomorphic replacements by amphibole and/or biotite. However, SW of the summit, at [NG 8255 2055], a coarse-grained felsic layer contains omphacite, garnet and kyanite, recording eclogite facies conditions of 20kbar and 750°C (Storey *et al*., 2005). These rocks are strictly high-pressure granulites due to the presence of plagioclase, although their peak metamorphism occurred at eclogite facies. The basement here is moderately strained, but not mylonitised. However, the relative ages of the protoliths of the mafic and felsic gneisses are difficult to establish on the basis of field evidence alone. The author's unpublished work indicates that the protoliths of the felsic gneisses are Late Archaean in age, whereas geochemical evidence, from Hf isotopes in zircon from the eclogites, suggests that their protolith may have formed close to 2.0 Ga (Brewer *et al*., 2003). It therefore seems likely that the protoliths of the eclogites intruded the pre-existing felsic basement.

Retrace the route back towards Locality 7.1A until you find the path that led up from the road. Continue uphill on the path which finishes as the hillside flattens out; exposures ahead around [NG 838 209] continue NW to the southern termination of a prominent ridge at [NG 8365 2105]. Follow the ridge in a NNE direction examining the excellent exposure along the way. This is Locality 7.1C. These rocks are a different type of eclogite, termed by Sanders (1988) 'streaky eclogite'. The rock is mafic with white quartzo-feldspathic streaks that vary from mm-scale isolated threads up to cm-dcm-scale networks of veins that form locally up to half of the rock mass. They typically are intensely rodded with a dominant L>S D_1 fabric. Intervening eclogite patches also have a tectonic fabric defined by aligned omphacite grains and tabular garnet. Kyanite, sometimes preserved within the streaks at the microscopic scale, is also aligned and occasionally forms asymmetric fish, indicating non-coaxial shearing. Sanders (1988) demonstrated that the streaks formed during eclogite facies metamorphism, and Storey *et al*. (2005) estimated peak conditions at around 20 kbar and 750°C.

Along the length of this ridge, up to around [NG 834 223] (area marked on OS maps as Cruachan Meadhon), the rodding lineation plunges shallowly towards between 010° and 040°, which has been attributed to possible transcurrent shearing during eclogite facies metamorphism (Sanders, 1988).

Continue NE from Cruachan Meadhon towards the east side of Lochan na Beinne Faide. At [NG 86251 23497], in low cliff exposures on the SW side of the loch, browny-grey weathered ultrabasic rocks occur at Locality 7.1D. Rawson *et al*. (2001) described both garnet-bearing olivine websterites and their garnet-absent equivalents, websterite. The olivine websterites contain two pyroxenes, olivine, garnet, amphibole and minor magnetite and spinel. Websterites are essentially identical in mineralogy but lack garnet and, generally, the olivine has been replaced by serpentine and the pyroxenes by amphibole as a retrograde reaction. Similar rocks are reported by Rawson *et al*. (2001) from the north side of a small loch approximately 0.5km SE of Lochan na Beinne Faide [NG 866 233]. The garnet-bearing olivine websterite gave a pressure-temperature estimate of ~20 kbar and 730°C (Rawson *et al*., 2001). The relationship of the ultrabasic rocks to the other lithologies is unclear and it cannot be determined whether they represent tectonically emplaced alpine-type peridotites or whether they crystallized from a basaltic magma as a result of crystal accumulation. The agreement of the pressure-temperature estimate with that of the surrounding high-pressure granulites (felsic gneisses) and the streaky eclogites implies that they are cofacial, and thus achieved peak conditions at ~1082 Ma (during the Grenvillian orogeny), but their earlier history is enigmatic. If they are related to the basic protoliths of the eclogites, then

they may have formed at ~2.0 Ga. On the north side of Lochan na Beinne Faide lies a large mass of exposure elongated in a NE–SW direction for approximately 2km, known as Beinn Fhada, Locality 7.1E. This mainly comprises a distinctive type of garnet and pyroxene-bearing felsic gneiss, which is trondhjemitic in bulk-rock composition. In fresh outcrops, omphacite and garnet co-exist with plagioclase. These rocks are strictly high-pressure granulites, although the presence of omphacite indicates eclogite facies conditions (Sanders, 1979). These rocks are considered identical to the more limited exposure of felsic high-pressure granulite at Creag Dubh, Locality 7.1B. Concordant mm- dcm-scale eclogite layers are interbanded with the felsic gneisses. It is within this exposure, within a thick eclogite layer at ([NG 860 234]; (Figure 7.3)), that Sanders *et al*. (1984) obtained a garnet-clinopyroxene-whole rock Sm-Nd age of 1082 ± 24 Ma, interpreted to be close to the peak of eclogite facies metamorphism.

Summary of the early history

It is thought that the majority of the basement gneisses formed from trondhjemitic and granitic protoliths in the Late Archaean, and thus there are similarities with gneisses of the Lewisian Gneiss Complex within the Caledonian foreland and also with the gneisses of the western Glenelg inlier (see also Friend *et al*., 2008). The major difference is the preponderance of eclogite and paragneisses, which do not have a direct comparison, although possibly similar metasediments occur within the Gairloch region of the Lewisian outcrop. It is considered likely that the metasediments and the majority of the eclogite protoliths formed as part of a volcano-sedimentary sequence that accumulated upon pre-existing trondhjemitic gneisses possibly at around 2.0 Ga. The eastern Glenelg inlier was subsequently buried to depths of around 70 km and metamorphosed within the eclogite facies during the ~1.1-1.0 Ga Grenvillian orogeny, most likely as a result of the deep subduction of continental crust in a collision zone.

Locality 7.2 [NG 823 193] to [NG 8223 1873] Between Glen More and Glen Beag

Between Glen More and Glen Beag (Figure 7.4). A traverse from the uppermost part of the western Glenelg inlier across the intervening 'Moine strip' and into the shear zone which defines the structural base of the eastern Glenelg inlier.

Either park in Glenelg village or it is possible to drive up a small partially made road that turns sharply to the left off the main road through the village as you head southwards; the junction is between the two entrances to the Glenelg Inn car park. The road follows the edge of the south side of Glen More towards a farm at Cósag [NG 823 193]. The farm is gated at the end of the road, but approximately 200m before the gate there is a disused croft and it is possible to park here on the side of the track. Space is limited to two cars or one minibus. Allow 3-4 hours for this locality.

Walk back towards Glenelg and, where the road turns a first right bend, cross the barbed wire fence and a small stream and walk uphill to the SW. After about 0.5km, around Locality 7.2A [NG 817 187] , low hummocky outcrops expose highly strained gneisses of the western Glenelg inlier. It is recommended that some of the localities in Excursion 6 are visited first in order to be able to recognize these lithologies in their lower strain state.

Here, these gneisses commonly contain a strong ductile D_2 L-S fabric, with a mineral stretching lineation plunging moderately down-dip to the east. In exposures where banded tectonised mafic and felsic layers occur, surfaces parallel to the lineation show low-angle C' shear bands that indicate a top- to-the-west sense of shear. Upright D_3dcm-scale extensional shear bands disrupt the earlier fabric and are associated with a mineral elongation lineation that plunges fairly steeply towards the SE.

To the east, around Locality 7.2B [NG 818 187] low angular outcrops expose Moine psammites assigned to the Morar Group with variably deformed feldspathic sedimentary clasts and thin pegmatitic segregations. The fabric is mylonitic and contains a strong mineral stretching lineation formed mainly by muscovite. Low-angle truncations within the mylonitic foliation are thought by Ramsay (*pers. comm*.) to be relicts of cross-bedding and therefore that the Moine has a modified unconformable relationship with the western basement inlier. However, the high state of strain makes this conclusion difficult to accept and, with a critical eye and looking on variously oriented surfaces, it is more likely in the view of the present author that these low-angle truncations originated as rootless, detached isoclinal folds within the mylonitic

foliation. There are two mineral stretching lineations within the Moine rocks: the earliest plunges moderately towards the east (L_2), whereas a later lineation, often associated with upright extensional shear bands, formed during D_3. Occasional kinematic evidence from D_2 fabrics can be found, particularly where pegmatitic layers are disrupted, and these indicate a top-to-the-west sense of shear.

To the east, around Locality 7.2C [NG 819 188] are exposed strongly banded ultramylonites of the eastern Glenelg inlier. Felsic and mafic components are interlayered on the mm scale, the latter commonly containing highly rounded porphyroclasts of garnet and dark green-brown amphibole. The ultramylonitic foliation is often disrupted by disharmonic folds with curvilinear hinges and sometimes eye structures can be observed. A strong mineral stretching lineation plunges moderately towards the east and the fold hinges are generally sub-parallel to this lineation. These are sheath folds formed during shearing. The state of strain is so high that it is impossible to gain kinematic information. The rocks remain mylonitic towards the east for several hundred metres, forming part of the Barnhill Shear Zone which separates the Moine rocks and the eastern Glenelg inlier (Storey, 2002). At the summit of Sgiath Bheinn, around Locality 7.2D [NG 8223 1873], the rocks are locally in a lower state of strain and it is possible to see disrupted migmatitic textures within the trondhjemitic gneisses.

Locality 7.3 Eilean Donan Castle [NG 885 254] to [NG 8430 2445]

Eilean Donan Castle (Figure 7.5). A traverse across the boundary between the western and eastern Glenelg inliers; this is similar to Locality 7.2 (although no intervening Moine strip is present), but road cuttings offer more complete exposure.

Allow 2-3 hours for this locality. Park either at the car park at Eilean Donan Castle or at a more convenient location approximately 0.5km south along the main A87 road where there is a conspicuous crag of green-black rock on the loch side of the road and an unofficial parking area for several vehicles (Locality 7.3A, [NG 885 254]). This is within the western Glenelg inlier. The outcrop is high-pressure mafic granulite of Late Archaean age (Storey, 2002; Friend *et al.*, 2008) and clinopyroxene, garnet, plagioclase, hornblende and minor quartz form a coarse granoblastic polygonal texture (Figure 7.6). Patches and veinlets of trondhjemitic leucosome result from partial melting. On the opposite side of the road, melt veins are more widespread and have locally coalesced to form dcm-scale sheets. A serpentinite body is typical of the rare ultrabasic bodies that are ubiquitously altered to low-grade hydrous assemblages. Walk southwards along the road examining the roadside exposures; a strong, composite steep SE-dipping fabric characterizes the banded gneisses. After ~300m (Locality 7.3B, [NG 887 252]) there is a large sub-vertical road cutting on a shallow left hand bend covered by wire netting. Behind the netting is exposed the contact between the western and eastern Glenelg inliers. It is cryptic as there are no intervening Moine sedimentary rocks to guide. At the southern end of the netting, dark strongly banded ultramylonites contain rounded porphyroclasts of garnet and amphibole and are thought to have been derived by shearing of the eastern basement inlier.

The strong mylonitic fabric persists for up to 1km to the SE along the road. There are two dominant sets of fabrics. D_2 structures often comprise rootless isoclinal folds within the mylonitic foliation and have a strong associated mineral stretching lineation and axial planar mylonitic fabric. These are reworked by D_3 structures which comprise a strong L_3 mineral elongation steeply plunging towards the SE and F_3 curvilinear fold hinges generally close to parallel with the principal D_3 stretching orientation. F_2 isoclines and the mylonitic S_2 fabric are refolded around F_3 folds. Hence, D_2 was the main ductile shearing event, whilst D_3 involved both shearing and folding but, in this area at least, generally not a new penetrative axial planar foliation. Temperley & Windley (1997) describe the same structures; although their interpretation that the D_2 fabric was extensional is questionable, their observations that the later D_3 deformation is accompanied by steep, extensional shear bands associated with the SE-plunging mineral stretching lineation appears sound. At Locality 7.3C [NG 8930 2445], low outcrops on the landward side of the road demonstrate that the strain here is lower because recognizable trondhjemitic rocks are exposed with migmatitic textures, enclosing partially melted xenoliths of basic rock. These xenoliths must presumably be older than the protoliths of the eclogites (see discussion at end of Locality 7.1 above). By the lochside here, banded trondhjemitic gneisses can be seen translated into high strain zones and, thus, afford an excellent glimpse into the protoliths at different states of strain.

Locality 7.4 Carr Brae to Loch a' Mhuilinn [NG 8995 2445] to [NG 9065 2480]

Carr Brae to Loch a' Mhuilinn (Figure 7.5). A section across the highly tectonized contact between the upper boundary of the eastern Glenelg inlier and the overlying Moine rocks.

Allow 3-4 hours for this locality. Park at Carr Brae [NG 8995 2445] on the old road along the east side of Loch Duich where there is ample parking for a small coach/minibus and several cars. There is a small picnic area and a pleasant view, ideal for breaking up a day involving one of the other half-day excursions. Head directly uphill to the NE, following the Allt a' Mhuilinn stream, to outcrops on a steep section of the stream approximately 200m from Carr Brae at Locality 7.4A [NG 901 245]. Small layers of eulysite within marble and garnet-biotite gneisses outcrop on the immediate northern side of the stream. Eulysites are metamorphosed manganiferous rocks, characteristically containing fayalite, but hedenbergite, Fe-hypersthene, garnet, magnetite and grunerite are also common. They were first described from Glenelg by Tilley (1936). The eulysites typically have a bluish-black weathered surface (hydrated Mn-oxide) and are very hard; hammering is required to search out these layers for fresh samples. The intimate association of the eulysites with other metasediments can be demonstrated here and they are probably sedimentary (exhalative?) in origin.

Walk ~500m upstream to the NE to Locality 7.4B [NG 906 247] to lowlying outcrops of mylonitised felsic and mafic gneisses. The latter contain rounded porphyroclasts of garnet and amphibole, very similar to the highly deformed units at the base of the eastern inlier, suggesting a comparable state of strain and metamorphic evolution. Garnet-biotite gneisses (metapelites) occur sporadically and contain conspicuous leucosome, which has been remobilized during shearing. It is common to see two lineations on the foliation surfaces throughout this zone, with the earlier L_2 plunging gently towards the east, and a later, steeper L_3 (around 40°) plunging towards the SE (130-140°). The mylonitic S_2 fabric and L_2 are folded around curvilinear F_3 hinges. Locally, a new penetrative S_3 fabric develops axial planar to the F_3 folds and this is in the form of a platy biotite-dominated foliation, which also contains the L_3 mineral stretching lineation. In contrast, S_2 is defined by amphibole rather than biotite, and thus indicates higher grade conditions (i.e. $D_3$is retrograde).

The boundary with the overlying Morar Group psammites is exposed at Locality 7.4C [NG 9065 2480]. The contact is intensely sheared and all rocks are ultramylonitic. The contact is marked by a ~5cm layer of ultraphyllonite, which would correlate with the 'basal pelite' of Ramsay & Spring (1962). If this is truly sedimentary in origin, rather than a tectonic phyllonite derived from breakdown of mafic basement rocks, then its preservation is truly remarkable. Although it has been proposed that this contact marks a modified unconformity between the Moines and underlying basement rocks (Ramsay, 1958; Ramsay & Spring, 1962), this view is difficult to sustain given the lack of anything resembling a basal conglomerate and the uniformly high tectonic strain. About 10m above the contact, the Moine psammites contain cm-dcm layers of intensely sheared and friable coarse grained pegmatite. The common presence of such pegmatites within the Moine in the vicinity of contacts with the basement suggests that they may be syn-kinematic, but fixing their precise timing with respect to D_2 and D_3 remains elusive. The ultramylonitic contact can be followed to the SE around the southern side of Boc Beag, and the zone of highly sheared rocks (the Inverinate Shear Zone of Storey, 2002) is at least 300-400m thick within this part of the eastern Glenelg inlier.

Interpretation of the D_2 history of ductile shearing D_2 mylonitization of basement lithologies and Moine rocks occurred under upper amphibolite facies conditions (13 kbar and 650-700°C; Storey *et al*., 2005) and has been correlated with static replacement of the eclogite paragenesis within low strain eclogite boudins and layers. Brewer *et al*. (2003) dated this retrogression at ~995 Ma, by the U-Pb method on zircon. However, this is older than the youngest detrital zircon age obtained so far within the Moine rocks of the Morar Group (980 ± 2 Ma, Peters, *pers. comm.* in Cawood *et al*., 2007), and so it is likely that D_2 is composite, comprising an older phase associated with initial retrogression of the eclogites before the Moine rocks were deposited, and a younger phase common to both the basement and the Moines. Dating of syn-D_2 titanite within the shear zone at the base of the eastern Glenelg inlier yields an age of ~670 Ma (Storey *et al*., 2004) and thus the basement and the Moines may have been juxtaposed by shearing within the middle crust at some stage in the late Neoproterozoic.

Locality 7.5 Loch Duich roadside [NG 905 233] to [NG 900 239]

Loch Duich roadside (Figure 7.5). Metasedimentary rocks within the eastern Glenelg inlier.

A superb road cutting that exposes metasediments of the eastern Glenelg inlier occurs behind double crash barriers beside the main A87 road on the east side of Loch Duich at [NG 905 233] northward to [NG 900 239]. This is Locality 7.5. There is a lay-by just to the south of the crash barriers in which to park and there is plenty of room for a coach/minibus and several cars. Beware of common sheep and deer ticks at this locality! At the south end of the cutting, pelitic schists contain biotite, plagioclase, garnet, kyanite, quartz, muscovite and chlorite. Leucosome is ubiquitous, demonstrating partial melting and, as much of the muscovite is retrograde, indicates that the muscovite-out melt reaction has been crossed. Rawson (2004) recorded phengitic (= high pressure) mica in preserved microlithons within these schists, which along with kyanite is probably the only remaining evidence of the earlier eclogite facies history. Further northwards, the rocks grade into calc-pelitic lithologies, with ubiquitous epidote imparting a greeny colouration. At the furthest north part of the outcrop the succession is capped by a marble horizon, although at the time of writing this has been largely overgrown. The rocks here display M and W folds as they are in the hinge zone of a major F_3 fold. Rootless F_2 isoclines occur within the folded S_2 fabric and melt veins cut across S_2 but are folded around F_3 hinges and have undergone boudinage. Hence, partial melting occurred between D_2 and D_3; an attempt was made to date these melts, but they did not yield uranium-bearing accessory minerals.

Locality 7.6 Loch Duich roadside [NG 9115 2260]

Loch Duich roadside (Figure 7.5). Relationships between dated pegmatite and D_2 and D_3 structures.

Head south to the junction where the old road over to Dornie, via Carr Brae, meets the A87 at [NG 911 227]. It is possible to park in a lay-by on the A87 here and there is room for a coach/minibus and several cars. Walk approximately 100m south along the road and cross to low-lying outcrops on the landward side of the road [NG 9115 2260]. These expose typical banded mafic and felsic gneisses of the eastern Glenelg inlier with a dominant high-strain S_2 fabric. Conspicuous granitic pegmatites cut the dominant S_2 fabric in a number of places. F_3 folds, with curvilinear hinges, refold the S_2 fabric and a pegmatite. The pegmatite has yielded a U-Pb titanite age of 437 ± 6 Ma (Storey *et al*., 2004); D_3 must therefore be younger than this and D_2 older.

Locality 7.7 Loch Duich lochside [NG 8845 2380]

Loch Duich lochside (Figure 7.5). Relationships between dated granite sheet and D_2 and D_3 structures.

Head southwards to Shiel Bridge on the A87 and take the turn towards Ratagan and Glenelg. After about 1 km take the sharp right turn downhill towards Ratagan on the small single lane lochside road that ends at Totaig. Continue past the Ratagan Youth Hostel to Letterfearn and use one of the passing places to park, leaving plenty of room for other cars to pass by. Space is restricted to a small minibus or two cars.

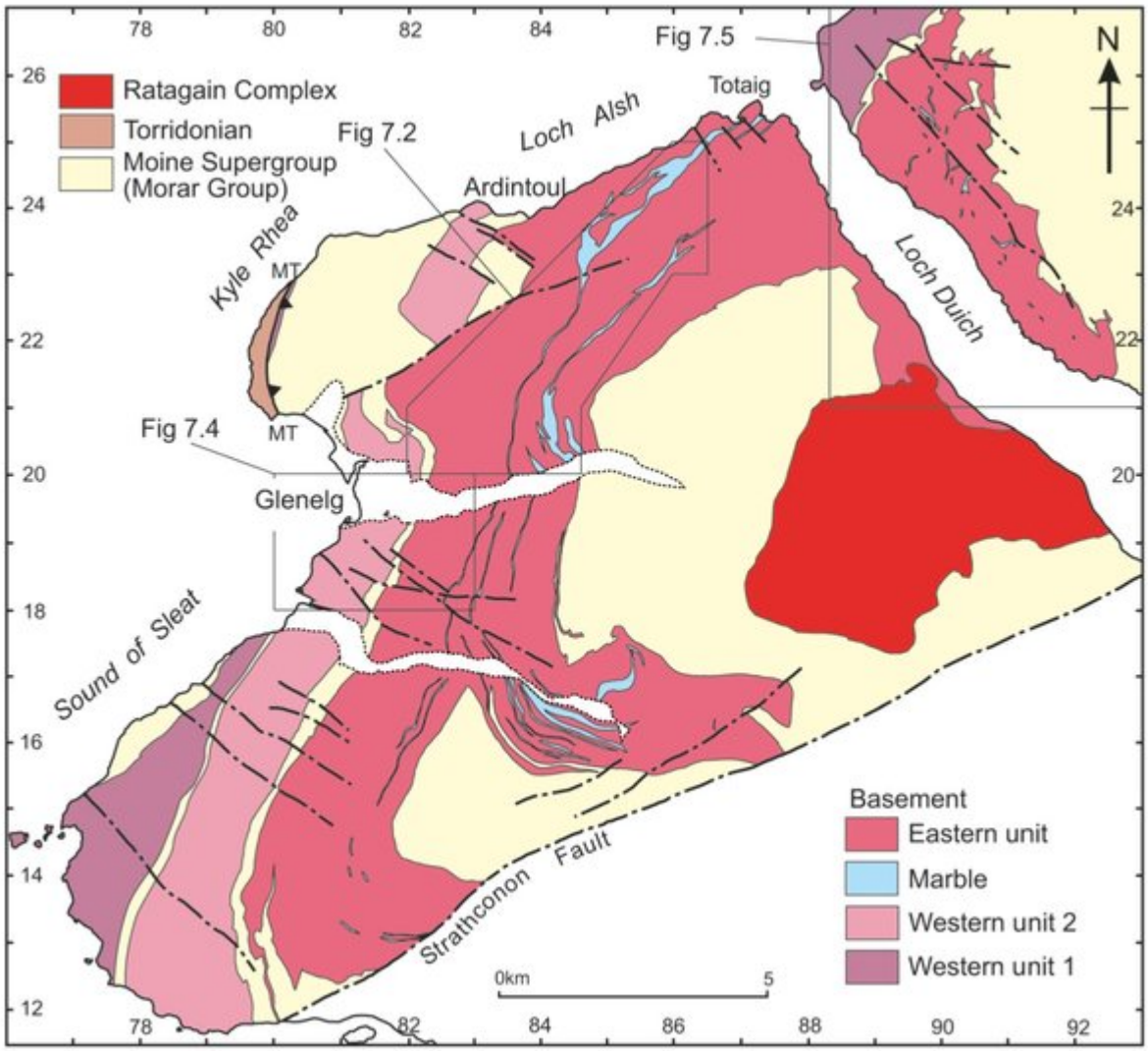
Exposures to be visited are on the loch shore at [NG 8845 2380] on the north side of a small bay at Letterfearn. Care is required as the tide imparts a treacherous slippery surface to the outcrops! A ~3m high south-facing exposure contains a granite sheet about 20cm wide coincident with a fracture in the rock. The margin of the granite cuts the dominant S_2 fabric. The S_2 fabric is within amphibolite and is defined chiefly by amphibole and plagioclase; on the east-dipping foliation surfaces a dip-slip L_2 mineral stretching lineation plunges moderately towards the east, but is variable as it is reworked by D_3 deformation. In the highest part of the outcrop, to the right (lochward) of the granite sheet, the amphibolite contains tabular garnet and elongated prisms of relict omphacite, replaced by symplectites of amphibole and plagioclase and neoblastic garnet. The retrogressed eclogite is of the streaky variety, containing quartzo-feldspathic threads, but no kyanite has survived. This is a relict of the D_1 eclogite fabric that has been statically overprinted during upper amphibolite facies retrogression. The fabric is coplanar and colinear with D_2 and implies that D_1 had a similar principal stretching axis to D_2. At the margins of the granite sheet the D_2 (and relict D_1) fabric is deflected into an upright attitude and a new S_3 foliation and L_3 lineation, defined by aligned amphibole and biotite, is developed that dips towards the SE with a dip-slip lineation. This D_3 fabric is also well developed within the granite sheet. Minor fold hinges throughout the host amphibolite are markedly curvilinear and vary in plunge by up to 80°. A metre behind this small

exposure, on the beach, a prominent F_3 fold hinge plunges gently towards the SE. Note that the earlier L_2 lineation is folded around the hinge and reoriented into near horizontal with a N-S azimuth. The granite sheet was therefore intruded after D_2 and before D_3. Zircon fractions from the granite give a U-Pb discordia lower intercept age of 672 ± 75 Ma, whereas euhedral titanite gives a concordant age of 520 ± 11 Ma (Storey *et al*., 2004). D_2 is therefore at least late Neoproterozoic in age, and D_3must be younger.

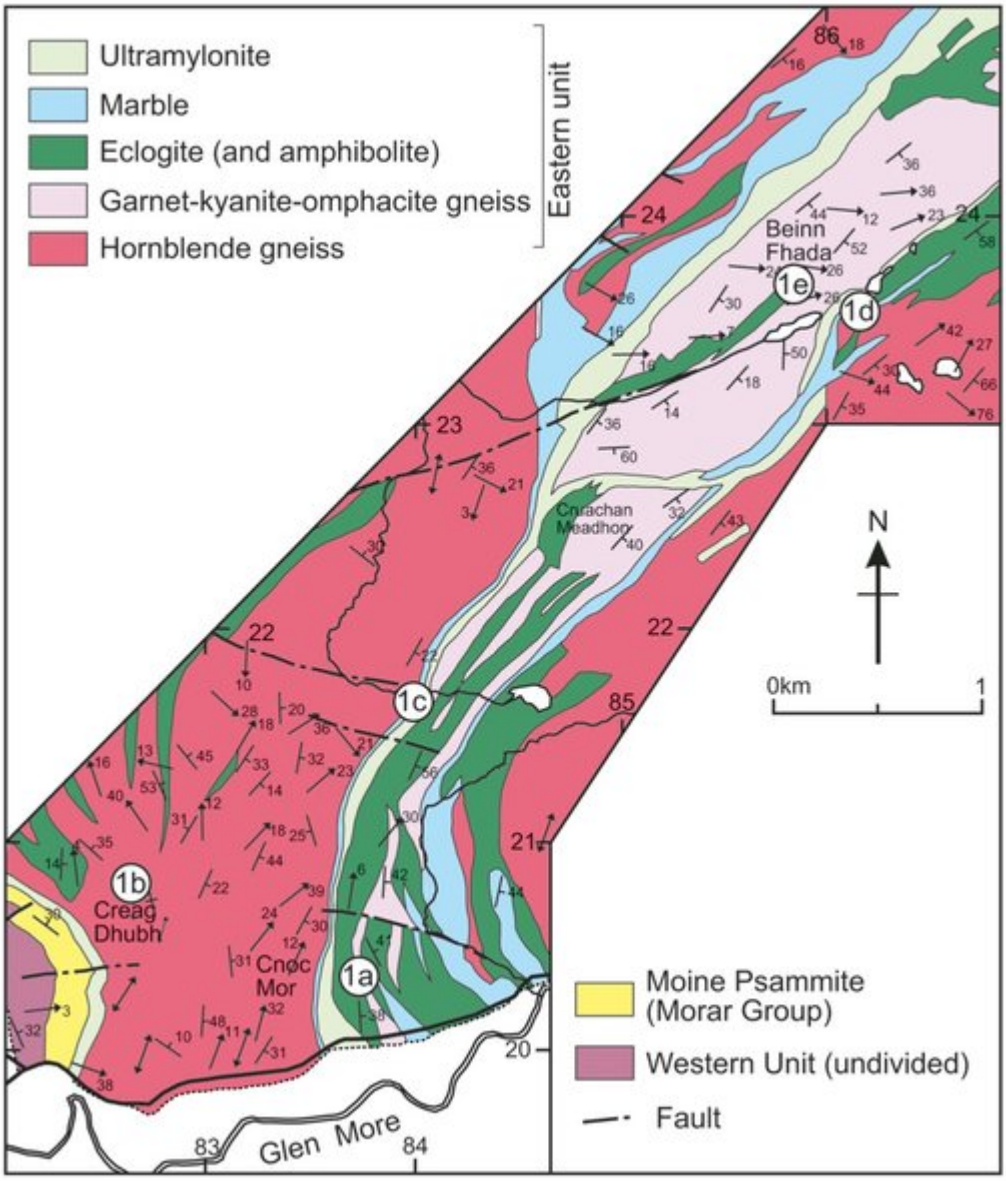
Interpretation of the D_3 history of folding and shearing

The evidence obtained from Locality 7.6 suggests that D_3 structures are younger than 437 ± 6 Ma and hence must have developed during the Lower Palaeozoic Caledonian orogeny. The D_3 fabric is reworked by brittle-ductile chlorite grade (greenschist facies) shear zones that can be confidently correlated with movements on the Moine Thrust Zone at 437-430 Ma (Freeman *et al*., 1998). Hence, it appears that D_3 is fairly tightly bracketed. Whilst it is clear that D_3 involved large-scale folding with axes trending NE–SW affecting the Glenelg inlier and surrounding Moine and giving rise to the spectacular fold interference patterns described by Ramsay (1958 and this volume), what has been understated is the amount of shearing associated with this deformation. Evidence of a locally penetrative lower amphibolite facies S_3 and associated L_3 mineral stretching lineation has been presented and is often associated with upright extensional top-to-the-SE shears. Temperley & Windley (1997) presented kinematic evidence for this episode of extensional shearing, but due to the lack of geochronology at the time interpreted this as being part of the extensional exhumation history of the eastern Glenelg inlier. However, since this is not the case, an explanation must be sought within the framework of the Caledonian orogeny. The Glenelg area is in the footwall of the Sgurr Beag Thrust, which has an earlier history than the Scandian (*c*.435-430 Ma) deformation that typifies much of the NW Highlands (Kelley & Powell, 1985; Kinny *et al*., 2003b). There is evidence of earlier Grampian (*c*.470-460 Ma) crustal thickening within the NW Highlands (Kinny *et al*., 1999; Friend *et al*., 2000) and one possible explanation is that the Morar Group and underlying basement underwent crustal thickening during the Grampian that was followed by extensional reworking prior to Moine Thrust (Scandian) times.

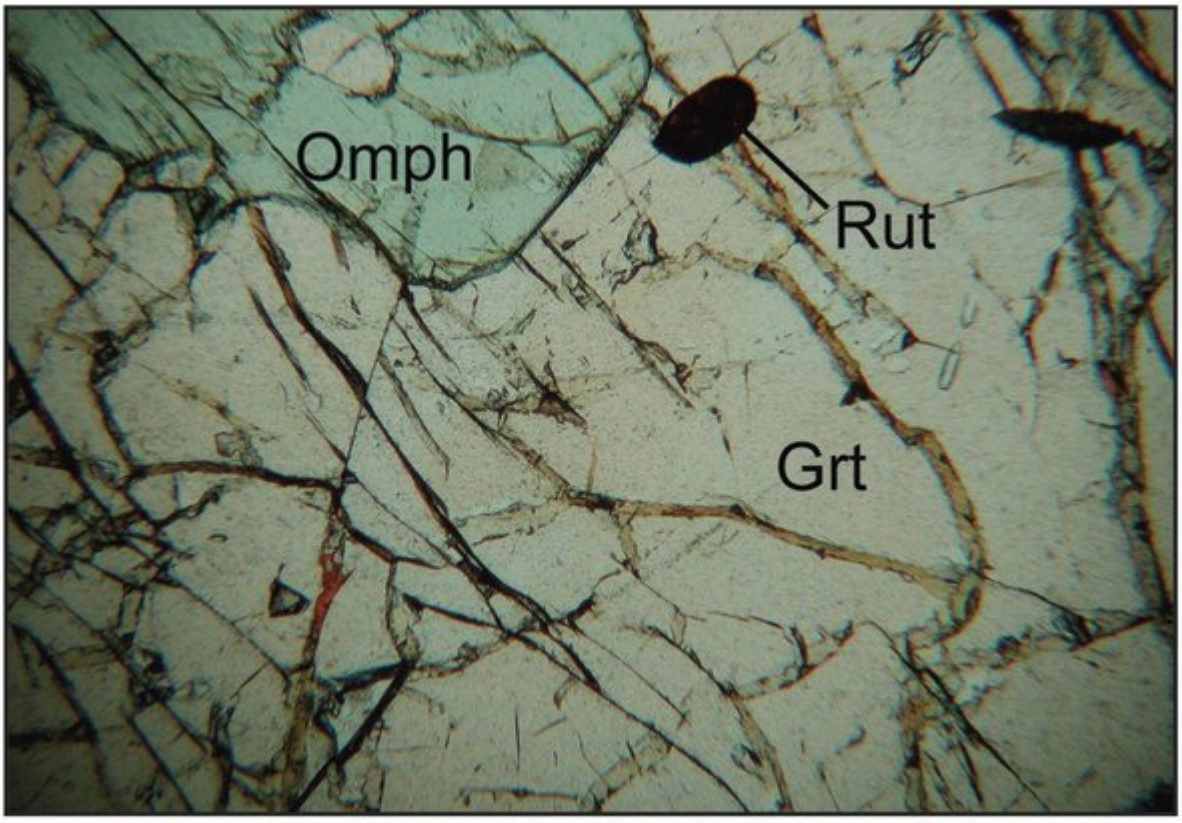
References



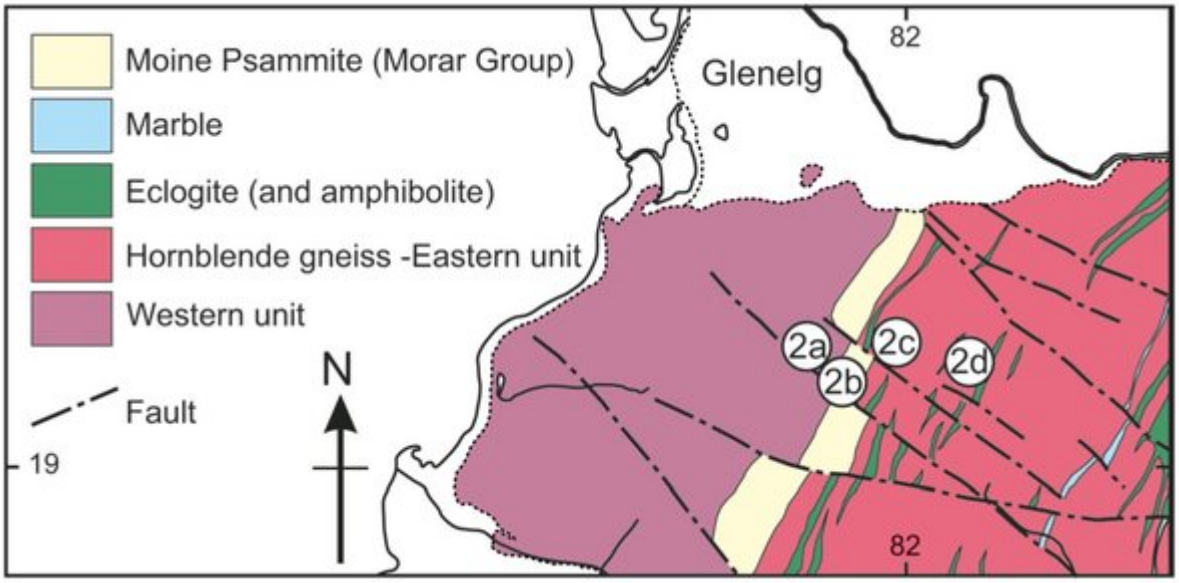
Geological map of Glenelg and Loch Duich, showing the locations of ((Figure 7.2)), ((Figure 7.4)) and ((Figure 7.5)).



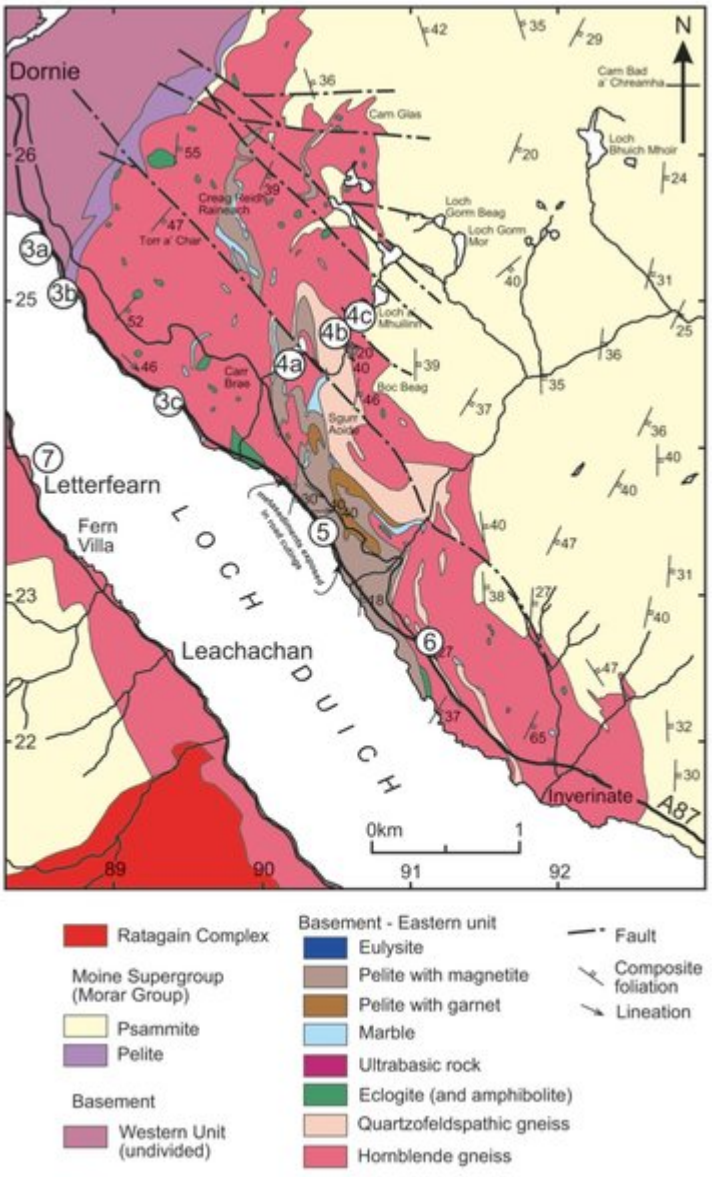
Geological map north of Glen More covering Localities 7.1A-E (modified from Sutton & Watson, 1959, plate 9).



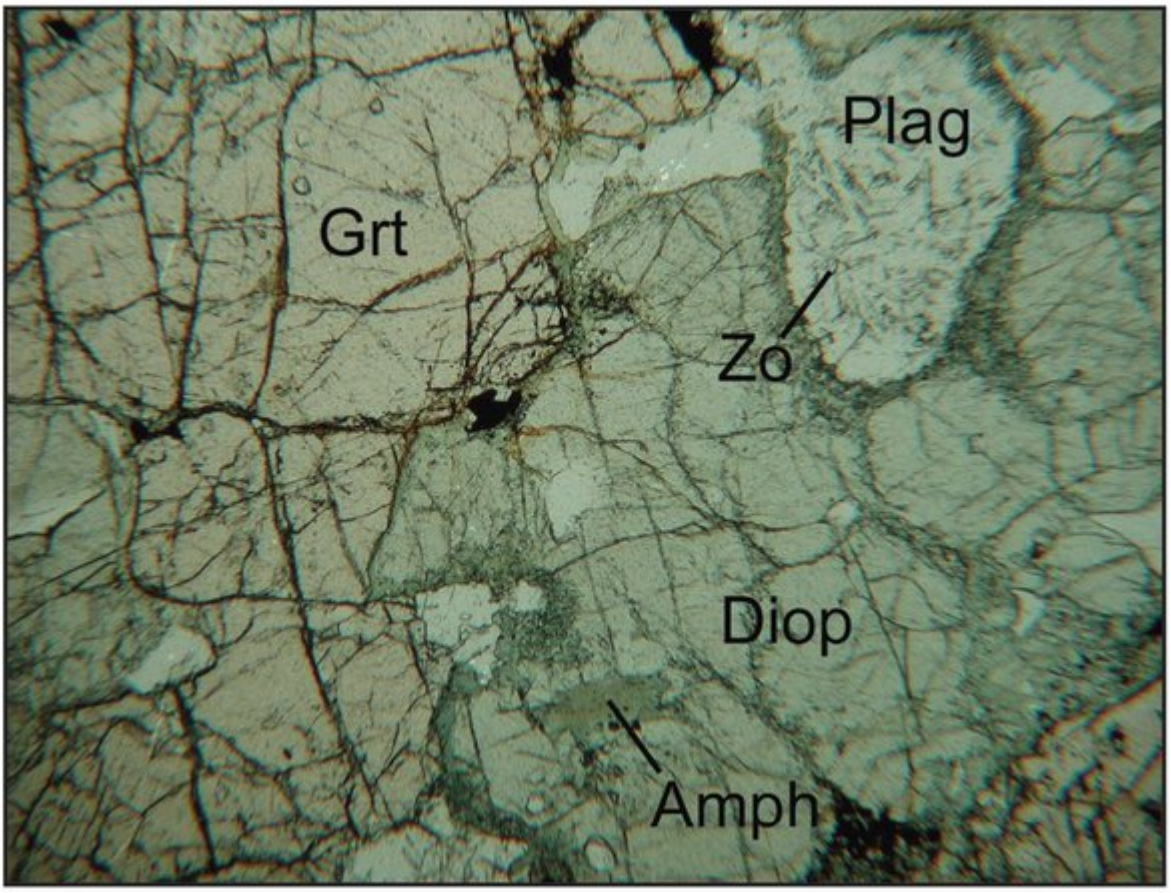
Thin section of typical eclogite from Locality 7.1E.Grt = garnet; Rut = rutile; Omph = omphacite. Field of view = 3 mm.



Geological map south of Glenmore covering Locality 7.2A-C (modified from Ramsay, 1958, plates 37 & 38).



Geological map north of Loch Duich covering Localities 7.3 to 7.7 (based on May et al., 1993, figure 5).



Thin section of high-pressure mafic granulite from Locality 7.3A. Grt = garnet Plag = plagioclase Zo = zoisite Diop = diopside Amph = amphibole Field of view = 3 mm